In cooperation with the Chester County Water Resources Authority and the Chester County Health Department

Ground-Water Resources of Big Elk Creek Basin, Pennsylvania and Maryland

Many rural areas in southeastern Pennsylvania, including the Big Elk Creek Basin, are undergoing a rapid population increase. New development and an expanding population increase consumptive water use, increase surface runoff, and have the potential to reduce ground-water recharge. The Big Elk Creek Basin is between the Delaware and Susquehanna River Basins and drains directly to the Chesapeake Bay. Both the Delaware and Susquehanna River Basins have basin commissions that regulate and oversee surface-water and ground-water withdrawals. The Big Elk Creek Basin does not have a regulatory agency to oversee withdrawal of water.

Ground-water quantity and quality were evaluated for the 79.4-mi^2 (square mile) study area that extends from the headwaters of Big Elk Creek in Chester County, Pa., downstream to the U.S. Geological Survey (USGS) streamflow-measurement station 01495000, Big Elk Creek at Elk Mills, Md., and to inactive USGS streamflow-measurement station 01495500, Little Elk Creek at Childs, Md. (fig. 1). The study was done by the USGS in cooperation with the Chester County Water Resources Authority and the Chester County Health Department. The full results of the study are published in a technical report by Sloto (2002). This fact sheet summarizes the key findings presented in the technical report.

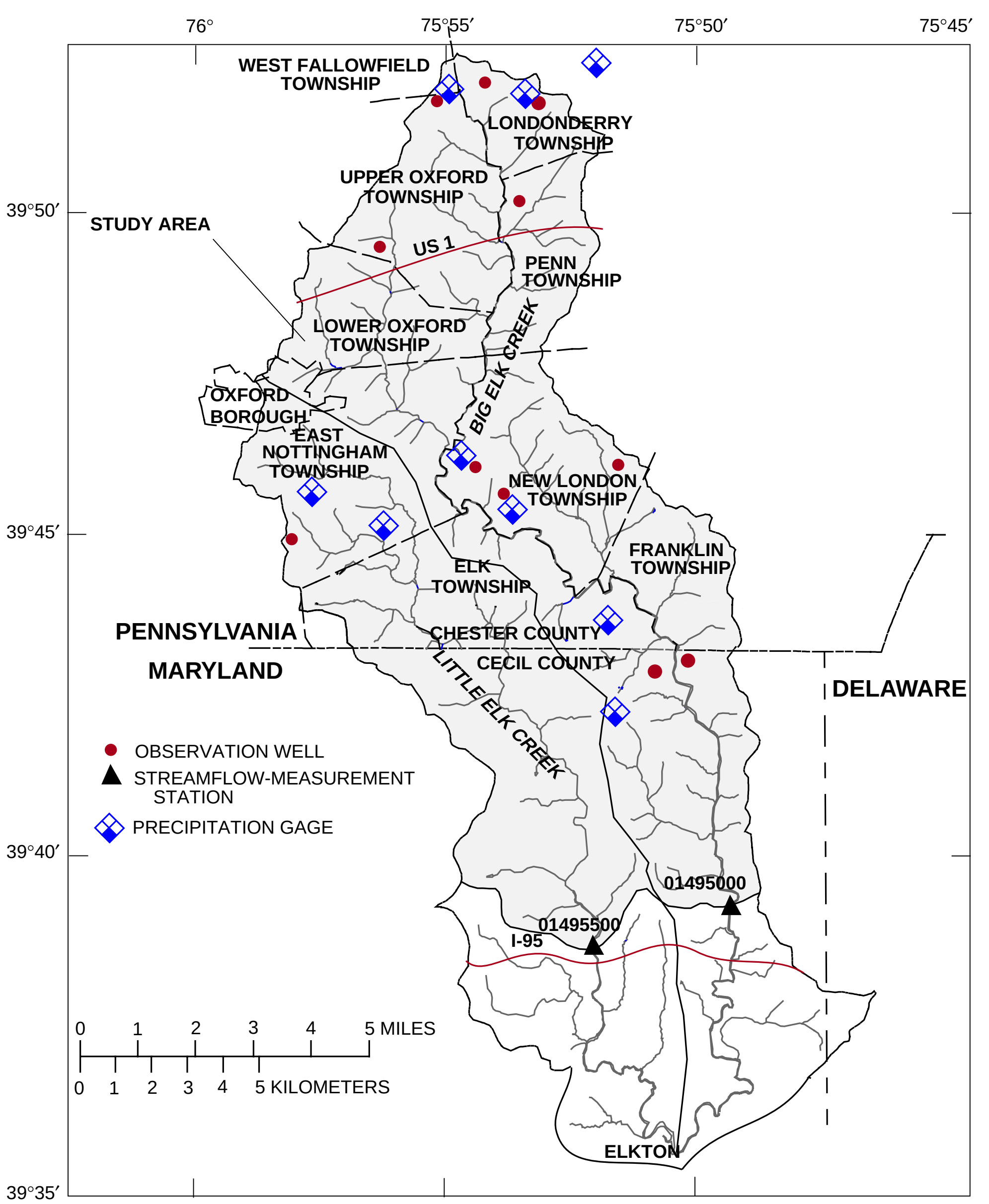

Figure 1. Data-collection sites in the Big Elk Creek Basin, Pennsylvania and Maryland.

GROUND-WATER RESOURCES

The Big Elk Creek Basin above the streamflow-measurement stations is underlain chiefly by crystalline rocks. Most of the basin in Pennsylvania is underlain by Wissahickon Schist (fig. 2). All of the crystalline-rock geologic units in the basin are considered to be aquifers. Ground-water-flow paths in these rocks are short, and ground water flows from areas of higher elevation to nearby streams, where it discharges. Ground water generally is under water-table (unconfined) conditions. The lowermost part of the Big Elk Creek Basin is underlain by unconsolidated sediments of the Potomac Group (fig. 2). The geology of Chester County, Pa., is described by Sloto (1994), and the geology of Cecil County, Md., is described by Higgins and Conant (1990).

Nearly all wells drilled in crystalline rock have casing set into the upper few feet of unweathered rock and are completed as open-hole wells. Ground water in the weathered zone (saprolite) moves through intergranular openings. Ground water in the unweathered part of the aquifer moves through a network of interconnecting openings—fractures and joints—that comprise the water-bearing zones that provide water to wells. The larger, more numerous, and more interconnected the openings, the greater the yield of a well. For all crystalline rocks in the basin, the number of water-bearing zones generally decreases with depth. Yields of wells in the Wissahickon Schist range from 5 to 200 gallons per minute (gal / min) with a median yield of 15 gal / min. The hydrology of the unconsolidated Potomac Group is discussed by Overbeck and others (1958).

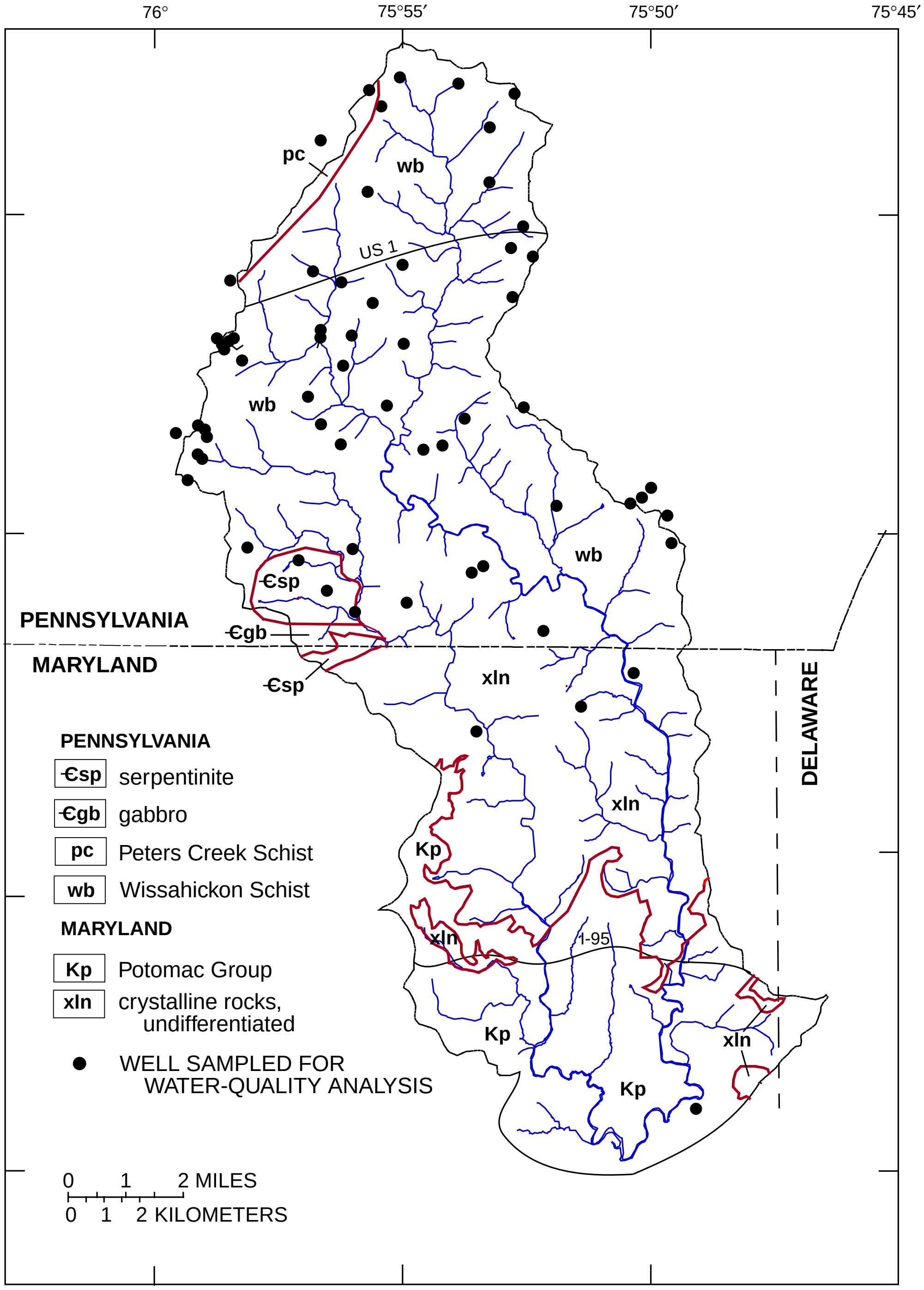

Figure 2. Generalized geology and location of wells sampled for water-quality analyses, Big Elk Creek Basin, Pennsylvania and Maryland.

Water Levels

Water levels in wells indicate the level of the water table in an aquifer. Approximately 800 wells were measured on a one-time only basis to construct two water-table maps of the Big Elk Creek Basin in Pennsylvania. The upper part of the basin was mapped in 1999 (Mohammad, 2000), and the lower part was mapped in 2000 (Mohammad, 2001). The maps show the water table is a subdued replica of the topography, with ground water flowing from areas of higher elevation to nearby streams.

Water levels fluctuate in response to recharge to the ground-water system from precipitation and discharge from the ground-water system to pumping wells, to the atmosphere by ground-water evapotranspiration, and to streams. Water levels generally rise during the late fall, winter, and early spring, when ground-water and soil-moisture evapotranspiration are at a minimum and recharge is at a maximum. Water levels generally decline during the late spring, summer, and early fall, when ground-water evapotranspiration and soil-moisture evapotranspiration are at a maximum, and recharge is at a minimum.

Water levels were measured in 11 observation wells (fig. 1) from January 1998 through December 1999. Water-level fluctuations for 1998-99 were as great as 12.55 feet (ft). Water levels in wells in different geologic units in the Big Elk Creek Basin show similar patterns of response to seasonal changes in recharge and evapotranspiration. The water level in well CE Ae 9, which is typical of water levels in the basin, is shown on figure 3.

Water levels generally are closest to land surface in valleys near streams (discharge areas) and deepest below hilltops (recharge areas). Water-level data categorized by topographic position for wells in the Wissahickon Schist show the median depth to water is 19 ft for wells in valleys, 25 ft for wells on hillsides, and 30 ft for wells on hilltops.

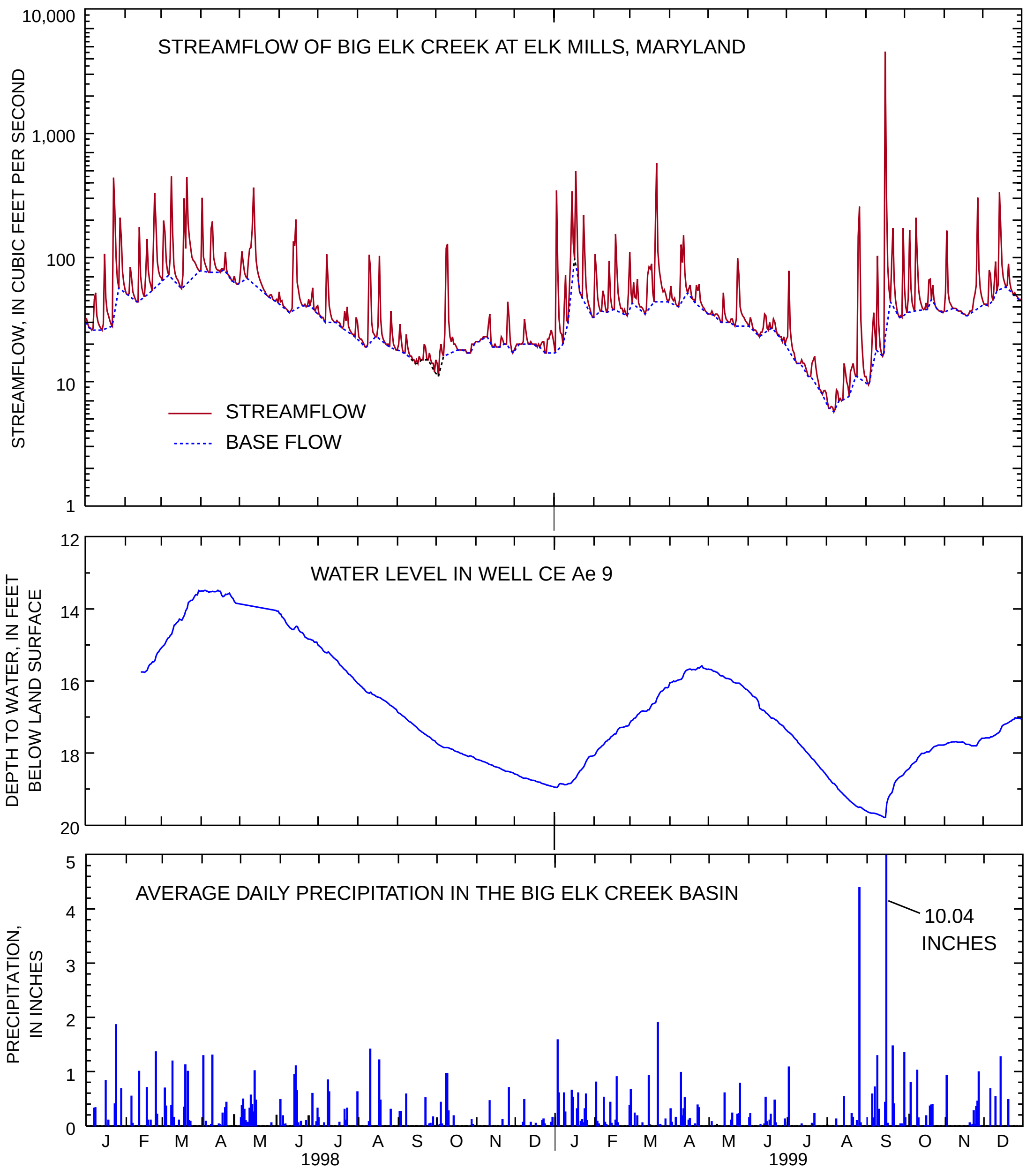

Figure 3. Relation among precipitation, ground-water levels, and streamflow in the Big Elk Creek Basin, Pennsylvania and Maryland, 1998-99.

The Relation Between Ground Water and Surface Water

The ground-water and surface-water systems in the Big Elk Creek Basin are well connected. Generally, streams act as drains for the shallow ground-water system and gain water. Streamflow is composed of base flow and surface runoff. Base flow is ground water discharged to streams. After rainfall or snowmelt, water that does not infiltrate or evaporate enters streams as surface runoff. The relation among precipitation, ground-water levels, streamflow, and base flow during 1998-99 is shown in figure 3. The shapes of the base-flow and water-level hydrographs are similar. Base flow generally declines as ground-water levels decline and increases when ground-water levels increase. The time of lowest base flow generally coincides with the lowest ground-water levels. Precipitation during the summer (June through September) generally produces little increase in ground-water levels; most infiltrated precipitation replenishes soil moisture and does not recharge the ground-water system.

Base Flow

Ground-water discharge to streams accounts for more than half of streamflow. Hydrographs for Big Elk Creek for the period of record 1933-99 were separated into base-flow and surface-runoff components (table 1). Ground-water discharge to streams (base flow) ranged from 49 to 76 percent of total streamflow; the median was 63 percent. The median annual base flow for the period was 10.79 in. (inches) or 0.518 (Mgal / d) / mi^2 (million gallons per day per square mile) (table 1). The annual base flow ranged from 5.32 in. or 0.255 (Mgal / d) / mi^2 in 1966 to 17.98 in. or 0.863 (Mgal / d) / mi^2 in 1972. The median base flow for Big Elk Creek in table 1 is representative of a long-term average. Streamflow, base flow, and surface runoff in table 1 are expressed in inches so that they can be compared to precipitation. Inches in tables in this report can be converted to million gallons per day per square mile by multiplying by 0.048.

Table 1. *Annual streamflow and estimated annual base flow for the Big Elk Creek, Pennsylvania and Maryland,1933-99*

	Total streamflow (inches) and year	Estimated base flow (inches) and year	Percentage of streamflow as base flow and year	Estimated surface runoff (inches) and year	Percentage of streamflow as surface runoff (inches) and year
Minimum	8.65 (1966)	5.32 (1966)	49.2 (1942)	2.47 (1954)	23.6 (1997)
Maximum	33.01 (1996)	17.98 (1972)	76.4 (1997)	15.94 (1966)	50.8 (1949)
Median	17.04	10.79	63.0	6.22	37.0

Low-Flow Statistics

Low-flow statistics derived from long-term streamflow data for the Big Elk Creek Basin were published by Schreffler (1998). Statistical information based on streamflow data can be used to predict future variability of streamflow, not in terms of specific events but in terms of probability of occurrence over a span of years. A statistic typically determined to characterize low flow is the 7-day, 10-year (7Q10 or $Q_{7\text{-}10}$) low-flow value, which is defined as the lowest mean streamflow over 7 consecutive days, which, on average, has and probably will occur once in a 10-year period. Low-flow statistics determined by Schreffler (1998) also include the minimum 1-day flow (1Q10) and the 30-day flow (30Q10) having a 10-year recurrence interval (table 2).

Table 2. *Low-flow statistics for streamflow-measurement station Big Elk Creek at Elk Mills, Maryland (01495000) (From Schreffler, 1998, p. 15)*

[1Q10, 1-day, 10-year low-flow value; 7Q10, 7-day, 10-year low-flow value; 30Q10, 30-day, 10-year low-flow value]

Period of record	Low-flow statistics (cubic feet per second)		
	1Q10	7Q10	30Q10
1932-94	9.1	10.3	12.8

Water Budget

A water budget is an estimate of water entering and leaving a basin, plus or minus changes in storage within the basin for a specified period. A water budget quantifies the water balance in a basin. For the Big Elk Creek Basin, water enters as precipitation and leaves as streamflow, evapotranspiration (ET), and exported ground water. Water also is taken into or released from ground-water storage. All components of the water budget were measured except ET, which was calculated. Water budgets for the Big Elk Creek Basin for 1998-99 are presented in table 3. The locations of the data-collection stations (precipitation gages, observation wells, and streamflow-measurement station 01495000) used for the water budgets are shown on figure 1.

The 1998-99 average annual streamflow was 15.38 in., average change in ground-water storage (water in and moving through the aquifer) was an increase of 1.32 in., average net ground-water exports (water pumped from wells in the basin and distributed outside the basin) were 0.03 in., and the estimated average ET was 30.5 in. Despite a 12.27-in. difference in precipitation between 1998 and 1999, the percentage of precipitation as ET (65.6 and 64 percent, respectively) is similar.

Recharge

All natural recharge to the ground-water system is from local precipitation. Infiltrated precipitation first replenishes soil moisture. After the soil moisture has been replenished, infiltrated precipitation recharges the ground-water system. Recharge depends on many factors, including the duration and intensity of precipitation, antecedent soil-moisture conditions, slope, quantity of impervious surface areas, and soil and bedrock characteristics. Recharge varies from season to season and from year to year. Generally, recharge occurs on hilltops and hillsides; topographically low areas commonly are discharge areas.

Table 3. *Annual water budgets for the Big Elk Creek Basin, Pennsylvania and Maryland, 1998-99*

[A negative number indicates a decrease in ground-water storage.]

Year	Precipitation (inches)	Streamflow (inches)	Change in ground-water storage (inches)	Net ground-water exports (inch)	Evapotranspiration and other losses (inches)	Percentage of precipitation as streamflow	Percentage of precipitation as evapotranspiration
1998	41.04	14.22	-0.12	0.03	26.94	34.7	65.6
1999	53.31	16.54	2.76	.02	34.12	40.3	64
Average	47.18	15.38	1.32	.03	30.53	37.5	64.8

Recharge was estimated for the Big Elk Creek Basin for 1998-99 (table 4). Recharge was 11.28 in. [0.54 (Mgal / d) / mi^2] in 1998, and 12.95 in. [0.62 (Mgal / d) / mi^2] in 1999. Average estimated annual recharge for 1998-99 was 12.12 in. [0.58 (Mgal / d) / mi^2]; this is equal to a recharge rate of 909 gallons per day per acre. Recharge as a percentage of annual precipitation was 27.4 percent for 1998 and 24.3 percent for 1999. The estimated average annual recharge as a percentage of average annual precipitation was 25.9 percent.

***Table 4.** Estimated recharge for the Big Elk Creek Basin, Pennsylvania and Maryland, 1998-99*

[A negative number indicates a decrease in ground-water storage.]

Year	Recharge (inches)	Base flow (inches)	Change in ground-water storage (inches)	Estimated ground-water evapo-transpiration (inches)	Net ground-water exports (inch)	Percentage of precipitation as recharge
1998	11.28	9.37	-0.12	2.00	0.03	27.4
1999	12.95	8.28	2.76	2.00	.02	24.3
Average	12.12	8.83	1.32	2.00	.03	25.9

The water budgets (table 3) and recharge estimates (table 4) show that, on average for 1998-99, about 67 percent of precipitation returned directly to the atmosphere as evapotranspiration, about 26 percent of precipitation recharged the aquifer, and about 7 percent of precipitation ran off the land surface into streams.

Ground-Water Availability

Ground-water availability is defined and estimated in a number of ways. It commonly is based on the concept of "safe yield," "optimal basin yield," or "perennial yield." Todd (1980, p. 363) defines "perennial yield" as the rate at which water can be withdrawn perennially from a ground-water basin under specified operating conditions without producing an undesired result. Undesired results can include reduced streamflow, reduced base flow, reduced ground-water levels, interference between wells, and degradation of water quality.

Methods to determine ground-water availability in a basin include determinations of average annual recharge (assumed to be equal to average annual base flow), median annual base flow, 1-year in 25 average annual base flow, dry-year base flow, and the 7Q10 or a percentage of it. A comparison of withdrawal rates using these methods is presented in table 5. The optimal method is the one that best meets a set of socioeconomic and / or social and environmental objectives associated with the use of the water. However, all of these methods (table 5) indicate that there will be sufficient ground water on a basin-wide scale to meet the 162-million-gallon-per-day increase in water demand projected to 2020 (Chester County Water Resources Authority, 2001).

***Table 5.** Ground-water availability in the Big Elk Creek Basin, Pennsylvania and Maryland*

[7Q10, 7-day, 10-year low-flow value]

Method of availability determination	Withdrawal rate	
	Million gallons per day per square mile	Gallons per day per acre
Average annual base flow	0.535	836
Median annual base flow	.518	809
1-year in 25 average annual base flow	.409	639
Dry-year base flow (1966)	.255	389
7Q10	.127	198

GROUND-WATER QUALITY

The quality of water is determined primarily by the type and quantity of substances dissolved in it. As water moves through the hydrologic cycle, gases and minerals from the atmosphere, soil, and rock are dissolved. Additional substances may be added by human activities. Biological activity also can change the chemical composition of ground water. A discussion of water quality is given by Hem (1985).

For this study, water samples from 20 wells were collected for analysis for inorganic constituents and pesticides (fig. 2). In addition, data collected by the USGS in and just outside the basin since 1925 were available for an additional 44 wells. Major ions dissolved from soil and rock constitute most dissolved substances in ground water. Major ions in ground water, in order of decreasing concentration, are silica, calcium, chloride, sodium, sulfate, magnesium, and potassium.

Overall, ground-water quality in the Big Elk Creek Basin is very good. The U.S. Environmental Protection Agency (USEPA) sets maximum contaminant levels (MCL's) and secondary maximum contaminant levels (SMCL's) for some constituents in drinking water. MCL's usually are set because elevated concentrations of these constituents may cause adverse health effects. SMCL's usually are set for aesthetic reasons; elevated concentrations of these constituents may impart an undesirable taste or odor to water. USEPA SMCL's were not exceeded for chloride or sulfate. Out of 43 volatile organic compounds analyzed, only four were detected—chloroform, phenols, tert-butyl methyl ether (MTBE), and toluene. None of the concentrations exceeded USEPA MCL's.

Water from 2 percent of sampled wells exceeded the USEPA SMCL of 500 mg / L (milligrams per liter) for total dissolved solids. Water from 10 percent of sampled wells exceeded the USEPA MCL of 10 mg / L nitrate as nitrogen; all of the wells are in the Wissahickon Schist. The median nitrate concentration in water samples from the Wissahickon Schist is 3.6 mg / L, and the maximum concentration is 36 mg / L. Fourteen percent of water samples analyzed for iron and 29 percent of water samples analyzed for manganese exceed the USEPA SMCL's. The median activity of radon-222 for all formations was 2,400 pCi / L (picoCuries per liter). Water from 94 percent of sampled wells in the basin exceeded the proposed USEPA MCL of 300 pCi / L, and water from 25 percent of sampled wells exceeded the proposed USEPA alternate MCL of 4,000 pCi / L.

Pesticides are used widely in the Big Elk Creek Basin. The most commonly detected pesticides in the basin are deethyl atrazine (71 percent of sampled wells), atrazine (35 percent), metolachlor (32 percent), carbaryl (19 percent), picloram (14 percent), simazine (13 percent), and carbofuran (11 percent of sampled wells). Most concentrations are extremely low and are in the parts per trillion range. Pesticide concentrations detected did not exceed USEPA MCL's. Atmospheric deposition may be the source of some pesticides in the ground water of the basin. The atmosphere is now recognized as a major pathway by which pesticides can be transported and deposited in areas sometimes removed from their source. Pesticides have been found in both air and rain in all parts of the United States (U.S. Geological Survey, 1995).

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—Ronald A. Sloto

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District Chief
U.S. Geological Survey, WRD
215 Limekiln Road
New Cumberland, PA 17070-2424
(717) 730-6900
Fax: (717) 730-6997
Email: dc_pa@usgs.gov

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Chester County Water Resources Authority
Government Services Center
Suite 270, 601 Westtown Road
West Chester, PA 19382-4537
(610) 344-5400
Fax: (610) 344-5401