AQUIFERS OF THE NORTHERN NECK, VIRGINIA

by

The SAIF Water Committee

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Technical Paper #1

ACKNOWLEDGMENTS

The descriptions of the aquifers in this presentation are adapted from a body of work that includes hydrogeologic summaries prepared by the U. S. Geological Survey (Harsh and Laczniak, 1990 and Meng and Harsh, 1988), the Virginia State Water Control Board (Newton and Siudyla, 1979), the Maryland Geological Survey (Achmad and Hanson, 1997), the Northern Neck Planning District Commission (Northern Neck Groundwater Committee, 2000), and the Lancaster County Planning and Land Use Office (Frere, 1995). Without these studies the current work would not have been possible.

FOREWORD

The SAIF Water Committee is pleased to present the following technical report by committee member Frank W. Fletcher. We believe it is a major contribution to our knowledge of the hydrology of Virginia's Northern Neck. Dr. Fletcher has volunteered his services to SAIF Water since his retirement in the Northern Neck and is currently directing a much-needed three-year research project on large bore wells for SAIF Water. This study has been funded by the Jessie Ball duPont Fund and Southeast Rural Community Assistance Project along with many local contributors. Dr. Fletcher has over 40 years of experience in geology, hydrogeology, and water pollution investigations. He holds a A.B. in geology from Lafayette College (1959) and a Ph.D. in geology from The University of Rochester (1964). He held the Charles B. Degenstein Chair in Environmental Science at Susquehanna University (Selinsgrove, Pennsylvania) where he also served as Dean of the School of Arts and Sciences, was President and Principal Hydrogeologist of EnvironMetrics, Inc. (a hydrogeologic consulting firm), and held positions with the Pennsylvania Geologic Survey, the New York Geologic Survey, and the New Jersey Department of Highways. In 1968 he was Visiting Professor of Geology at the University of Bologna (Bologna, Italy). He is the author of *Basic Hydrogeologic Methods: a Field and Laboratory Manual* and numerous scientific articles and reports, which have been published in the Bulletin of the Geological Society of America, Environmental Science and Technology, Journal of Geological Education, and by the Pennsylvania Geologic Survey, and others.

To highlight only a few of his professional affiliations, Dr. Fletcher is a Fellow of the Geological Society of America and a registered Professional Geologist in the Commonwealth of Pennsylvania, served as a national councilor in the Council for Undergraduate Research and a projects reviewer for the National Science Foundation. He has been awarded scientific grants by the National Science Foundation, the Research Corporation (ACS), the American Geological Institute, the Kellogg Foundation, and Pennsylvania Higher Education Authority. He was a member of the Snyder County (Pennsylvania) Planning Commission and was appointed by then Governor Thomas Ridge to the Pennsylvania State Registration Board for Engineers, Land Surveyors, and Geologists.

Dr. Fletcher has taught undergraduate courses in Groundwater Hydrology, Groundwater Pollution and Monitoring, Groundwater Modeling, Environmental Risk Assessment, Environmental Laws and Regulations, and Research in Hydrogeology. His geologic and hydrogeologic projects conducted in Pennsylvania, New York, New Jersey, Utah, and Italy included stratigraphic and structural geologic surveys, floodplain delineation and characterization, identification and characterization of sites for groundwater supply wells, aquifer testing, and description and interpretation of groundwater pollution cases. Dr. Fletcher's hydrogeologic studies include field mapping of geologic formations and aquifers, description and interpretation of rock discontinuities, analysis of the water-bearing capacity of geologic units, identification of groundwater recharge and discharge areas, interpretation of groundwater flow directions and rates, computer modeling of groundwater occurrence and movement, location of optimum sites for water wells, conducting and analyzing aquifer pumping tests, and prediction of well yield. He has carried out studies to determine the quality of groundwater supplies, identified and characterized sources of groundwater contamination, designed groundwater-monitoring systems, computed the migration rates of groundwater contaminants, and supervised groundwater-monitoring programs.

As the SAIF Water Committee seeks to help rural Virginians with private wells maintain a safe supply of drinking water, we are most grateful for the professional expertise and good fellowship that he has contributed.

Rev. Gayl Fowler, Chair
SAIF Water Committee

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INTRODUCTION AND PURPOSE

A growing population and an expanding economy in the Northern Neck of Virginia has created an ever-increasing demand for freshwater. This pressure is now beginning to strain the supply of this natural resource and threatens to impose severe restraints on future development. The Virginia Department of Environmental Quality estimates that water users currently pump more than 6 million gallons of water a day (2.2 billion gallons per year) from the aquifers of the Northern Neck. In addition, large groundwater withdrawals in the Tidewater region and in southern Maryland also come from the same aquifer system that serves the Northern Neck.

Although water of the earth's crust is commonly viewed as a renewable resource, regional groundwater supplies are renewed at rates much slower than they are used up.

Moreover, history shows us that the most readily available and least expensive water supplies are exploited first. As regional development progresses, we are compelled to seek more distant and more expensive sources of water. We must drill ever deeper for groundwater, often until we approach the lower limits of the regional hydrogeologic system. The total supply of freshwater shrinks, as more and more groundwater is removed from aquifer storage. If a productive water supply is to be ensured for the future, then we must manage this resource wisely. It is obvious that the wise management of water resources requires a clear and thorough understanding of aquifer systems and of the scientific principles that govern the occurrence and movement of groundwater. The purpose of this report is to provide a review and summary of the hydrogeology of the aquifers of the Northern Neck in order to form a foundation for the sound utilization and future development of the water resources of the region.

LOCATION AND SETTING

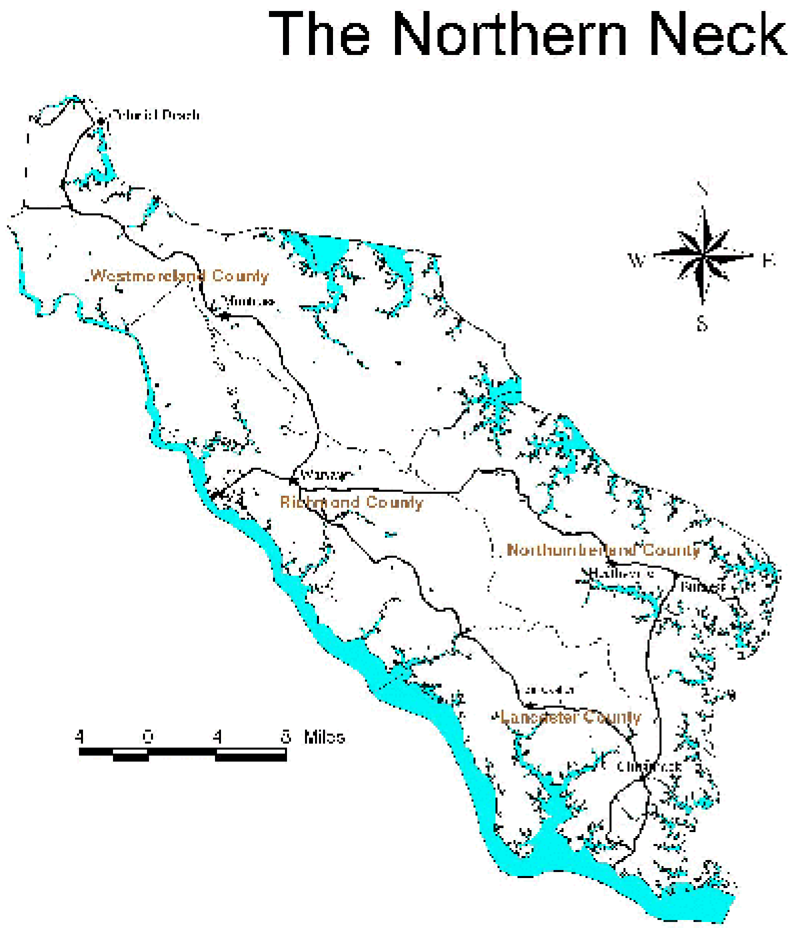
The Northern Neck is the most northern of three long peninsulas that form the great part of the Tidewater of Virginia (**Figure 1**). (The other two, from north to south, are the Middle Peninsula and the Virginia Peninsula.) It is bounded on the northwest by the Potomac River, on the southwest by the Rappahannock River, on the east by the Chesapeake Bay, and on the west by King George County. Consisting of a total of 829 square miles--754 square miles of land area, the Northern Neck is approximately 65 miles long and 20 miles wide. It lies entirely within the Coastal Plain physiographic province, which extends from the Fall Line (or Fall Zone) in the vicinity of Richmond, Fredericksburg, and Washington, D.C. to the Atlantic Ocean.

GROUNDWATER TERMS AND CONCEPTS

This section presents a brief review of common terms and basic concepts that are important for understanding the structure and function of aquifers. This information is adapted from Driscoll (1986) and Fletcher (1997). Readers familiar with the science of groundwater may skip over the section and go on the description of the hydrogeologic system of the Northern Neck.

Aquifers and Confining Units

An ***aquifer*** is defined as a geologic unit that contains enough saturated permeable rock or sediment that it can supply significant volumes of water to wells and springs. Examples of productive aquifers are sedimentary layers of sand or gravel. Not all kinds of rock make good aquifers, however. Some are not porous enough to store large amounts of water nor permeable enough to conduct water at a sufficient rate of flow. These materials form geologic bodies called ***confining units,*** or ***aquicludes***.



1**. Index map of the Northern Neck, Virginia (courtesy of the Northern Neck Planning District Commission).**

Examples of confining units include clay or marl. It is important to recognize that confining units contain water, albeit in small amounts, and can under special conditions conduct water through them. In nature, there are few types of rock that are completely non-porous or impermeable. Thus, the difference between an aquifer and a confining unit is the relative extent of their respective storage and transmission qualities (see **Aquifer Properties** below).

Types of Aquifers

There are several types of aquifers; the major ones are water-table aquifers and artesian aquifers.

Water-table Aquifers*.--*The shallowest aquifers that underlie the Northern Neck are ***water-table aquifers*** (**Figure 2**)*.* Water contained in these aquifers originates as precipitation that infiltrates downward from the land surface and is stored in the open spaces of the soil and rock below, like the water of a saturated sponge. This “sponge” is called the ***saturated zone*** and the top surface of the saturated zone is termed the ***water table***.

Unlike the water of a saturated sponge, however, the groundwater of an aquifer isn’t immobile but flows slowly from ***recharge zones*** at the earth’s surface to ***discharge zones*** such as springs, seeps, and bodies of surface water (lakes, streams, wetlands, etc.) where the water table intersects the land surface. This discharged water sustains stream flow between rainstorms and keeps non-coastal wetlands wet. Unlike the water of deeper aquifers, which is under great pressure, the water in the water-table aquifers is subject only to the pressure of the atmosphere. For this reason, they are commonly referred to as ***unconfined aquifers***. Consequently, wells that are dug or bored into water-table aquifers are rarely ***free flowing*** at the wellhead. Instead, water rises in these wells only to the level of the water table; from there it must be pumped or lifted to the top of the well.

Although water-table aquifers offer a readily-accessible and inexpensive source of domestic water to residents of the Northern Neck, they exhibit several characteristics of quantity and quality that must be considered if they are to be developed in a safe and efficient manner.

Because the level of the water in shallow wells marks the level of the water table, these wells are vulnerable to the periodic rise of the water table that is a normal feature of a temperate climate like that of Virginia. During dry periods, when precipitation falls below the long-term average, less water is available to recharge the shallow aquifer. Groundwater still continues to flow out of the aquifer at zones of discharge, however; and the volume of water stored in the aquifer is reduced and the water table declines. (The level of the water table at any time is a measure of the volume of water stored in a water-table aquifer.) As the water table declines, the level of water in shallow wells (see **Figure 2**) likewise declines. If the water level falls below the bottom of the well, the well

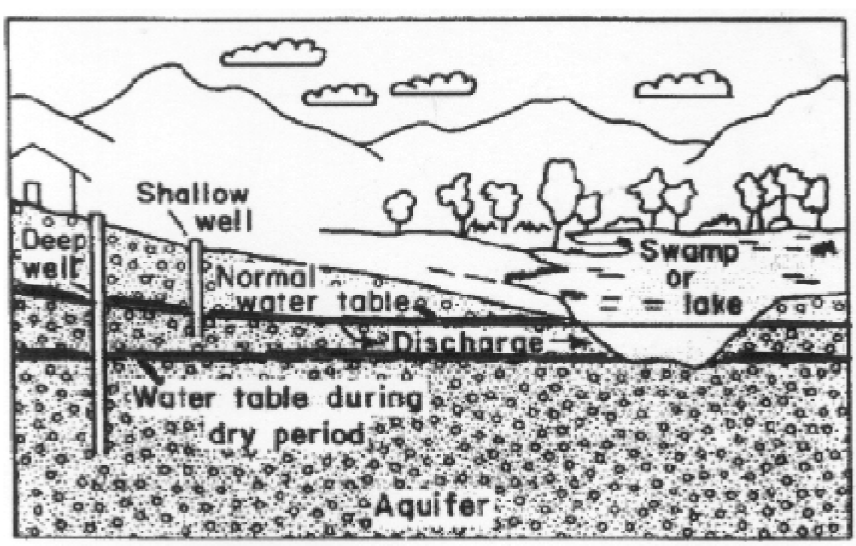


Figure 2. Illustration of a water table aquifer.

will “go dry.” (Deeper wells may be unaffected by the decline of the water table.) Even if be obtained from the well. The only practical method to restore water flow is to deepen the water level falls below the level of the pump installed in the well, no more water can the well (gaining additional storage) or reinstall the pump at a position lower in the well. Dry conditions may last several years, but eventually the end of such a drought will see the increase in precipitation and the rise of the water table once again.

Moreover, because water-table aquifers lie close to the land surface, they may experience more problems of water quality than artesian aquifers. In the absence of proper well construction and maintenance, and effective measures of aquifer protection, water-table aquifers and the shallow wells that are constructed in them may be prone of contamination. For example, shallow wells situated in rural regions are commonly polluted by septic tank seepage, agricultural runoff, and road drainage. The poorer the well construction and maintenance, the more likely serious pollution problems will be present. The SAIF Water Committee estimates that approximately 3,500 shallow wells in Northumberland and Lancaster Counties suffer from unsanitary conditions.

Artesian Aquifers.--Deep wells of the Northern Neck always draw water from artesian aquifers. Unlike a water-table aquifer, an ***artesian aquifer***, or ***confined aquifer***, is not in direct contact with the atmosphere through open spaces in the overlying permeable soil or rock; but rather is bounded above and below by impermeable layers called confining units (**Figure 3**). Consequently, water in a confined aquifer is under a significantly greater pressure than atmospheric pressure and will rise in tightly-cased wells to levels far above the top of the aquifer. The cause of this pressure is the weight of groundwater that occupies the aquifer at an elevation higher than the point where the well penetrates the top of the aquifer. This pressure is referred to as ***confining pressure*** or ***hydrostatic pressure****.* In some cases, the confining pressure is great enough to force the water out of the top of the well, producing a ***free-flowing well****.*

The imaginary surface representative of all of the levels to which water rises in wells cased in an artesian aquifer is called the ***potentiometric surface****.* The potentiometric surface should never be confused with the water table of an unconfined aquifer. It is sound to view water levels in wells drilled into artesian aquifers as gauges of the confining pressure in the aquifer and not, as in the case of water-table aquifers, as the top surface of the saturated zone. Changes in the elevation of the potentiometric surface at any location may be used to determine the loss or gain of water in storage in an aquifer.

Typically, water recharges an artesian aquifer in the region where it is exposed at the surface of the earth. For some of the aquifers of the Northern Neck, this recharge zone is situated inland east of the Fall Line, which marks the boundary between the Coastal Plain and Piedmont physiographic provinces and passes through Fredericksburg and Richmond. From there groundwater flows down slope through the aquifer and then discharges by several means to coastal waters. In addition to this mechanism, deep aquifers may also be recharged by leakage from overlying layers, including confining units. Such aquifers, then, are called ***leaky aquifers*** or ***semiconfined aquifers***. Because of the low permeability of confining units, vertical

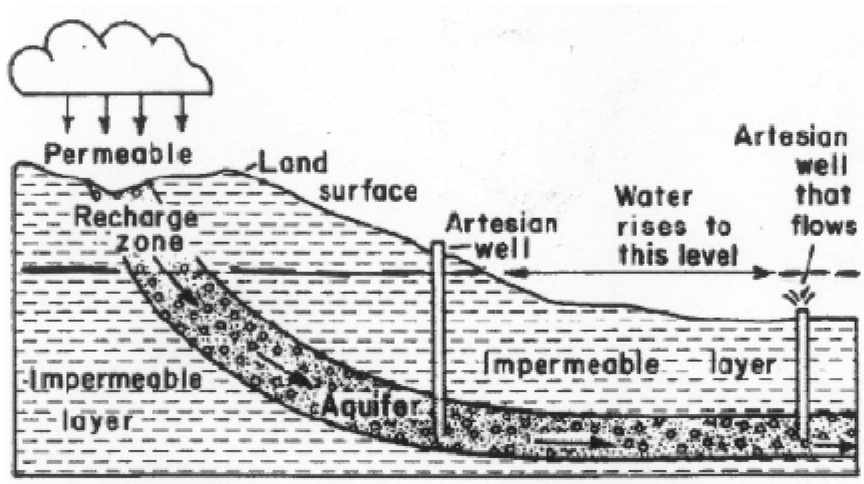


Figure 3. Illustration of an artesian aquifer.

leakage occurs at rates that are much slower than the rates of lateral groundwater flow through the aquifer.

Some Characteristics of Pumped Wells

Several characteristics of pumped wells are important to the understanding of aquifers. The first characteristic is ***static water level***, which is the level at which water stands in a well when no water is being withdrawn. In a water-table aquifer, the static water level marks the position of the water table; while in an artesian aquifer, it signifies the level of the potentiometric surface. The ***pumping water level*** is the level at which water stands in a well when pumping is in progress. The difference between the water table or potentiometric surface and the pumping level is referred to as ***drawdown*** in the well. The volume of water discharged from a well in a given unit of time, e.g., gallons per minute (gpm) by pumping or free flow is called ***well yield***. The "best" well is one that can produce a high well yield with a minimum of drawdown. The yield per unit of drawdown, usually expressed as gpm/ft, is known as the ***specific capacity*** of a well. Specific capacity may range from less than 1.0 gpm/ft in an aquifer of low permeability to more than 100 gpm/ft for a highly permeable aquifer. Productive aquifers in the Northern Neck exhibit typical specific capacities in the range 3 to 8 gpm/ft.

Aquifer Properties

In human terms, aquifers serve two important functions: 1) they store vast quantities of water in their open spaces–their pores or fractures--and 2) they transmit water through these open spaces. A productive aquifer performs both of these functions very well. Ignoring for the moment issues of water quality, the worth of an aquifer as a source of water is measured by two properties that represent the important aquifer functions stated above: storage and transmission.

The property that measures the storage capacity of an aquifer is called ***storativity***. A given value of storativity represents the volume of water that is either expelled from or taken into aquifer storage in relation to a change in the level of the saturated thickness. Storativity is a dimensionless ratio and is expressed by the equation ***S = V / A)h***, where ***S*** is storativity, ***V*** is the volume of water gained or lost, ***A*** is the surface area of the aquifer affected by the recharge or discharge, and ***)h*** is the average decline in the water level. For a pumped water table aquifer, storativity represents the quantity of water drained from the aquifer by gravity and typically lies in the range of 0.01 to 0.03. In artesian aquifers, it is the result of compression of the aquifer and expansion of the confined water when pumping reduces the confining pressure. Storativity is much less in artesian aquifers than that of a water-table aquifer, ranging from 0.00001 to 0.001. Its obvious that pumping water from an aquifer exhibiting a high value of storativity will result in a smaller decline of the water level (that is, drawdown) than pumping water from an aquifer with a low storativity value. That is to say, drawdown is inversely related to storativity. Thus, high values of storativity identify "good" aquifers. The reason for this is obvious. A "good" aquifer is one that can yield large volumes of water and, at the same time, produce only a small amount of drawdown.

The property that measures the amount of water that can be transmitted through an aquifer is known as ***transmissivity***. A given value of aquifer transmissivity incorporates the permeability of the geologic material–known as ***hydraulic conductivity***--and the saturated thickness of the aquifer. In equation form, transmissivity is expressed as ***T = Kb***, where ***T*** is transmissivity, ***K*** is horizontal hydraulic conductivity, and ***b*** is the saturated thickness of the aquifer. Hence, high values of transmissivity are associated with highly permeable or thick aquifers. Conversely, low transmissivity is characteristic of thin aquifers or those of low permeability. Aquifers exhibiting high values of transmissivity are capable of transmitting large volumes of water to wells with little resultant drawdown of the water table or potentiometric surface. It follows, then, that confining units exhibit low values of transmissivity. Many aquifers of the Northern Neck exhibit changes in transmissivity throughout their geographic extent. For example, a decrease in transmissivity may result from 1) a facies change from sandy to clayey sediments, 2) a thinning of the aquifer, or 3) both. In this region, a transmissivity of 15,000 to 20,000 ft^2/day denotes an excellent aquifer, one capable of supplying water to large industrial or municipal users. Transmissivity values in the range of 1,000 to 3,000 ft^2/day indicate good aquifers, which provide reliable supplies of water for light industrial and domestic purposes.

HYDROGEOLOGIC SYSTEM OF THE NORTHERN NECK

The Northern Neck of Virginia--and all of the Atlantic Coastal Plain--is underlain by an eastward-thickening wedge of unconsolidated and semi-consolidated sedimentary layers, chiefly sand and clay, that reaches a maximum thickness of approximately 6,200 feet in the vicinity of Virginia's Eastern Shore. The western edge of this wedge is marked by the Fall Line, where the sediments of the Coastal Plain terminate against the igneous and metamorphic rocks of the Piedmont physiographic province. This sedimentary wedge forms a complex and dynamic ***hydrogeologic system*****, which** serves as the major source of freshwater for the residents of the borderland of the Chesapeake Bay

This valuable hydrogeologic system consists of alternating layers of water-bearing zones called aquifers and water-poor zones known as confining units (see **Figure 4**). Well drillers seek out aquifers, usually layers or lenses of sand, which have potentially high well yields and bypass the clayey confining units, which produce only low well yields. Well yields adequate for some household uses may be obtained inexpensively from shallow, large-bore wells dug into the water-table aquifers of the Northern Neck. Many homeowners, however, draw their household water from deeper wells drilled into one of the artesian aquifers of the region. Also, high volume wells desired by municipal water systems and industries are invariably drilled into the deeper, artesian aquifers.

Our understanding of the hydrogeologic system of the Northern Neck is by no means complete, nor without some disagreement among the authorities who have studied this system. One important point of difference involves the scientific scheme by which the aquifers of the region are identified and classified. It has been customary in the Northern Neck to describe the hydrogeologic system of the region in terms of three aquifers: the ***water table aquifer***, the ***upper artesian aquifer***, and the ***principal artesian aquifer*** (see Newton and Siudyla, 1979 and Northern Neck Groundwater Committee, 1990). This classification is based on two distinct characteristics of the aquifers. First, and most obvious, it distinguishes between the two hydrologic types of

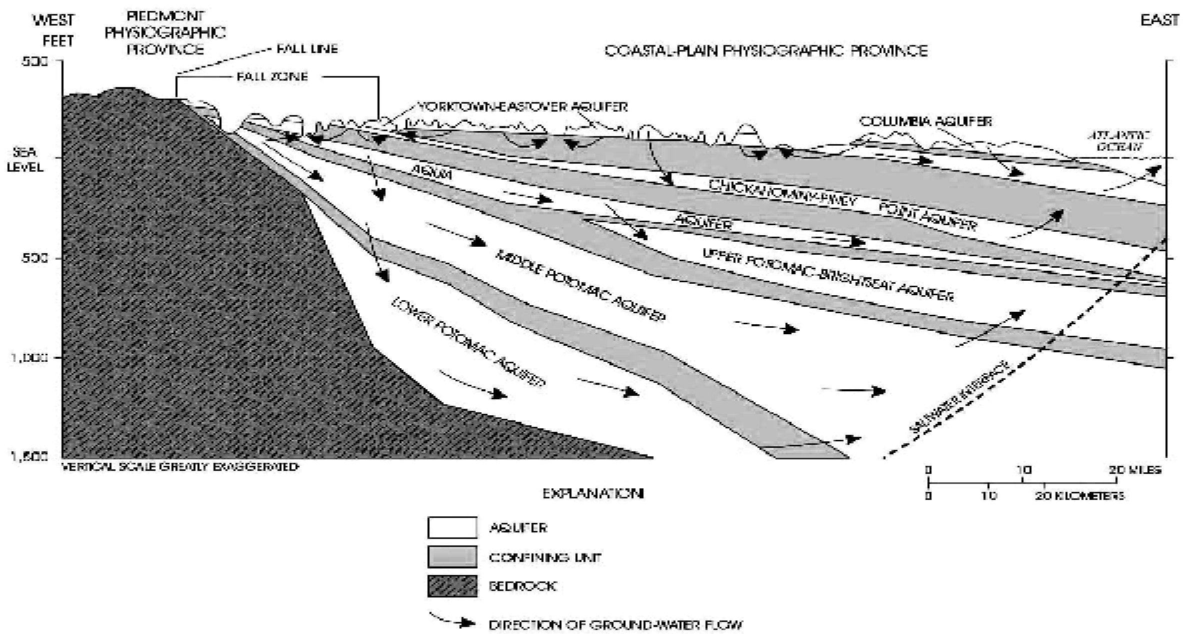


Figure 4. Idealized cross-section of Northern Neck hydrogeologic system (modified from Meng and Harsh, 1988).

aquifers present, separating confined (artesian) aquifers from unconfined (water table) aquifers. Second, it groups the aquifers according to their relative depth below the surface of the land.

Although simple and easily grasped, this informal classification of aquifers is the source of some confusion. For example, the Virginia State Water Control Board (SWCB) report on the groundwater of the Northern Neck (Newton and Siudyla, 1979) applied the term “upper artesian aquifer” to a series of sediments of Eocene age and “the first, good, water-bearing horizon beneath the poorly productive Yorktown Formation of Miocene age,” and illustrates correctly the stratigraphic position of this aquifer on Cross Section A-A’ of the report. It is clear from a comparison of this cross section with Plate 2 of USGS Professional Paper 1406-C (Meng and Harsh, 1988) that the upper artesian aquifer corresponds to the Chickahominy-Piney Point aquifer. Unfortunately, Plate 4 of the SWCB report, a structural contour map of the top of the upper artesian aquifer, shows an erroneous interpretation of the elevation of the top of the aquifer in the western portion of the Northern Neck, placing the top much deeper than actuality. (The contours there appear to be drawn on the top of the Aquia aquifer rather than on the Chickahominy-Piney Point aquifer.) To make matters worse, a more recent report (Northern Neck Groundwater Committee, 1990) states incorrectly that the upper artesian aquifer “largely corresponds to the Aquia and/or Middle Potomac aquifers in the western and southern portion of the Northern Neck, and to the Aquia aquifer in the eastern portion of the Northern Neck.” (The Aquia aquifer actually corresponds to the principal artesian aquifer, see below.)

The term “principal artesian aquifer” was used in the SWCB report to refer to “many sands of the Mattaponi and Patuxent formations that have a high potential yield from depths which vary from 300 feet below sea level in the western third of the Study Area to nearly 600 feet below sea level in Lancaster County.” The chief problem with the use of this informal name for the water-bearing strata is that they do not constitute one continuous sedimentary formation across the Northern Neck. In the western portion of the region, the top of the principal artesian aquifer corresponds to the Aquia aquifer, while in the western portion it corresponds to the Brightseat aquifer.

Because of these problems, the SWCB classification of aquifers based on the relative depth of water-bearing zones is abandoned in the present report, and the USGS classification of aquifers based on stratigraphic formations is employed (see Meng and Harsh, 1988).

WATER-TABLE AQUIFERS OF THE NORTHERN NECK

Two water-table aquifers are recognized in the Northern Neck: the Columbia aquifer and the Yorktown-Eastover aquifer. Large-bore, dug wells draw water from one of these aquifers. The Columbia aquifer crops out at the surface chiefly east of the Richmond County-Northumberland County line and, in most of Northumberland and Lancaster Counties, overlies the Yorktown-Eastover aquifer. Only in the western portion of the region is the Yorktown-Eastover aquifer exposed at the land surface, where it constitutes a water-table aquifer. In the eastern portion of the region, it drops below the land surface and is semiconfined (see **Figure 4**).

Columbia Aquifer

The Columbia aquifer is the shallowest source of freshwater in the eastern portion of the Northern Neck. Generally, all land surfaces less than 100 feet above sea level in Northumberland and Lancaster Counties are underlain by sediments of the Columbia aquifer, and most shallow, dug wells of this region are constructed in this aquifer. The aquifer is unconfined throughout the region, although lenses of clay may produce locally confined conditions. Because this aquifer is only poorly to moderately productive, it is suitable primarily as a water supply for households or businesses that utilize shallow wells. It is thought to be, however, a major source of recharge to the underlying artesian flow system.

The Columbia aquifer is composed of interbedded gravel, sand, silt, and clay; some sand layers exhibit a distinctive yellow-red ("rusty") appearance due to the presence of oxidized iron. The saturated thickness of the aquifer ranges across the Virginia Coastal Plain from about 15 feet near its western margin to about 80 feet in the Tidewater region. The SWCB report (Newton and Siudyla, 1979) states that typical well yields for the Columbia aquifer are low, ranging only from 5 to 20 gallons per minute (gpm). Accurate values for aquifer hydraulic properties are difficult to come by. Transmissivity is estimated to be approximately 250 ft^2/day, and storage coefficient is reported to be approximately 0.15.

The sediments of the Columbia aquifer are primarily modern and Pleistocene in age. They are underlain by the Yorktown confining unit, a series of gray and multicolored, sandy and silty clays of Pliocene age.

Yorktown-Eastover Aquifer

The Yorktown-Eastover aquifer is both unconfined and artesian, depending on geographic location. In Northumberland and Lancaster Counties, the aquifer lies beneath the Yorktown confining unit (and the Columbia aquifer) and is artesian. The aquifer is unconfined, however, in a broad belt that lies nearby and parallel with the Fall Line. Like the overlying Columbia aquifer, the Yorktown-Eastover aquifer is a common source of shallow freshwater, and where it is unconfined, likely serves as a source of recharge to the underlying confined flow system.

The sediments of the Yorktown-Eastover aquifer are composed chiefly of fine to coarse sand with shell, clay, and sandy clay. Thickness ranges across the region from approximately 6 feet near the Fall Line to about 100 feet in the Tidewater counties. Reported yields for residential, commercial, and light industrial wells range from 25 to 250 gpm. Data from Lancaster County indicate specific capacity values in the range of 1.2 to 2.3 gpm/ft. Transmissivity values are available only from the Tidewater and range from 200 to 3,000 ft^2/day. Storativity values reported from the confined aquifer of the same region occur in the range from 0.0006 to 0.000077.

The Yorktown-Eastover aquifer is made up of sediments of the Pliocene Yorktown Formation and the upper part of the Miocene Eastover Formation. It is underlain directly by a series of sand and clay layers of variable thickness making up the St. Marys confining unit, the St. Marys-Choptank aquifer, and the Calvert confining unit.

ARTESIAN AQUIFERS OF THE NORTHERN NECK

The classification of the artesian aquifers of the Northern Neck in this report follows that of the USGS Regional Aquifer System Analysis (RASA). It recognizes six deep aquifers that are sources of groundwater for the residents of the region. These are (from shallowest to deepest): Chickahominy-Piney Point, Aquia, Brightseat, Upper Potomac, Middle Potomac, and Lower Potomac aquifers.

Chickahominy-Piney Point Aquifer

The Chickahominy-Piney Point aquifer is not a major producer of water throughout the Northern Neck, although it is used in Lancaster County by villages, light industries, and households. The aquifer is traditionally utilized by driven wells of moderate depth. Like other Coastal Plain aquifers, it slopes eastward from its outcrop belt in Stafford and King George Counties near the Fall Line, at an average of 12 feet per mile (ft/mi) and passes beneath the Chesapeake Bay (**Figure 4**). The top of the aquifer drops from 64 feet above sea level at Oak Grove, Westmoreland County, to 102 feet bsl at Montross, Westmoreland County, and to 353 feet bsl at Reedville, eastern Northumberland County (see **Table 1**). Furthermore, the aquifer is wedge-shaped in cross-section and thickens eastward from approximately 28 feet at its western limit to 140 feet at Reedville. East of Reedville, however, it becomes predominately clayey and loses its definitive sandy character in the vicinity of the Eastern Shore Peninsula.

The Chickahominy-Piney Point aquifer is made up of thick bedded olive-green to dark greenish-gray, fine to coarse, glauconitic quartz sands and calcareously cemented shell beds. The shelly beds typically range from a few inches to 1 or 2 feet thick, but locally reach 8 feet or more. Well drillers describe the aquifer as black and white ("salt-and-pepper") sands containing shell rock, limestone, and dark silty clay. Reported well yields range from 20 to 250 gpm. No accurate information concerning aquifer hydraulic properties exists for the Northern Neck; however, transmissivity values of 150 to 2,000 ft^2/day have been reported from the Middle Peninsula. In southern Maryland, values of transmissivity reach as high as 4,000 to 5,000 ft^2/day (on the Eastern Shore). Storativity values of this aquifer range from 0.0003 to 0.0004 (see **Table 2**).

The Chickahominy-Piney Point aquifer includes sediments of the Miocene and Oligocene Old Church Formation and the Chickahominy and Piney Point Formations of Eocene age. It is correlated with the Piney Point-Nanjemoy aquifer in Maryland and the Castle Hayne aquifer in North Carolina. The aquifer is underlain by the Nanjemoy -Marlboro clay (confining unit). This confining unit is lens-shaped in the Northern Neck; its thickness varies from 15 feet in the vicinity of the Fall Line to more than 130 feet in western Westmoreland County and to 75 feet region of the Chesapeake Bay.

The SWCB report (Newton and Siudyla, 1978) did not expressly identify the Chickahominy-Piney Point aquifer, but it is clear that it was referring to this aquifer when it designated the "upper artesian aquifer." Besides defining the upper artesian aquifer as "the first, good, water-bearing horizon beneath the poorly productive Yorktown Formation of Miocene age," a geophysical cross section in Appendix F 5 illustrates a stratigraphic position that matches that of the Chickahominy-Piney Point aquifer given by Meng and Harsh (1988, Plate 2).

Table 1. Altitude and Thickness of Artesian Aquifers of the Northern Neck of Virginia

Aquifer	Oak Grove Westmoreland County (Well 54P 3)		Montross Westmoreland County (Well 56N 1)		Reedville Northumberland County (Well 60L 19)	
	Altitude of Top (ft msl*)	Approx. Thickness (ft)	Altitude of Top (ft msl)	Approx. Thickness (ft)	Altitude of Top (ft msl)	Approx. Thickness (ft)
Chickahominy-Piney Point	64	28	-102	49	-353	140
Aquia	-58	125	-283	89	-574	26
Brightseat	Absent	0	-383	76	-658	152
Upper Potomac	Absent	0	-497	130	-860	70
Middle Potomac	-400	380	-660	–	-1000	--

- feet, mean sea level
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Table 2. Hydraulic Properties of Selected Deep Artesian Aquifers of the Northern Neck of Virginia

Aquifer	Horizontal Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)	Storativity
Chickahominy-Piney Point	25	150 - 2,000	0.0003 -0.0004
Aquia	40	500 - 2,000	0.0001 - 0.0002
Brightseat (incl. Upper Potomac)	33	1,000 - 4,000	
Middle Potomac	3.8 - 52	190 - 12,000	0.0002 - 0.00005

Aquia Aquifer

The shallowest artesian aquifer of the Northern Neck that produces large well yields suitable for high-volume water use is the Aquia aquifer. It forms a continuous lense-shaped sand body that exhibits a maximum thickness of approximately 125 feet in King George County near Dahlgren and thins greatly to the east, decreasing to a thickness of 26 feet at Reedville (Northumberland County) and pinching out near the western shore of the Chesapeake Bay (see **Figure 1** and **Table 1**). The eastern pinch out is the result of a sand-to-clay facies change. The Aquia aquifer is exposed on the land surface along a thin belt near the Fall Line and, from there, slopes eastward at an average of 10 ft/mi. The top of the aquifer drops from 58 feet bsl at Oak Grove in Westmoreland County to 283 feet bsl at Montross, Westmoreland County, and to 574 feet bsl at Reedville (see **Table 1**).

The Aquia aquifer is a massively bedded lense of very fine to medium glauconite and quartz sands, containing minor amounts of shells and clay. Well drillers describe it as fine black sands or greensands. They also report the unit as made up of "caving sands." The Aquia aquifer of the Northern Neck is very similar to the Aquia of Maryland, but somewhat thinner. At the eastern margin of the region and in the Virginia Tidewater, however, it is finer grained than in the Northern Neck, with a limy-mud matrix, and is not commonly used as an aquifer. Typical values of specific capacity lie in the range of 3.5 to 8.6 gpm/ft. Transmissivity values range from 500 to 2,700 ft^2/day, and storativity is reported to lie in the range of 0.0001-0.00023. In southern Maryland, a transmissivity value of 5,000 ft^2/day has been reported from Queen Anne's County, where the aquifer reaches a thickness of more than 225 feet.

The aquifer consists of sediments of late Paleocene age. It is correlated with the Aquia-Rancocas aquifer of Maryland and the Beaufort aquifer of North Carolina. In the Northern Neck it is underlain by the Brightseat confining unit, which separates the Aquia and Brightseat aquifers. This confining unit is nearly 60 feet thick in the vicinity of Reedville, but thins to only 10 feet in Westmoreland County

In the western portion of the Northern Neck, i.e., King George County and western Westmoreland County, the Aquia aquifer (and likely the Middle Potomac aquifer) matches the water-bearing zone referred to in the SWCB report (Newton and Siudyla, 1979) as the principal artesian aquifer. For example, the position of the top of the principal artesian aquifer at Oak Grove that is illustrated on Cross Section A-A' (page F 3) of the SWCB report is identical to stratigraphic position of the top of the Aquia aquifer shown in Meng and Harsh (1988) and reported here in **Table 1**. It is evident, then, that the Aquia-Middle Potomac aquifer is equivalent to the so-called principal artesian aquifer in the western Northern Neck and not to the upper artesian aquifer as reported by the Northern Neck Groundwater Committee (1990). The stratigraphic position of the principal artesian aquifer in the eastern Northern Neck is discussed below (see section on the Brightseat aquifer).

Brightseat Aquifer

The Brightseat aquifer represents on the best water producing zones of the eastern and central Virginia Coastal Plain. Numerous industrial and municipal groundwater users exploit this aquifer. Except in the region of Windmill Point (southeastern Lancaster County) where groundwater contains high concentrations of sodium, this aquifer is capable of producing large quantities of high-quality water suitable for most common uses. The Brightseat aquifer is not exposed on the surface of the land anywhere in the Northern Neck, but is restricted to the subsurface (see **Figure 1**). As a result, all recharge to this aquifer must come from downward leakage from the overlying aquifers and confining units--and perhaps from upward leakage from underlying sediments. It slopes eastward toward the Atlantic Ocean at approximately 14 ft/mi. The top of the Brightseat aquifer descends from 383 feet bsl at Montross to 658 bsl at Reedville. The aquifer is lenticular in cross-section, attaining a maximum thickness of approximately 150 feet beneath the Chesapeake Bay east of Reedville and thins to nearly zero thickness along its western and southern margins. It is 76 feet thick at Montross, Westmoreland County, but is absent in King George County, where it had been eroded prior to the deposition of the overlying late Paleocene sediments (see **Figure 4** and **Table 1**). In southeastern Maryland, the strata of the Brightseat aquifer are thin and are included in the Lower Confining Bed, which directly underlies the Aquia aquifer (Achmad and Hansen, 1997).

This useful aquifer consists of silty clay beds, with some interbedded thin sands or sandy clays. The sands are composed of predominantly fine, well-sorted white quartz with lenses of shells, lignite, mica, and minor amounts of glauconite. Well drillers refer to this aquifer as “the white sand.” Values of specific capacity from wells in Northumberland and Lancaster counties range from 3.3 to 5.8 gpm/ft. Little is known of the hydraulic properties of this aquifer in the Northern Neck, but reports from outside the region describe the Brightseat-Upper Potomac aquifer as having a transmissivity of 1,000 to 2,000 ft^2/day. A transmissivity value of 13,000 ft^2/day has been reported from West Point on the Middle Peninsula. No reliable values of storativity have been reported, but data from similar artesian aquifers suggest values in the range of 0.0001 to 0.0005 (see **Table 2**).

The Brightseat aquifer is composed of sediments of Early Paleocene age. It is correlated with the Brightseat aquifer in Maryland, but it pinches out southward against the north flank of the Norfolk arch and is absent in North Carolina. It is underlain by the Brightseat-Upper Potomac confining unit, consisting of 40 feet or less of black to dark green, micaceous clay with interbeds of red to yellow clay.

The lenticular shape of the Brightseat aquifer and the pinch out in the western portion of the Northern Neck accounts for the miscorrelation of this unit in the SWCB report (Newton and Siudyla, 1979). Evidently unaware of the unconformity (i.e., ancient erosion surface) that truncates the western edge of the aquifer in Westmoreland County and of the thinning of the Aquia aquifer eastward into Northumberland County (see **Figure 4**), the authors of the SWCB report (Newton and Siudyla, 1979) erroneously matched strata belonging to the Aquia aquifer at Oak Grove with those of the Brightseat aquifer at Reedville, thus misassigning two different water-bearing geologic units to the same aquifer, the principal artesian aquifer.

Upper Potomac Aquifer

Like the Brightseat aquifer, the Upper Potomac aquifer is present only in the subsurface and is restricted largely to the eastern half of the Northern Neck (see **Figure 4**). And like the overlying Brightseat aquifer, it is truncated by a buried erosion surface and absent from the stratigraphic column west of the King George-Westmoreland County line. In Northumberland and Lancaster counties, this aquifer is often considered together with the Brightseat aquifer and termed the Brightseat-Upper Potomac aquifer. Here, well drillers seldom differentiate between the Brightseat and Upper Potomac aquifers, preferring instead to refer to the composite aquifer as the top zone of the so-called ‘principal artesian aquifer.” The Upper Potomac aquifer itself slopes eastward at approximately 15 ft/mi. It thickens rapidly from the pinch-out in western Westmoreland County to 130 feet at Montross and, from there, thins again to approximately 70 feet in the vicinity of Reedville, Northumberland County (see **Table 1**). The top of the Upper Potomac aquifer lies at approximately 500 feet bsl in the vicinity of Montross and at 860 feet bsl at Reedville.

The composition of the Upper Potomac aquifer is chiefly a series of white, micaceous, very fine to medium quartz sand layers, with wood fragments and interbedded dark, micaceous clays and silty clays. Well drillers report that the sediments of this aquifer are “easily penetrated.” they describe the sediments of the aquifer as “fine, white micaceous sands” and dark micaceous clays, ”that commonly contain “wood fragments.” The aquifer exhibits hydraulic properties similar to the Brightseat aquifer, with which it is often associated.

The sediments the aquifer are early late Cretaceous in age. They correlate with the upper Patapsco aquifer in Maryland, the upper Cape Fear aquifer in North Carolina, and the Raritan aquifer in New Jersey. The Upper Potomac aquifer is underlain by the Middle Potomac confining unit, a massive and thick-bedded layer of predominately red clay. The confining unit is relatively thin in the Northern Neck, averaging 80 feet or so.

Middle Potomac Aquifer

The Middle Potomac aquifer is too deep and too salty to serve as a major source of groundwater for the eastern portion of the Northern Neck, but it is an important source of water in the western portion of the region, where the top of the aquifer occurs at a depth of approximately 400 feet bsl (see **Table 1**). It serves small industrial, municipal, and domestic uses, producing large quantities of high-quality water. The top of the aquifer slopes eastward to 660 feet bsl at Montross and to 1,000 feet bsl or more in eastern Northumberland and Lancaster Counties. It reaches a depth of more than 2,500 feet bsl beneath the Eastern Shore. The Middle Potomac aquifer contains increasingly high chloride concentrations in the down slope direction, which restricts its use as a source of potable water by residents of the Chesapeake Bay borderland. The aquifer also thickens eastward, attaining a thickness of more than 1000 feet in the Eastern Shore (see **Figure 4**). A thin band of the aquifer is exposed at the land surface near the Fall Line, where a small part is unconfined.

The Middle Potomac aquifer typically is composed of interfingering lenses of medium sand, silt, and clay of various thicknesses. Wells yields from this aquifer in the Tidewater region are known to exceed 700 gpm. Average transmissivity values range from 2,000 ft^2/day in Westmoreland County to nearly 20,000 ft^2/day in the Tidewater. Storativity values are reported to be in the range from 0.0002 to 0.0015.

Sediments of the Middle Potomac aquifer are assigned to the Cretaceous Potomac Formation. They correlate with the lower part of the Patapsco aquifer in Maryland and the Cape Fear aquifer in North Carolina. The aquifer is underlain by the lower Potomac confining unit. This body is composed of thick sequences of finely laminated, brown, gray, and dark-green carbonaceous clay. This confining unit has a thickness of 150 to 200 feet beneath the Northern Neck.

Lower Potomac Aquifer

The Lower Potomac aquifer forms the deepest artesian aquifer in the Coastal Plain of Virginia and lies unconformably on the crystalline bedrock of the basement complex (see **Figure 4**). It is potentially a major source of water throughout the western and central Coastal Plain, but generally it lies too deep for all but large, industrial users. Also, in the eastern region high salinity restricts the use of this aquifer. The Lower Potomac aquifer is reported to thicken eastward from a featheredge at the Fall Line, reaching a maximum thickness of more than 3,000 feet beneath the Eastern Shore. The top of the aquifer descends rapidly from approximately 200 feet bsl near the Fall Line to more than 1,800 feet bsl in eastern Northumberland and Lancaster Counties, where the extreme depth of the aquifer and high salinity has precluded extensive development of the aquifer.

The sediments of the Lower Potomac aquifer typically consist of medium to coarse quartz and feldspar sand with interbeds of clay. Wood fragments (lignite) are common. Well drillers refer to the sediments of the Lower Potomac aquifer as “coarse gray sands” that may contain “gravels” and “light to drab-colored clays.” Drillers also refer to the sands as “hard” or “tough” and to the clays as ‘ tight” or “hard.” Well yields exceeding 700 gpm have been reported from this aquifer. Average transmissivity ranges from 12,000 ft^2/day to 19,000 ft^2/day, and storativity ranges from 0.0005 to 0.0015.

The Lower Potomac aquifer is assigned to the Early Cretaceous, and this sediments correlate with the Patuxent aquifer in Maryland and the Lower Cretaceous aquifer in North Carolina.

SUMMARY AND CONCLUSIONS

Residents of the Northern Neck of Virginia currently pump an estimated 2.2 billion gallons of water per year from the aquifers of this region. Additionally, these same aquifers are the source of groundwater for high-volume users of the Tidewater region and Southern Maryland. As the volume of water withdrawal increases annually, the total supply of groundwater available for future use is threatened.

The major types of aquifers of the Northern Neck are water table aquifers and artesian aquifers. The shallowest aquifers of the region are water table (or unconfined) aquifers, and are generally tapped by large-bore wells of depths of 80 feet or more below the land surface. Two water table aquifers are present: the Columbia aquifer and the Yorktown-Eastover aquifer. Typical well yields are low, ranging from 5 to 20 gallons per minute (gpm), but may reach more than 100 gpm in wells serving large industries.

Six deep aquifers are the primary sources of groundwater of the Northern Neck. These are (from shallowest to deepest): Chickahominy-Piney Point, Aquia, Brightseat, Upper Potomac, Middle Potomac, and Lower Potomac aquifers.

The Chickahominy-Piney Point aquifer is the shallowest of the artesian aquifers of this region, but it is not a major producer of groundwater. Well yields are sufficient for residential use, but high-volume users must rely on deeper aquifers. Like other Coastal Plain aquifers, it slopes eastward from its outcrop belt near the Fall Line, at an average of 12 feet per mile (ft/mi) and passes beneath the Chesapeake Bay. The top of the aquifer drops from 64 feet above sea level at Oak Grove, Westmoreland County, to 102 feet bsl at Montross, Westmoreland County, and to 353 feet bsl at Reedville, eastern Northumberland County. Furthermore, the aquifer thickens eastward from approximately 28 feet at its western limit to 140 feet at Reedville. Although considerable confusion surrounds the informal names applied to the artesian aquifers of this region, it is now clear that the Chickahominy-Piney Point aquifer represents the "upper aquifer system" of the State Water Control Board report (Newton and Siudyla, 1978).

The artesian aquifer closest to the land surface that produces large well yields suitable for high-volume users is the Aquia aquifer. The Aquia aquifer is exposed on the land surface along a thin belt near the Fall Line and, from there, slopes eastward at an average of 10 ft/mi. The top of the aquifer drops from 58 feet bsl at Oak Grove in Westmoreland County to 283 feet bsl at Montross, Westmoreland County, and to 574 feet bsl at Reedville. The aquifer forms a continuous lense-shaped sand body that exhibits a maximum thickness of approximately 125 feet in King George County near Dahlgren and thins greatly to the east, decreasing to a thickness of 26 feet at Reedville (Northumberland County) and pinching out near the western shore of the Chesapeake Bay. In the western portion of the Northern Neck, the Aquia aquifer corresponds to the top of the principal artesian aquifer of the SWCB report (Newton and Siudyla, 1978). In the eastern portion of the region, the Aquia sediments are too thin to form a productive aquifer. (Near Reedville, the underlying Brightseat aquifer represents the principal artesian aquifer.)

The Brightseat aquifer is one of the most productive water producing zones of the eastern and central Virginia Coastal Plain. Numerous industrial and municipal groundwater users exploit this aquifer. It slopes eastward toward the Atlantic Ocean at approximately 14 ft/mi. The top of the Brightseat aquifer descends from 383 feet bsl at Montross to 658 bsl at Reedville. The aquifer is lenticular in cross-section, attaining a maximum thickness of approximately 150 feet beneath the Chesapeake Bay east of Reedville and thins to nearly zero thickness along its western and southern margins. It is 76 feet thick at Montross, Westmoreland County, but is absent in King George County, where it had been eroded prior to the deposition of the overlying late Paleocene sediments. The lenticular shape of the Brightseat aquifer and the pinch out in the western portion of the Northern Neck accounts for the miscorrelation of this unit in the SWCB report (Newton and Siudyla, 1979). Evidently unaware of the unconformity (i.e., ancient erosion surface) that truncates the western edge of the aquifer in Westmoreland County and of the thinning of the Aquia aquifer eastward into Northumberland County, the authors of the SWCB report (Newton and Siudyla, 1979) erroneously matched strata belonging to the Aquia aquifer at Oak Grove with those of the Brightseat aquifer at Reedville, thus misassigning two different water-bearing geologic units to the same aquifer, the principal artesian aquifer.

The three deepest aquifers of the Northern Neck are composed of Cretaceous sediments of the Potomac Group. The Upper Potomac aquifer is present only in the subsurface and is restricted largely to the eastern half of the Northern Neck. In Northumberland and Lancaster counties, this aquifer is often considered together with the Brightseat aquifer and termed the Brightseat-Upper Potomac aquifer. Here, well drillers seldom differentiate between the Brightseat and Upper Potomac aquifers, preferring instead to refer to the composite aquifer as the top zone of the so-called ‘principal artesian aquifer.” The Middle Potomac aquifer is too deep and too salty to serve as a major source of groundwater for the eastern portion of the Northern Neck, but it is an important source of water in the western portion of the region, where the top of the aquifer occurs at a depth of approximately 400 feet bsl. The Lower Potomac aquifer forms the deepest artesian aquifer in the Coastal Plain of Virginia and lies unconformably on the crystalline bedrock of the basement complex It is potentially a major source of water throughout the western and central Coastal Plain, but generally it lies too deep for all but large, industrial users. Also, in the eastern region high salinity restricts the use of this aquifer.

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