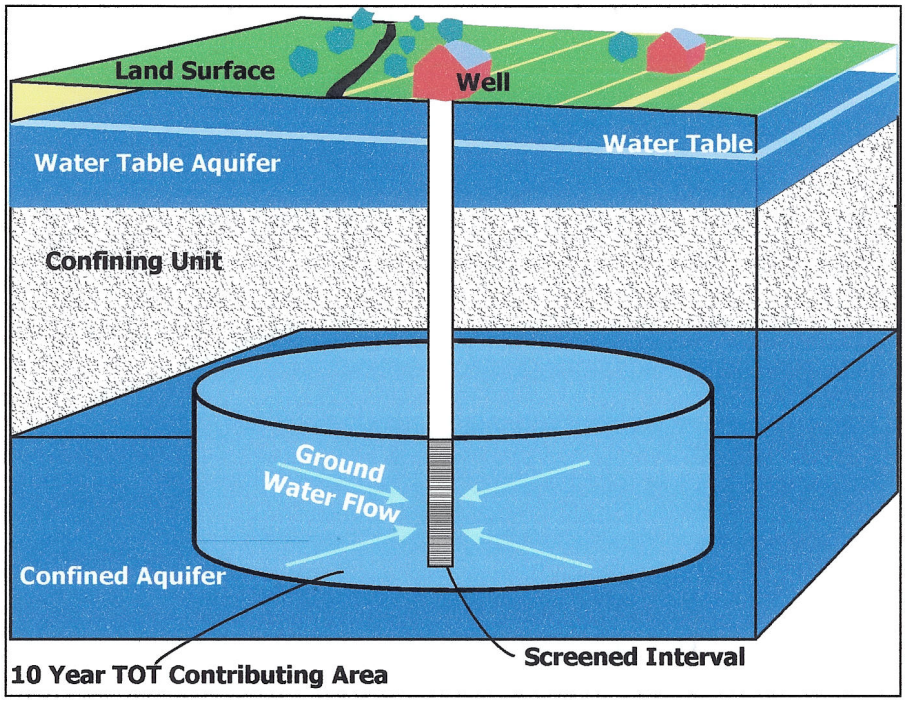
SOURCE WATER ASSESSMENT

FOR THE SEVERNDALE AND ARNOLD PLANT WELLS

IN ANNE ARUNDEL COUNTY, MD



Prepared By
Water Management Administration
Water Supply Program
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MDE

Robert L. Ehrlich
Governor

Kendl P. Philbrick
Secretary

Michael S. Steele
Lt. Governor

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SUMMARY

The Maryland Department of the Environment's Water Supply Program (WSP) has conducted a Source Water Assessment for the Glen Burnie-Broadneck Water System's Severndale Plant wells and the Arnold Plant wells. The required components of this report as described in Maryland's Source Water Assessment Program (SWAP) are 1) delineation of an area that contributes water to each source, 2) identification of potential sources of contamination within the areas, and 3) determination of the susceptibility of each water supply to contamination. Recommendations for protecting the drinking water supplies conclude this report.

The Severndale Plant treats water from seven wells that pump water from three different aquifers known as the Upper Patapsco, Lower Patapsco and Patuxent Formations. The Arnold Plant treats water from six wells that pump water from two different aquifers known as the Upper Patapsco and Lower Patapsco Formations. The Upper Patapsco Formation is the shallowest and youngest in age with the Patuxent Formations being the deepest and the oldest. All these aquifers are naturally protected confined aquifers. The Source Water Assessment areas were delineated by the WSP using U.S. EPA approved methods specifically designed for sources in confined aquifers.

Potential point sources of contamination were researched and identified within the assessment areas from field inspections, contaminant and well inventory databases, and land use maps. Well information and water quality data were also reviewed. Maps showing Source Water Assessment areas are included in this report.

The susceptibility analysis is based on a review of the existing water quality data for each plant, the presence of potential sources of contamination in the individual assessment areas, well integrity, and aquifer characteristics. It was determined that the wells are not susceptible to contaminants originating at the land surface due to the protected nature of confined aquifers. The wells are susceptible iron which occurs naturally in the aquifers.

INTRODUCTION

This report describes the Maryland Department of the Environment's Water Supply Program Source Water Assessment for the Glen Burnie-Broadneck Water System's Severndale plant wells and the Arnold plant wells in Anne Arundel County. The Glen Burnie-Broadneck System serves a population of 249,600 and has seventeen water treatment plants and twenty-six production wells. A population of 90,300 is estimated to be supported by the production from the Severndale and Arnold water treatment plants. The system is owned and operated by the County Department of Public Works (DPW). In 2003 the County DPW completed a Wellhead Protection Plan for two county operated systems and the City of Annapolis under a MDE grant funded project. The plan included source water assessments for the following water systems: Broad Creek, City of Annapolis, and all the wells for the Glen Burnie-Broadneck Water System except for the ones serving the Severndale and Arnold plants. The study focused on the north central portion of the County, hence the Severndale and Arnold plants were not included.

WELL INFORMATION

Well information for each plant was obtained from the Water Supply Program's database, site visits, well completion reports, sanitary survey inspection reports and published reports. A total of thirteen wells are currently used as production wells at these two plants. All these wells except for one (Severndale 3) were drilled after 1973 and should comply with Maryland's well construction regulations. This well which was drilled prior to 1973, when current regulations went into effect, may not meet the current construction standards. Table 1 contains a summary of well information for each of the plants.

Based on site visits, the wells were in good condition and appeared to be regularly maintained, sealed and protected to insure their integrity. A possible threat to water quality in confined aquifers is pathways created by other wells drilled into the same aquifer as the production wells. There is one unused well at the Severndale plant and if this well has no potential for use in the future it should be permanently abandoned and sealed by a licensed well driller as it represents a pathway for contamination to the deeper confined aquifer.

Plant Name	Well Name	Well Permit No.	Well Depth	Casing Depth	Year Drilled	Aquifer
SEVERNDALE	SEVERNDALE 6	AA860110	559	525	1988	LOWER PATAPSCO FM
	SEVERNDALE 7	AA860111	513	414	1988	LOWER PATAPSCO FM
	SEVERNDALE 3	AA043203	303	183	1961	UPPER PATAPSCO FM
	SEVERNDALE 4	AA734129	575	380	1976	LOWER PATAPSCO FM
	SEVERNDALE 5	AA734130	535	535	1975	LOWER PATAPSCO FM
	SEVERNDALE 8	AA885792	530	406	1991	LOWER PATAPSCO FM
	SEVERNDALE 9	AA946681	950	675	2001	PATUXENT FM
ARNOLD	ARNOLD 1	AA735562	565	432	1976	UPPER PATAPSCO FM
	ARNOLD 2	AA735564	551	390	1976	UPPER PATAPSCO FM
	ARNOLD 3	AA735563	560	426	1976	UPPER PATAPSCO FM
	ARNOLD 4	AA883644	996	786	1990	LOWER PATAPSCO FM
	ARNOLD 5	AA941104	945	760	1998	LOWER PATAPSCO FM
	ARNOLD 6	AA946680	515	415	2002	UPPER PATAPSCO FM

Table 1. Well Information

HYDROGEOLOGY

Ground water flows through pores between gravel, sand and silt grains in unconsolidated sedimentary rock aquifers such as those used by the community water systems in Anne Arundel County. An aquifer is any formation that is capable of yielding a significant amount of water. The transmissivity is a measure of the amount of water an aquifer is capable of producing and is related to the hydraulic conductivity and the thickness of the aquifer. A confining layer is generally composed of fine material such as clay and silt, which transmits relatively very little water. Confined aquifers are those formations that are overlain by a confining unit. Confined aquifers are recharged from the water stored in the confining unit above and from precipitation that infiltrates into the formation where it is exposed at the surface.

Anne Arundel County lies within the Atlantic Coastal Plain physiographic province. This province, which in Maryland includes roughly the area east of Interstate 95, is underlain by unconsolidated clastic sediments of Lower Cretaceous to recent age, which thicken to the southeast so that they appear wedge-shaped. These sediments crop out in a concentric band that lies parallel to the Fall Line which marks the western boundary of the Coastal Plain. The Arnold and Severndale plant wells pump water from three confined aquifers known as the Upper Patapsco, Lower Patapsco and Patuxent Formations. The Upper Patapsco Formation is the shallowest and youngest in age with the Patuxent Formation being the deepest and the oldest. These aquifers have been studied considerably and hydrologic, lithologic and geochemical data is available in several Maryland Geological Survey reports (1962, 1974, 1976, 1984, 1986, 1991 and 1995). The descriptive material below is summarized from these reports and the reader is referred to them for further information.

Patapsco Formation

The Patapsco Formation crops out over a wide area of north-central Anne Arundel County. This formation consists of irregularly stratified interbedded, variegated (gray, brown and red) silt and clay and argillaceous (clayey), subrounded, fine to medium-grained quartzose sand with minor amounts of gravel. The top of the formation dips about 40 feet to the mile in a southeasterly direction. In Anne Arundel County the elevation of the top of the formation ranges from about 200 feet above sea level in the outcrop area to 700 ft below sea level in the southeastern part of the county. The transmissivity of the Patapsco Formation ranges from 700 to 6700 ft^2/day. The Patapsco Formation is divided into the Upper and Lower Patapsco aquifers. The two are separated by confining layer of low permeable clay. The Upper Patapsco aquifer is used by four of the Arnold wells and one of the Severndale wells assessed in this report. The top of the Upper Patapsco aquifer is at sea level at the Severndale site and at about 250 feet below sea level at the Arnold site. The Lower Patapsco aquifer is used by five of the Severndale and two of the Arnold wells. The top of the Lower Patapsco aquifer is about 350 feet below sea level at the Severndale site and about 600 feet below sea level at the Arnold site.

Patuxent Formation

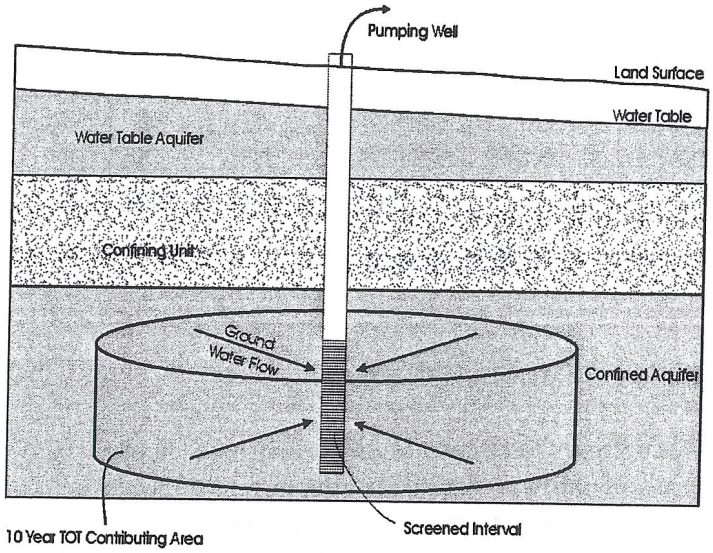
The Patuxent Formation is the deepest and oldest aquifer in Anne Arundel County. The top of the aquifer varies in depth from near land surface near the Fall Line to about 1500 feet below sea level in southeastern Anne Arundel County. The Patuxent Formation consists of irregularly stratified, cross-bedded and lenticular white or light gray to orange-brown, moderately sorted, angular sands and subrounded quartz gravels with gray to ocherouns silt and clay beds occurring locally in amounts ranging from less than 25 percent to greater than 75 percent of the formation. The Patuxent Formation is overlain by the Arundel Clay. The Arundel Clay is a dense reddish-brown low permeability clay, interbedded with thin layers of sand. The Patuxent Formation is used by one of the Severndale plant wells. The Patuxent Formation is about 600 feet below sea level at the Severndale site and about 950 feet below sea level at the Arnold site.

SOURCE WATER ASSESSMENT AREA DELINEATION

For ground water systems, a Wellhead Protection Area (WHPA) is considered to be the source water assessment area for the system. The WHPAs were delineated using the methodology described in Maryland's Source Water Assessment Plan (MDE, 1999) for confined aquifers in the Coastal Plain, often referred to as the "Florida Method". The area is a radial zone of transport within the aquifer and is based on a 10-yr time of travel (TOT), the pumping rate and the screened interval(s) for the well or wells included in the WHPA, and the porosity of the aquifer (see illustration below for conceptual model). The Florida Method is a modification of Darcy's Law for radial flow to a well and the WHPA's were calculated using the following volumetric equation:

$$r = \sqrt{\frac{Qt}{\pi n H}}$$

where r = calculated fixed radius (ft)
Q = pumping rate of well (ft^3/yr)
t = time of travel (yr.)
n = aquifer porosity (dimensionless)
H = length of well screen (ft)



Conceptual illustration of a zone of transport for a confined aquifer

Table 2 indicates the values used and the calculated radius for each water plant's WHPA. A review of the monthly operating reports for the plants showed no individual well pumpage. The pumping rate (Q) used is the permitted daily average. If more than one well was pumping from the same aquifer, the permitted amount was evenly divided between these wells for the calculations for the WHPA.

A conservative estimate of porosity (n) of 25% was used for each of the aquifers based on published reports. The lengths of the well screens (H) were obtained from well completion reports. In the instance that there were multiple screens, the sum of the individual screen lengths was used. Using these parameters the radius was calculated

with the above equation for the WHPA delineation using times of travel (TOT) of 1 and 10 years (table 2). The one year TOT was also used to be consistent with the earlier assessment conducted by the County DPW for the other wells in the system. Circles around each of the wells with the appropriate calculated radius represent the WHPAs which are shown in figures 1- 4. The circles represent the aquifer zone of transport in the subsurface as illustrated above.

Plant Name	Source Name	Well Pumpage (Q) in gpd	Well Pumpage (Q) in ft3/yr	Screened Interval in feet	Calculated Radius in feet for WHPA		Acreage of WHPA		Comments on WHPA
					1yr	10yr	1yr	10yr	
SEVERNDALE	SEVERNDALE 6	1400000	68306376.15	32	1700	5200	235	1953	Circles for Wells 4,5, 6,7, and 8 merged
	SEVERNDALE 7	1400000	68306376.15	87	1000	3200			
	SEVERNDALE 4	1400000	68306376.15	130	800	2600			
	SEVERNDALE 5	1400000	68306376.15	130	800	2600			
	SEVERNDALE 8	1400000	68306376.15	100	1000	3000			
	SEVERNDALE 9	1600000	78064429.89	100	1000	3200	18	185	
	SEVERNDALE 3	450000	21955620.91	120	500	1600	74	740	
ARNOLD	ARNOLD 1	375000	18296350.76	125	500	1400	56	297	Circles for Wells 1, 2, 3 and 6 merged
	ARNOLD 2	375000	18296350.76	123	500	1400			
	ARNOLD 3	375000	18296350.76	85	600	1700			
	ARNOLD 6	375000	18296350.76	83	600	1700			
	ARNOLD 4	1100000	53669295.55	161	700	2100	36	466	Circles for Wells 4 and 5 merged*
	ARNOLD 5	1100000	53669295.55	160	700	2100	36		

not for 1 yr WHPA

Table 2. Wellhead Protection Area (WHPA) Parameters

POTENTIAL SOURCES OF CONTAMINATION

In confined aquifer settings, sources of contamination at land surface are generally not a threat unless there is a pathway for direct injection into the deeper aquifer such as through unused wells or along well casings that are not intact or have no grout seal. Wells that are not being used or maintained will eventually corrode and provide a pathway for contaminants present in the shallow aquifers at higher-pressure heads to migrate to the deeper aquifers. Therefore, as long as there is no potential for direct injection into the deeper confined aquifers, the water supply used by the community systems should be well protected from ground water contamination.

Based on MDE databases and a field survey no potential sources of contamination were identified within the WHPAs for the Arnold and Severndale plant wells. The only potential contamination threat to the aquifers is unused wells or improperly constructed wells located in the WHPA. Any such well should be abandoned as per State well construction regulations.

WATER QUALITY DATA

Water Quality data was reviewed from the Water Supply Program's database for Safe Drinking Water Act (SDWA) contaminants. The State's SWAP defines a threshold for reporting water quality data as 50% of the Maximum Contaminant Level (MCL). If a monitoring result is greater than 50% of the MCL, this report will describe the sources of such a contaminant and, if possible, locate the specific sources that are the cause of the elevated contaminant level. All data reported is from the finished (treated) water unless otherwise noted. Table 3 summarizes the various treatment methods used at the Arnold and Severndale plants. A review of the monitoring data for the two plants indicates that currently the water supplies meet the drinking water standards

PLANT NAME	TREATMENT METHODS	PURPOSE
SEVERNDALE	pH ADJUSTMENT	CORROSION CONTROL
	GASEOUS CHLORINATION	DISINFECTION
	AERATION, CASCADE	IRON REMOVAL
	COAGULATION	IRON REMOVAL
	FILTRATION	IRON REMOVAL
	SEDIMENTATION	IRON REMOVAL
	FLOCCULATION	IRON REMOVAL
	FLUORIDATION	FLUORIDE ADDITION
ARNOLD	pH ADJUSTMENT	CORROSION CONTROL
	GASEOUS CHLORINATION, POST	DISINFECTION
	AERATION, CASCADE	IRON REMOVAL
	COAGULATION	IRON REMOVAL
	FILTRATION	IRON REMOVAL
	SEDIMENTATION	IRON REMOVAL
	FLOCCULATION	IRON REMOVAL
	FLUORIDATION	FLUORIDE ADDITION

Table 3. Treatment Methods

Table 4 summarizes the water quality results for each water treatment plant by contaminant group.

Plant Name	IOCS		SOCs		VOCs		Radionuclides	
	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL
Severndale	12	0	1	0	5	0	7	1
Arnold	11	0	1	0	7	0	5	0

Table 4. Summary of Water Quality Samples for Severndale and Arnold Water Treatment Plants

Inorganic Compounds (IOCs)

No IOCs above 50% of the MCL have been detected in either the Severndale or the Arnold plant's water supply since 1993. Both plants have treatment for removal of naturally occurring iron in the raw water.

Radionuclides

Severndale Plant: Radium-228 was the only radionuclide that was detected above 50% of the MCL. The level of radium-228 that was measured was 2.6 picoCuries/Liter (pCi/L). The MCL for radium-228 is 5 pCi/L. Subsequent sampling showed radium-228 levels below 50% of the MCL. Radium-226, and gross alpha activity have also been detected in the water supply a few times, but at levels well below 50% of the MCL.

Arnold Plant: No radionuclides above 50% of the MCL have been detected in this water plant. Radium-226 and radium-228 have been detected in several samples at levels well below 50% of the MCL.

Volatile Organic Compounds (VOCs)

No VOCs above 50% of the MCL have been detected in either the Severndale or the Arnold plant's water supply since 1993.

Synthetic Organic Compounds (SOCs)

No SOCs above 50% of the MCL have been detected in either the Severndale or the Arnold plant's water supply since 1993

Microbiological Contaminants

Routine bacteriological monitoring is conducted in the finished water for each water system on a monthly basis and measures total coliform bacteria. Since both the plants disinfect their water, the finished water data does not give much indication of the quality of raw water directly from the well. Total coliform bacteria are not pathogenic, but are used as an indicator organism for other disease-causing microorganisms. No coliforms have been detected in 94 samples takes for this system's water supply.

SUSCEPTIBILITY ANALYSIS

The Severndale and Arnold wells serving the Glen Burnie-Broadneck water system pump water from confined aquifers. Confined aquifers are naturally well protected from activity on the land surface due to the confining layers that provide a barrier for water movement from the surface into the aquifer below. A properly constructed well with the casing extended to the confining layer above the aquifer and with sufficient grout should be well protected from contamination at the land surface. The only instance in which a contaminant at the surface would impact the water supply is through direct injection into the aquifer from within the WHPA. This could occur via poorly constructed wells, wells out of use that penetrate the aquifer and underground injection wells drilled into the aquifer.

Some contaminants like radionuclides and other chemical elements (eg. radionuclides and iron) are naturally occurring in the aquifer and in some instances can reach concentrations that pose a risk to the water supply. In the case of confined aquifers, this is generally more problematic than contaminants at the land surface.

The susceptibility of the source water to contamination is determined for each group of contaminants based on the following criteria: 1) the presence of natural and anthropogenic contaminant sources within the WHPA, 2) water quality data, 3) well integrity, and 4) the aquifer conditions. The susceptibility analysis is summarized for each water system.

Inorganic Compounds

No IOCs above 50% of the MCL have been detected in Severndale or Arnold's plant's water supply. Based on the natural occurrence of iron at certain locations within the aquifers and treatment for iron removal at these plants the wells associated with these plants **is** susceptible to iron.

Due to the naturally protected characteristics of the confined aquifers, the water quality data, and the lack of potential sources of contamination, the wells associated with these plants are considered **not** susceptible to the other inorganic compounds.

Radionuclides

Radium-228 was detected one time at a level 50% of the MCL. The source of radionuclides in ground water can be traced back to the natural occurrence of uranium and thorium in rocks. Radionuclides are present in ground water due to radioactive decay of uranium and thorium bearing minerals in the sediment that makes up the aquifer material. Radium-226, radium-228 and gross alpha radiation have been detected in the Severndale and Arnold plants' water supply

Based on the water quality data, the Severndale and Arnold wells are not susceptible to radiological contaminants.

Volatile Organic Compounds

No VOCs above 50% of the MCL have been detected in the water supply being served by the Severndale and Arnold plants.

Due to the naturally protected characteristics of the confined aquifers, the water quality data, and the lack of potential sources of contamination, the wells associated with these plants are considered **not** susceptible to the other volatile organic compounds.

Synthetic Organic Compounds

No SOCs above 50% of the MCL have been detected in the water supply being served by the Severndale and Arnold plants.

Due to the naturally protected characteristics of the confined aquifers, the water quality data, and the lack of potential sources of contamination, the wells associated with these plants are considered **not** susceptible to the other synthetic organic compounds.

Microbiological Contaminants

Raw water monitoring for microbiological contaminants is not required of water systems in confined aquifers because they are considered naturally protected from sources of pathogens at the land surface. Routine bacteriologic testing for these plants revealed no positive total coliform in the water supply. Therefore, the community water systems are **not susceptible** to microbiological contaminants.

MANAGEMENT OF THE SOURCE WATER ASSESSMENT AREA

The County DPW completed a Wellhead Protection Plan (WHP) in 2003 with grants from MDE. The plan was reviewed and approved by WHP committee consisting of members from the County DPW, Planning and Health Departments, and MDE. The plan was also presented to upper management of the County DPW and Planning Departments. As part of the MDE wellhead protection grant application, the County made a commitment to implement wellhead protection for its water supplies.

It is recommended that the County incorporate the WHPAs delineated for the Severndale and Arnold plant wells to the plan and initiate adoption of this plan for protection of its drinking water supply.

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OTHER SOURCES OF DATA

Water Appropriation and Use Permits
Public Water Supply Sanitary Survey Inspection Reports
MDE Water Supply Program Oracle® Database
MDE Waste Management Sites Database
Department of Natural Resources Digital Orthophoto Quarter Quadrangles
USGS Topographic 7.5 Minute Quadrangles for Anne Arundel County

FIGURES

APPENDIX

Table 1. Generalized stratigraphic, lithologic, and hydrologic characteristics of geologic formations underlying Anne Arundel County, Maryland (modified from Mack and Andreasen, 1991, table 1)

SYSTEM	SERIES	GROUP	FORMATION	AVERAGE THICKNESS (FEET)	GENERAL LITHOLOGY	HYDROLOGIC CHARACTER	GEOHYDRO-LOGIC UNIT
Quaternary	Holocene and Pleistocene		Alluvium and terrace deposits	20	Sand, gravel, silt, and clay.	Confining unit in most places, limited aquifer in some places.	Not recognized
	Pleistocene		Talbot Formation	20	Clay, silt, brown to gray with some glauconite and pebbles.	Confining unit	Talbot confining unit
Tertiary	Pliocene (?) or Miocene (?)		Brandywine Formation	30	Sand, pebbly sand, and gravel; extremely limited distribution.	Aquifer	Not recognized
	Miocene	Chesapeake	Calvert Formation	75	Sandy clay and fine sand, fossiliferous, diatomaceous earth.	Limited aquifer	Not recognized
	Eocene	Pamunkey	Nanjemoy Formation	50	Glauconitic sand, silt, and clay.	Confining unit	Not recognized
	Paleocene		Marlboro Clay	15	Clay, silvery gray to pink	Confining unit	Marlboro confining unit
			Aquia Formation	130	Glauconitic, greenish to brown sand with thin indurated or "rock" layers, and silt layers.	Aquifer	Aquia aquifer
			Brightseat Formation	15	Silt and clay, olive-gray to black, glauconitic.	Leaky confining unit	Brightseat confining unit
Cretaceous	Upper Cretaceous		Severn Formation	45	Sand, silty to fine, with some glauconite.	Limited aquifer	Monmouth aquifer
			Matawan Formation	60	Silt and fine sand, clayey, dark-green to black, glauconitic.	Confining unit	Matawan confining unit
			Magothy Formation	120	Sand, light-gray to white, with interbedded thin layers of organic black clay.	Aquifer	Magothy aquifer
	Lower Cretaceous	Potomac	Patapsco Formation	25	Clay, tough, variegated.	Confining unit	Confining unit
				750	Sand, fine to coarse, brown, and tough, variegated clay.	Multiple-layer aquifer	Upper Patapsco aquifer
					Clay, tough, variegated.	Confining unit	Confining unit
					Sand, fine to coarse, brown, and tough variegated clay.	Multiple-layer Aquifer	Lower Patapsco aquifer
			Arundel Clay	250	Clay, red, brown, and gray, contains some ironstone nodules, plant remains, and thin sandy layers.	Confining unit	Arundel confining unit
			Patuxent Formation	300	Sand, gray and yellow, with interbedded clay; kaolinized feldspar, pyrite, and lignite common; locally clay layers predominate.	Multiple-layer aquifer	Patuxent aquifer
Triassic (?) and/or Paleozoic (?) to Precambrian			Basement	Unknown	Shale, sandstone,	Confining unit	Not recognized