WATER RESOURCES OF OLEY TOWNSHIP,

BERKS COUNTY, PENNSYLVANIA

By Gary N. Paulachok and Charles R. Wood

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4065

Prepared in cooperation with the

OLEY TOWNSHIP SUPERVISORS

Harrisburg, Pennsylvania

1988

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, PA 17108-1107

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer metric (International System) units rather than the inch-pound units in this report, the following conversion factors may be used:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
gallon (gal)	3.785 0.003785	liter (L) cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.207	liter per second per meter [(L/s)/m]
gallon per day (gal/d)	0.00004381	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	0.01692	cubic meter per second per square kilometer [$(m^3/s)km^2$]
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°C = 5/9\ (F-32)$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

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ABSTRACT

Oley Township covers an area of 24 square miles, about half of which is underlain by highly permeable carbonate rocks. Nondomestic wells in these rocks typically have yields of 200 gallons per minute, and some wells yield more than 1,000 gallons per minute. Ground-water yield for Oley Township is about 0.5 million gallons per day per square mile. Thus, about 12 million gallons per day could be pumped from wells on a sustained basis. However, pumping this amount would adversely affect streamflow. A series of discharge measurements on Manatawny Creek in January 1983 showed that the creek was gaining approximately 12 cubic feet per second where it crosses the more-permeable carbonate rocks. Thus, the streams are directly connected to these aquifers.

The northern and western parts of the township are mostly underlain by shale, quartzite, granite, gneiss, and carbonate rocks of low permeability, and some wells do not yield enough water for domestic supplies. A water-table map shows that two active quarries in low-permeability rocks have had little effect on the hydrologic system.

Specific yields are about 4.5 percent for the carbonate rocks; 5 percent for quartzite, granite, and gneiss; 1 percent for the noncarbonate sedimentary rocks; and 1.5 percent for the Jacksonburg Limestone, which consists of argillaceous limestone.

In 1982--a year of average precipitation--the ground-water contribution to total streamflow ranged from 56 to 88 percent. Basins with the highest percentage of carbonate rock contribute the largest amount of ground water to streamflow. Evapotranspiration averaged about 26 inches in 1982. Water loss was 32 inches in the Limekiln Creek basin; this suggests that about 6 inches of precipitation bypassed the Limekiln Creek gaging station as ground-water underflow.

The most serious water-quality problems are excessive nitrate concentrations and bacterial contamination. Water from 3 of 19 wells in carbonate rocks had nitrate concentrations in excess of the U.S. Environmental Protection Agency maximum contaminant level of 10 milligrams per liter. Water from 5 of the 19 wells had fecal streptococci counts of more than 20 colonies per 100 milliliters. Although most agencies concerned with the protection of public health have not set limits for fecal streptococci, they are pathogenic, and their presence in drinking water is undesirable.

INTRODUCTION

The population of Oley Township has increased by 35 percent since 1950. Development of additional water supplies needed to support this growth together with extensive limestone quarrying has placed new stresses on the hydrologic system. Several springs and a stream near the quarries have gone dry. The hydrology of the township needs to be studied so that the water resources can be properly managed. Because Oley Township has been chosen as one of two demonstration communities for the Rural Project of the National Trust for Historic Preservation, this report is intended to be a prototype for reports on other rural areas that are trying to protect water resources while accommodating new growth.

Purpose and Scope

The water resources of Oley Township, Berks County, Pennsylvania were studied by the U.S. Geological Survey in cooperation with the Oley Township Supervisors from 1981 until 1983. No previous investigations had covered this area in detail. The purpose of this report is to describe the local hydrologic system and to provide information on surface and ground water. Surface-water drainage basins are defined and the duration and quality of streamflow are described. Ground-water occurrence, movement, yield, and quality are discussed, as are water levels and aquifer characteristics. A water budget is given and ground-water withdrawals are related to streamflow.

Data on precipitation, surface water, and ground water were collected chiefly by volunteer observers. Five nonrecording gages were installed within Oley Township to collect information on the spatial and temporal distribution of precipitation. Six stream-gaging stations were established so that the surface-water flow into and from the township could be measured. One hundred and thirteen wells, most of which are in Oley Township, were inventoried by the U.S. Geological Survey to obtain information on the occurrence and availability of ground water. Twenty of these were selected as observation wells in which water levels were measured monthly. Twenty-four ground-water samples and six surface-water samples were collected and analyzed to obtain baseline information on water quality.

Description of Area

Physical and Cultural Setting

Oley Township encompasses 24 mi^2 (square miles) in southeastern Berks County, Pennsylvania (fig. 1). Reading, the nearest major city, lies about 10 mi (miles) to the southwest. The area of investigation lies within two physiographic provinces: (1) the eastern two-thirds is in the Oley Valley, which is part of the Great Valley section of the Valley and Ridge province; and (2) the western third, an upland area, lies within the Reading Prong of the New England province. Oley Township is characterized by flat to gently rolling landforms, and land-surface altitudes range from approximately 300 to 500 ft (feet) above sea level in the Oley Valley to nearly 900 ft in the hills to the northwest.

Oley Township is sparsely populated and predominantly rural. According to the U.S. Census of 1980 (U.S. Department of Commerce, 1982), 3,024 individuals or 126 persons per square mile resided in the township. Only 10 percent of the area is developed, whereas 80 percent is farmland, and 10 percent is wooded. The village of Oley, located centrally within the township (fig. 1), is the largest community in the study area.

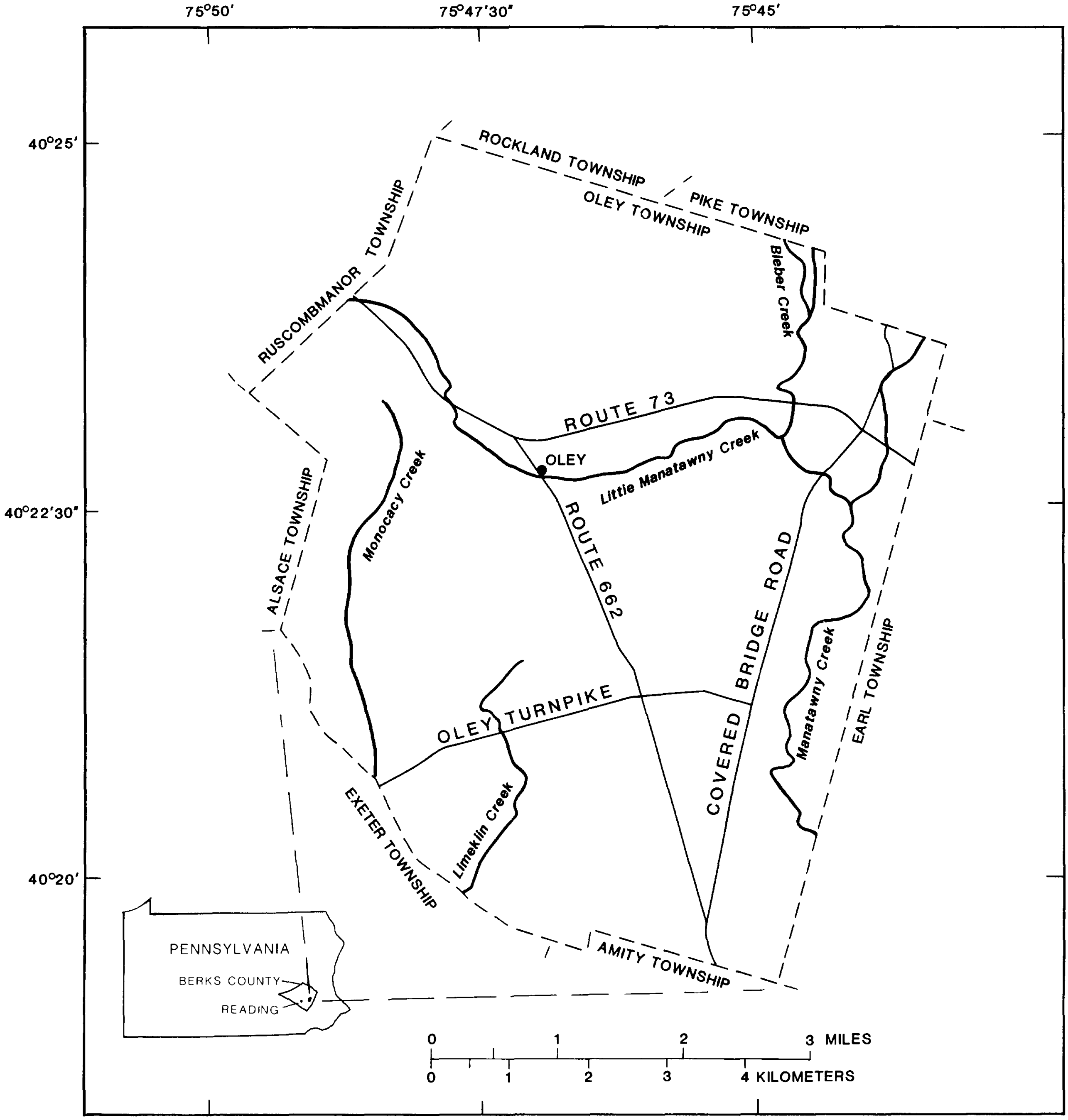


Figure 1.--Location of Oley Township.

Climate and Precipitation

The climate of Oley Township is classified as humid continental and is characterized by large annual temperature ranges, cold winters dominated by low-humidity air masses, hot summers typified by air masses of moderate to high humidity, and ample precipitation. The growing season lasts approximately 200 days.

Air temperatures in the township are generally moderate. Although no local temperature measurements were made for this study, those for nearby Reading (fig. 1) provide reasonable estimates. During 1982, roughly the period of data collection for this investigation, mean monthly temperatures at Reading ranged from -6.2°C in January to 23.4°C in July (fig. 2) and had an annual mean value of 10.5°C.

Except for a few small tributary streams that flow into the township from adjacent areas, precipitation is the source of all water in Oley Township. For this study, precipitation was measured and nonrecording gages established in 1981 at five sites (fig. 3). These gages were read daily through December 1982 by volunteer observers. In 1982, precipitation amounts averaged over the study area varied little compared to concurrent amounts measured at Reading (fig. 2). In 1982, average precipitation in Oley Township was 43.18 in. (inches), whereas that for Reading was 43.21 in. Although precipitation was slightly greater in April, May, and June than in the other months, long-term records for Reading indicate that precipitation is distributed fairly evenly throughout the year. Much of the summer rainfall is due to local thunderstorms; consequently, amounts throughout the area may vary greatly for any individual storm.

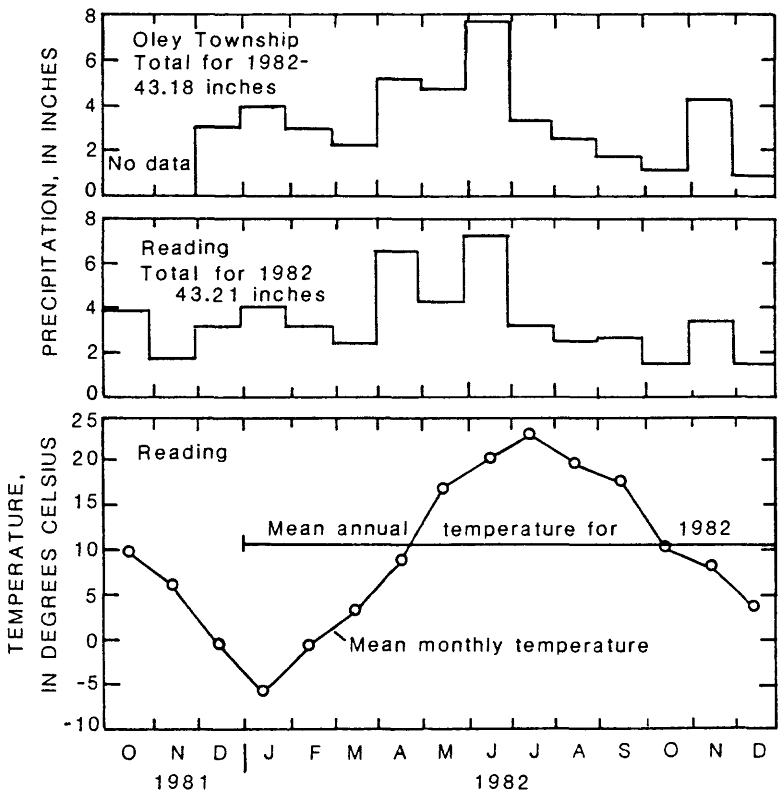


Figure 2.--Meteorological data for Oley Township and and Reading, 1981-82.

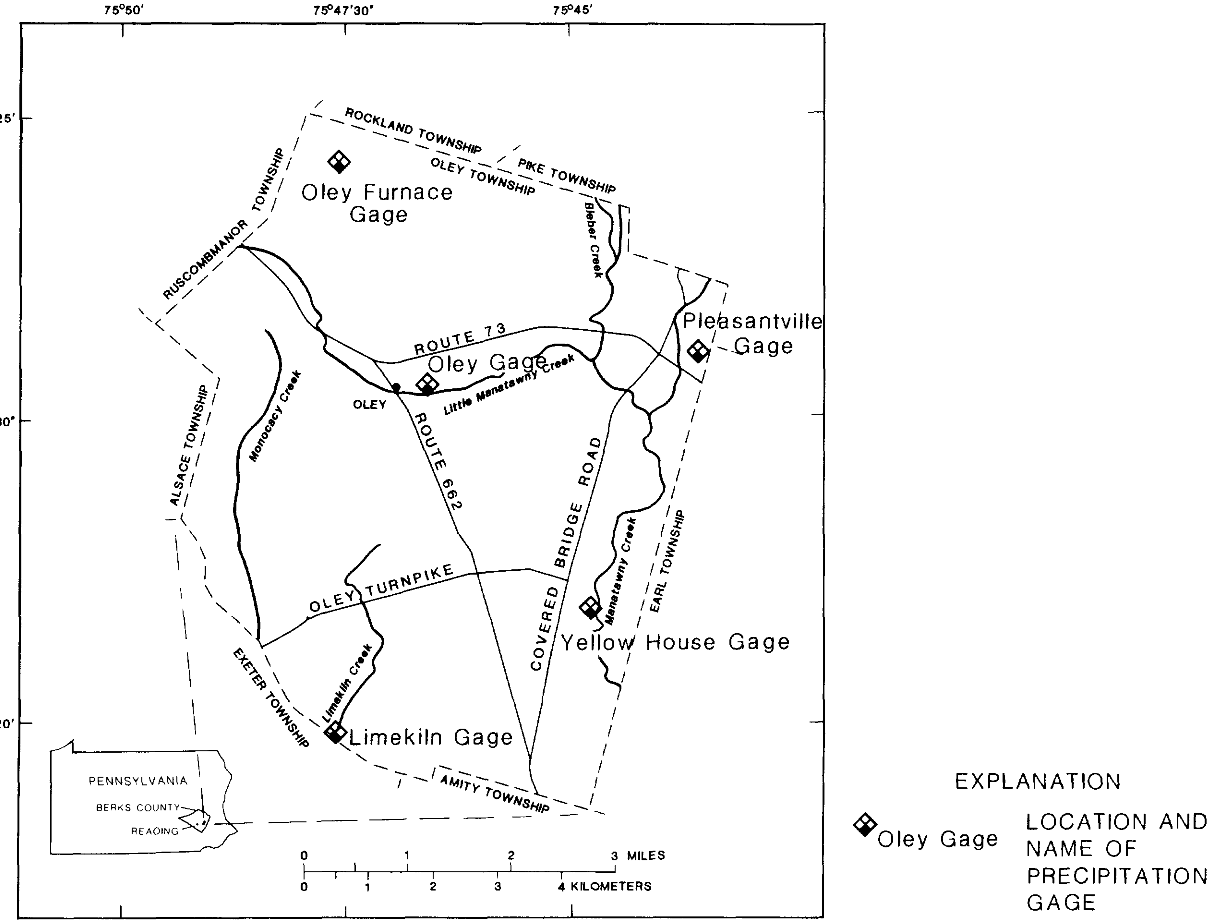


Figure 3.--Location of precipitation gages.

Geologic Setting

The rocks are in a system of major thrust slices or large overturned folds (nappes), which lie beside rocks of similar age but of different composition. The distinct assemblages of rocks in each major thrust slice or nappe is called a sequence. Three distinct sequences are recognized in the study area (plate 1).

Dominantly carbonate rocks of the Lebanon Valley, which lie in the Lebanon Valley nappe, comprise the Lebanon Valley sequence (MacLachlan, 1967). Approximately the upper half of the sequence, extending from the lowest Martinsburg Formation (Upper and Middle Ordovician) into the Millbach Formation (Upper Cambrian), is present.

The Lehigh Valley sequence was proposed by MacLachlan (1967) primarily to distinguish carbonate rocks of the eastern Great Valley of Pennsylvania from the somewhat different carbonate rocks of the Lebanon Valley. It is comprised of a Lower Cambrian basal quartzite and a large thickness of shallow-water Cambrian and Lower Ordovician limestones and dolomites that grade upward into Middle Ordovician shale. The sequence was deposited on a basement of Precambrian gneisses that are now preserved in the Reading Prong. Only the lower part of the sequence, extending upward to the Allentown Dolomite, is present in the study area.

The Hamburg sequence consists of a thrust complex of diverse, argillaceous to sandy, allochthonous rocks and associated subordinate limestones (MacLachlan and others, 1975). Dr. Paul B. Myers (Lehigh University, written commun., 1971) studied this sequence in great detail in the Bernville quadrangle and established a series of seven map units each of which is characterized by a distinctive lithologic assemblage. Wood and MacLachlan (1978) have shown that these seven and an eighth higher unit are sufficient to organize the major lithic variations of the Hamburg sequence throughout Berks County, and they map them as lithotectonic units 1 to 8 in possible ascending order of superposition. Only lithotectonic unit 6 has been recognized in the study area. The age of Hamburg sequence rocks is not fully resolved, but unit 6 is probably Lower Ordovician.

Beds commonly dip steeply and may be overturned in all three sequences, and both thrust faults and high angle faults are common. Diabase dikes of Late Triassic or Early Jurassic age locally intrude older rocks, and, locally, Triassic fanglomerates unconformably overlie rocks of the Lebanon Valley sequence. Deposits of Quaternary colluvium are extensive around the quartzite-gneiss hills but are commonly thin. Quaternary alluvial deposits are also present. Neither the colluvium or the alluvium are important aquifers.

Water Supply and Wastewater Treatment

Because the population is generally dispersed, approximately 60 percent of the residents of Oley Township rely on privately owned wells for water supply. In the village of Oley (fig. 1), however, public supply is provided by the Oley Water Company[1/] to a population of 1,200 (375 customers). The majority of customers are residential, although 23 are commercial and 4 are industrial (E. F. Rhoda, Oley Water Company, oral commun., 1982). The public water-supply system is composed of (1) three wells, which, on the average, pump a combined total of 72,000 gal/d (gallons per day); (2) a 200,000 gal (gallon) storage tank; (3) chlorination facilities; and (4) the distribution network.

In rural parts of Oley Township, wastewater is disposed of chiefly through individual, on-site systems (cesspools and septic tanks). In the village of Oley, however, the Oley Township Municipal Authority (OTMA) operates a public sewage-treatment system. The 411 service connections to the system include residential, commercial, industrial and institutional hookups. On the average, approximately 100,000 gal/d of wastewater receive primary treatment at the OTMA plant; treated effluent is discharged to Manatawny Creek (Harold Herbein, Oley Township Municipal Authority, oral commun., 1982). The average wastewater inflow of 100,000 gal/d at the treatment plant exceeds the average public-supply pumpage of 72,000 gal/d. The remaining inflow is likely due to discharge to sewers by users of private water supplies and ground-water seepage into sewers (infiltration).

[1/] Use of firm names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Well-Numbering System

The well-numbering system used in this report consists of a local well number and a site identification number. The local number has two parts: (1) a two-letter abbreviation that identifies the county in which the well is located, and (2) a sequential number assigned when the well was originally inventoried. All wells mentioned in this report are in Berks County and are identified by the abbreviation "BE." The site identification number has 15 digits and is based on latitude and longitude. The first six digits denote the degrees, minutes, and seconds of latitude; the next seven digits denote the degrees, minutes, and seconds of longitude; and the last two digits denote the sequential number. The sequential number is assigned to distinguish among sites located within a common 1-second grid block of latitude and longitude.

All of the wells in Oley Township that have been inventoried by the U.S. Geological Survey are shown on plate 1. The prefix "BE" has been omitted from the local well number on plate 1.

Geologic Names and Aquifer Codes

Table 1 lists the geologic units in which the wells mentioned in this report are completed and the corresponding aquifer codes. The codes have seven or eight characters and consist of two or three parts. The first part has three numeric characters that designate the era, system, or series of the geologic unit. The second part, or next four characters, is an abbreviation for the name of the geologic unit. The third part is a single character that denotes the lithology or stratigraphic position of the geologic unit. The aquifer codes appear in the column "Geologic Unit" in the records of wells (table 14, page 54) and in the water-quality table (table 15, page 58). The codes have been retrieved from the Water Data and Storage and Retrieval System (WATSTORE) of the U.S. Geological Survey and may not follow the current usage of the Survey.

Table 1.--Names and aquifer codes for geologic units

Series	Geologic unit	Aquifer code
Upper Ordovician	Martinsburg Formation	361MRBG
Middle Ordovician	Jacksonburg Limestone	364JKBG
Middle and Lower Ordovician	Beekmantown Group (undifferentiated)	364BKMN
Lower Ordovician	Hamburg sequence, lithotectonic unit 6	364HMBG6
Middle and Lower Ordovician	Ontelaunee Formation	364ONLN
Lower Ordovician	Epler Formation	367EPLR
Lower Ordovician and Upper Cambrian	Allentown Dolomite	371ALNN
Upper Cambrian	Richland Formation	371RCLD
Middle and Lower Cambrian	Leithsville Formation	374LSVL
Lower Cambrian	Hardyston Quartzite	377HRDS
Precambrian	Granite gneiss	000GRGS
Precambrian	Hornblende gneiss	000HBLD

Acknowledgments

The authors are indebted to the many individuals who provided assistance and information essential for the successful completion of this study, which was done in cooperation with the Oley Township Supervisors. Sincere thanks are extended to Phoebe L. Hopkins, Project Assistant, for her extensive help as liaison between the U.S. Geological Survey and the Oley Township Supervisors, and for her promotion of community participation in the study.

This study was made possible through the generous efforts of many volunteer observers who gave freely of their time to collect hydrologic data: John A. Caltagirone, David D. Glick, Petra Haas, William T. Haas, Phoebe L. Hopkins, Andrew F. Kent, and Vicki A. Weidner recorded precipitation data; Jennifer Atkins, John A. Caltagirone, Dennis G. Collins, Annette Hetrick, Janelle Hetrick, Phoebe L. Hopkins, Flitzi Kindig, Glenn Kline, Doris L. Lorah, and Ruth H. Stoltzfus recorded daily observations of stream stage; and Lorah P. Hopkins made monthly ground-water-level measurements.

The authors gratefully acknowledge the cooperation of the many individuals who kindly permitted access to their wells for the collection of data essential to this study. Acknowledgment is also made of the Pennsylvania Department of Environmental Resources, Bureau of Topographic and Geologic Survey, for compiling the geologic map included in this report.

Special thanks are due to Mr. Emil F. Rhoda of the Oley Water Company for providing data on the availability and quality of water from the Company's public-supply wells, and to Mr. Harold Herbein of the Oley Township Municipal Authority for furnishing information on the local wastewater treatment system. Thanks are also due to Mr. John Hall of the National Gypsum Company, and to Mr. Harry Schankweiler of Eastern Industries, Inc., who provided information on the geology and hydrology of their company's quarries in Oley Township.

SURFACE-WATER RESOURCES

Drainage Basins and Streamflow

The study area is drained chiefly by the Monocacy, Limekiln, Pine, Bieber, Oysterville, and Manatawny Creeks. Figure 4 shows the locations and drainage areas of the six nonrecording streamflow-gaging stations that were established in 1981 for this study and the location and drainage area for a long-term recording station on Manatawny Creek. Stream gages at the non-recording stations were read once daily through December 1982 by volunteer observers. Mean daily stream discharge was estimated from the rating curves that were based on periodic discharge measurements made by the U.S. Geological Survey. Table 2 classifies the basins according to the various rock types present in each.

The western and southwestern parts of Oley Township are drained by Monocacy and Limekiln Creeks, and the northern and northeastern localities are drained by Pine, Bieber, and Oysterville Creeks. The rest of the

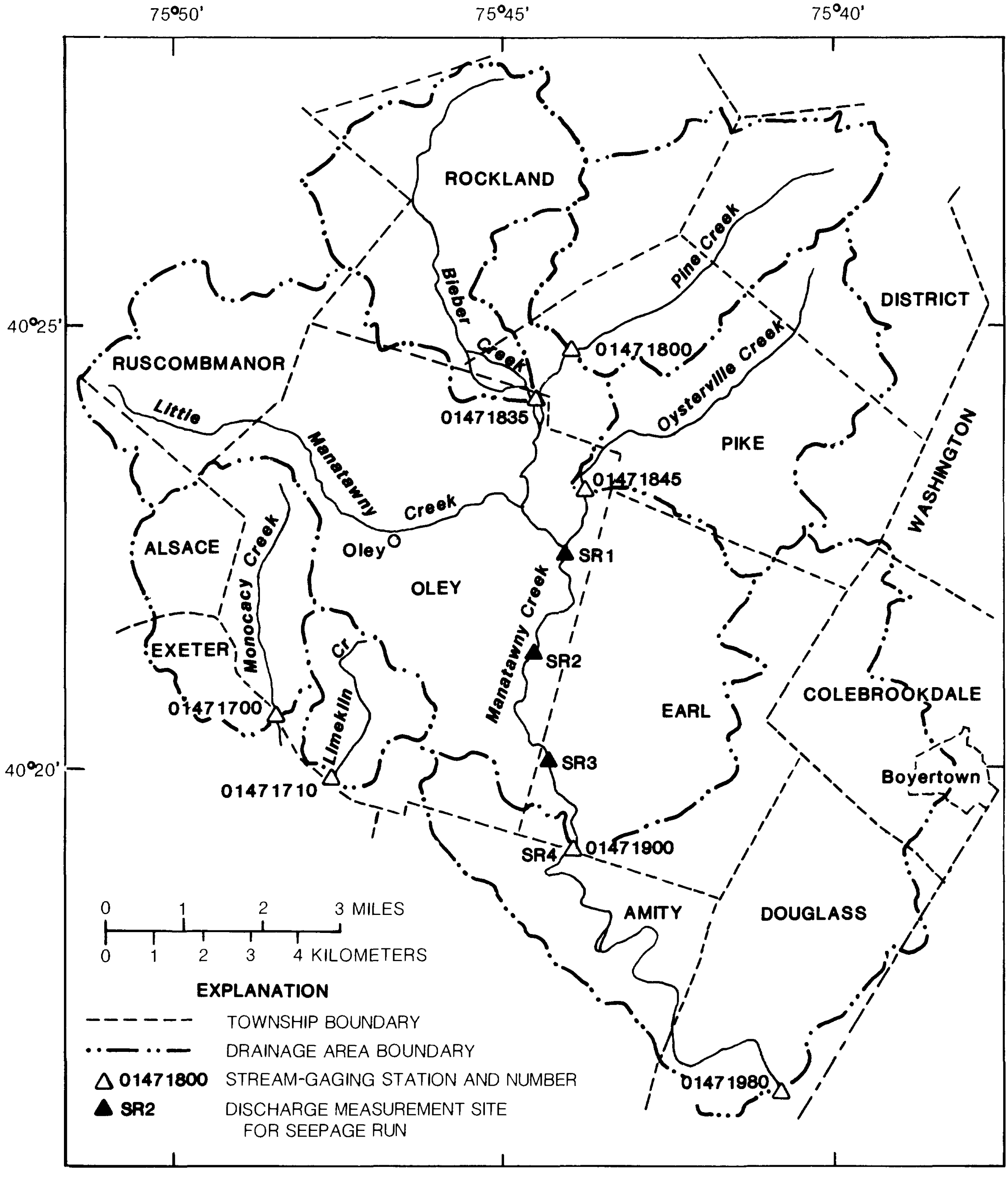


Figure 4.--Location of stream-gaging stations and drainage area boundaries.

township is drained by Manatawny Creek. Generally, these streams flow to the south or southwest, and all of their flows eventually discharge into the Schuylkill River.

Figure 5 shows the hydrographs of mean daily streamflow and baseflow during the 1982 water year (October 1, 1981 through September 30, 1982) measured at each of the gaging stations. The solid lines represent the total discharge of the stream, whereas the dashed lines indicate the ground-water discharge (baseflow) as determined with the local-minima, hydrograph-separation technique of Pettyjohn and Henning (1979). Summary information for gaging stations and discharge is presented in table 3. Station numbers are those assigned by the U.S. Geological Survey and are listed in downstream order along the principal stream.

Table 2.--Classification of drainage basins according to rock types present

Drainage basin	Drainage area (square miles)	Rock type (percentage of drainage area)		
		Carbonate	Noncarbonate sedimentary	Crystalline
Monocacy	6.68	25	20	55
Limekiln	2.49	93	7.2	0
Pine	9.70	5.3	5.9	89
Bieber	9.08	5.5	16	78
Oysterville	9.29	20	15	65
Manatawny	60.9	44	16	40

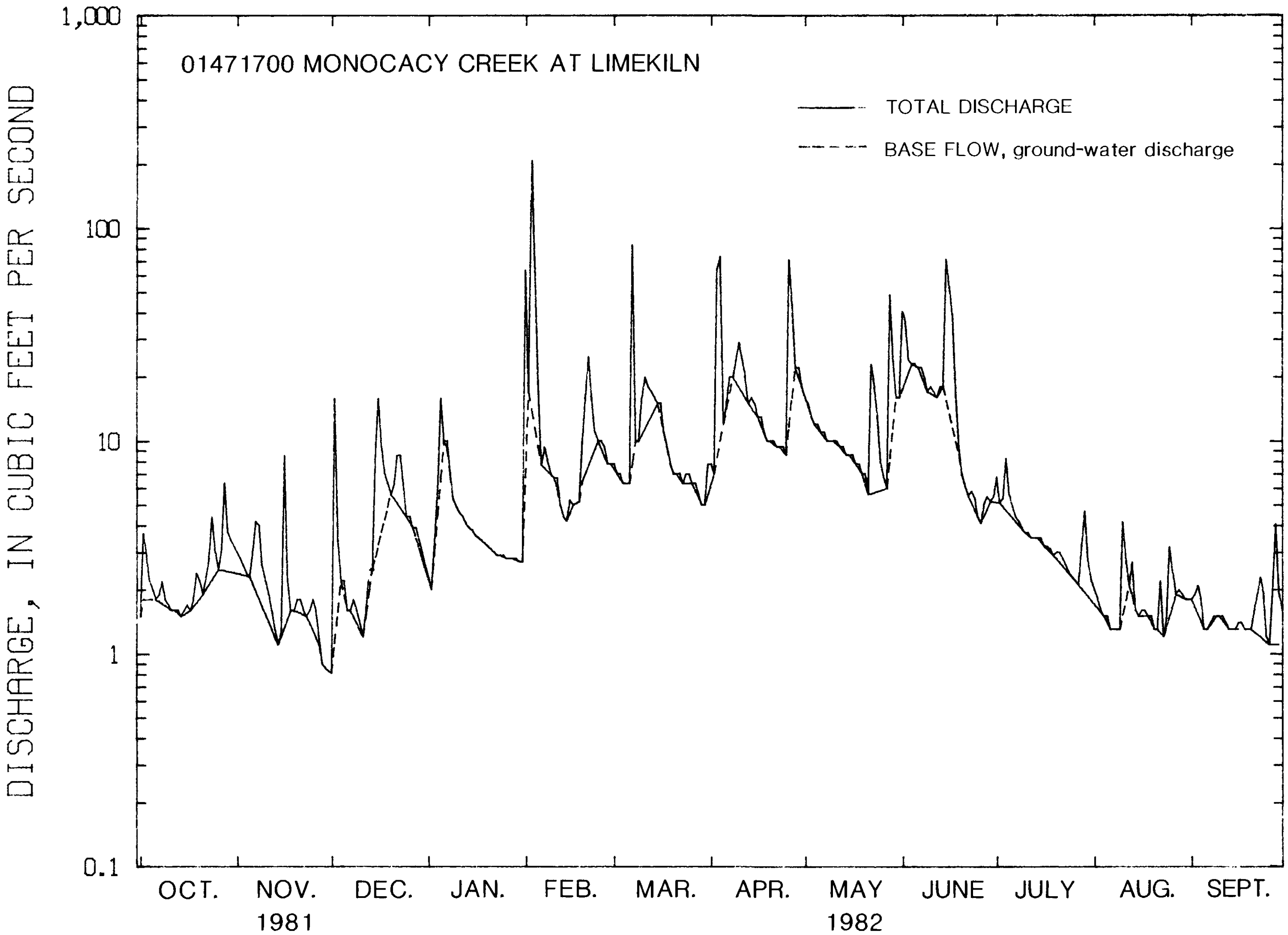


Figure 5a.—Hydrograph of mean daily streamflow and base flow, 1982 for Monocacy Creek at Limekiln.

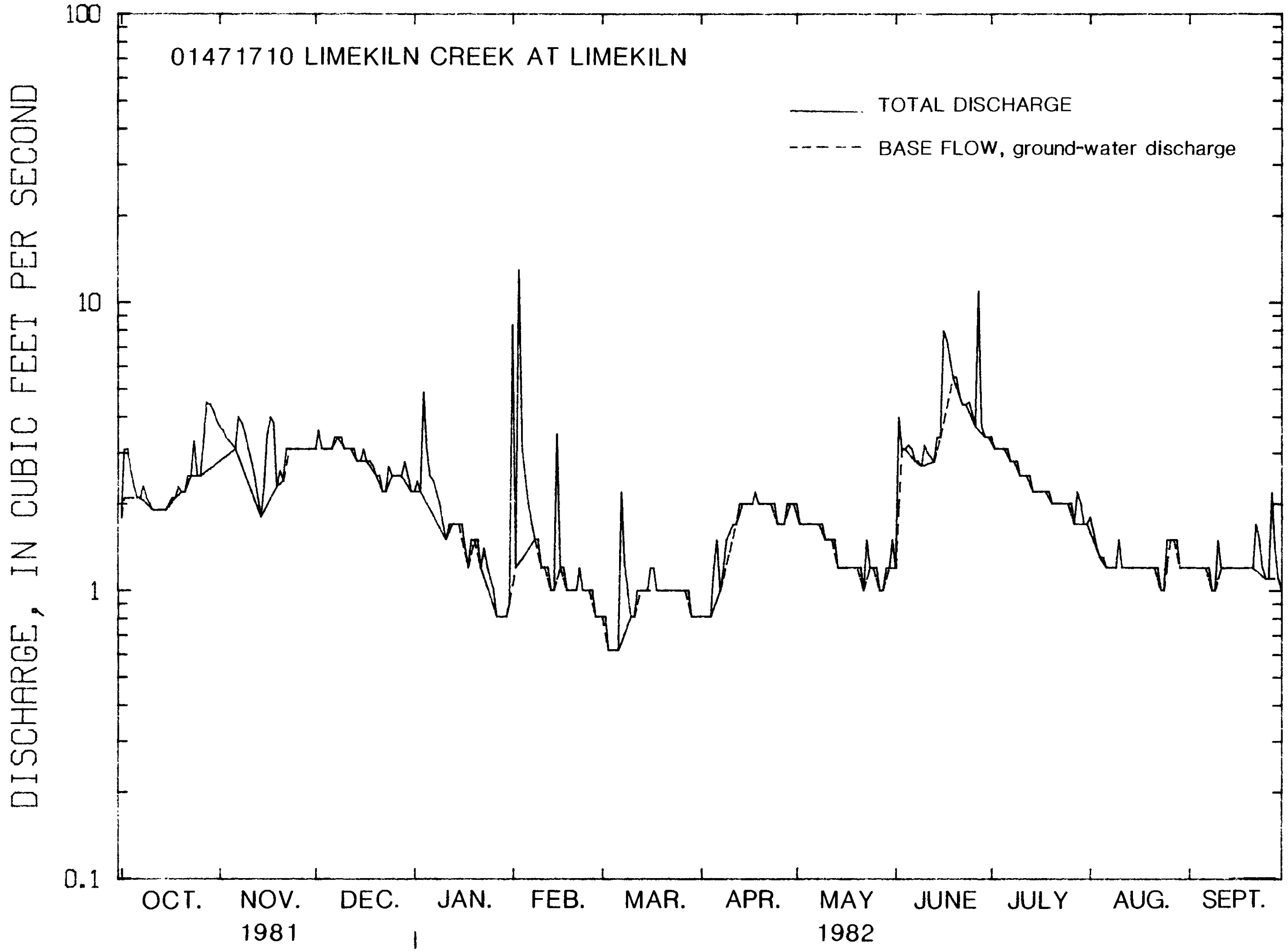


Figure 5b.--Hydrograph of mean daily streamflow and base flow, 1982 water year for Limekiln Creek at Limekiln.

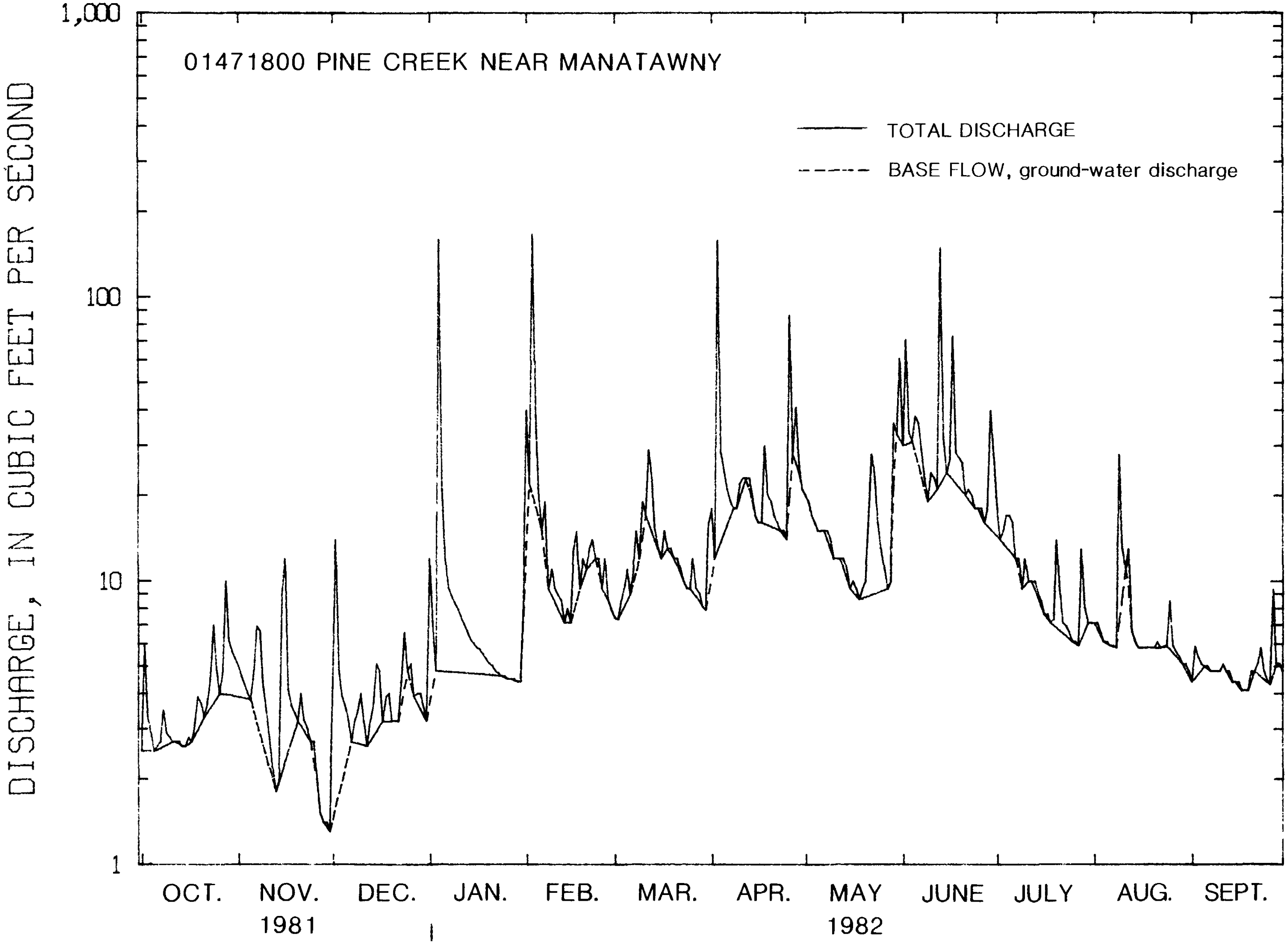


Figure 5c.--Hydrograph of mean daily streamflow and base flow, 1982 for Pine Creek near Manatawny.

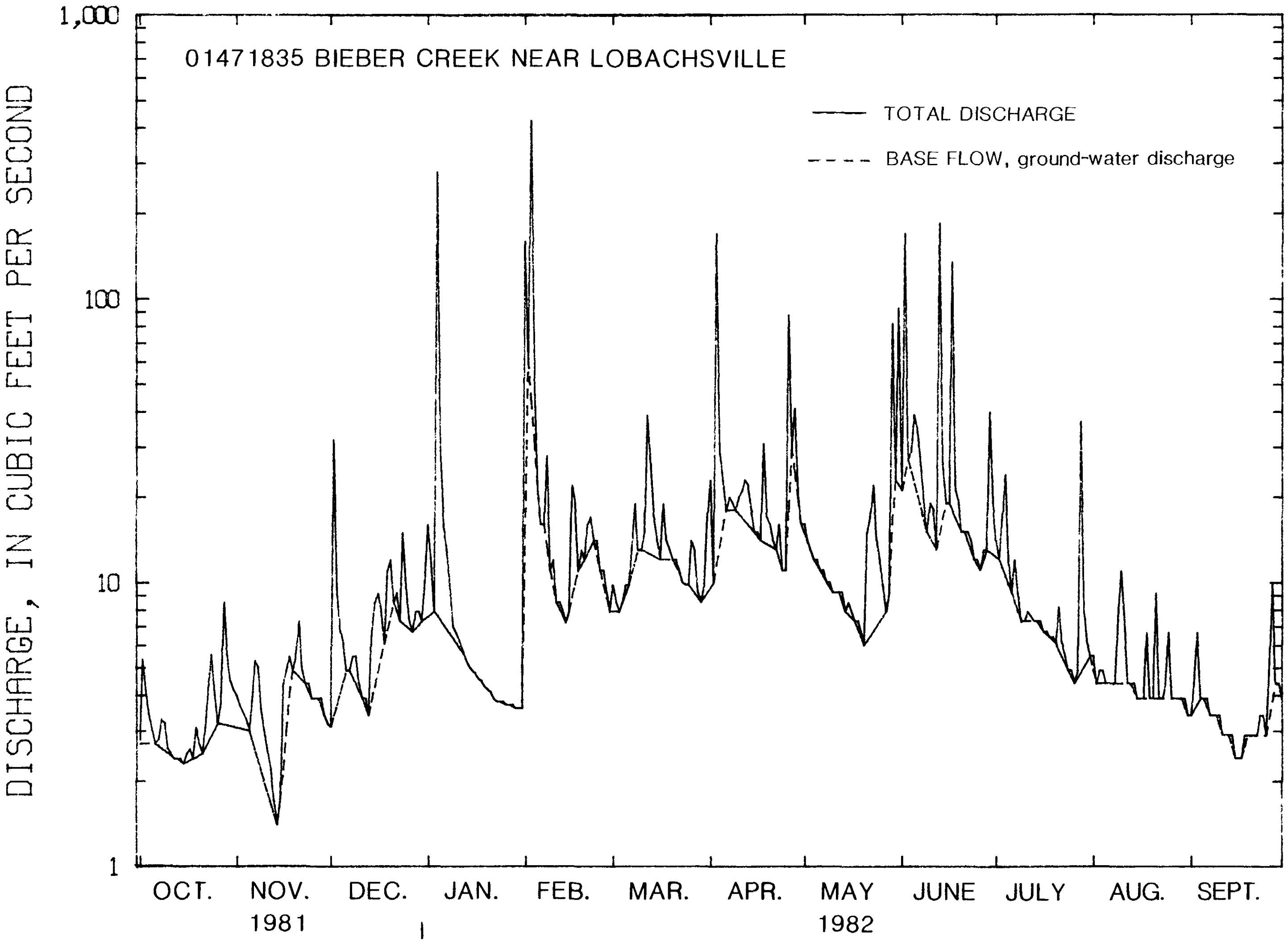


Figure 5d.--Hydrograph of mean daily streamflow and base flow, 1982 water year for Bieber Creek near Lobachsville.

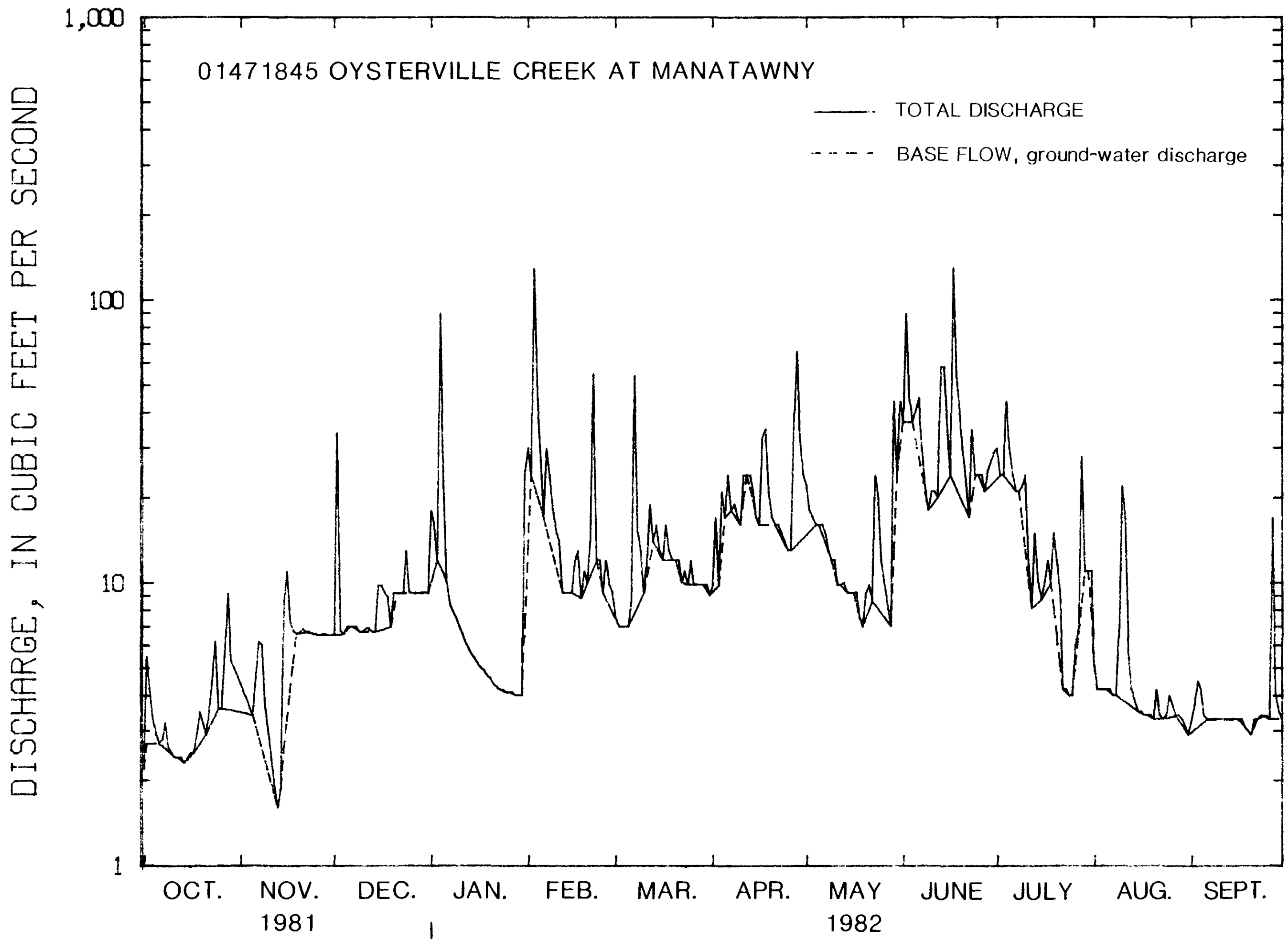


Figure 5e.--Hydrograph of mean daily streamflow and base flow, 1982 for Oysterville Creek at Manatawny.

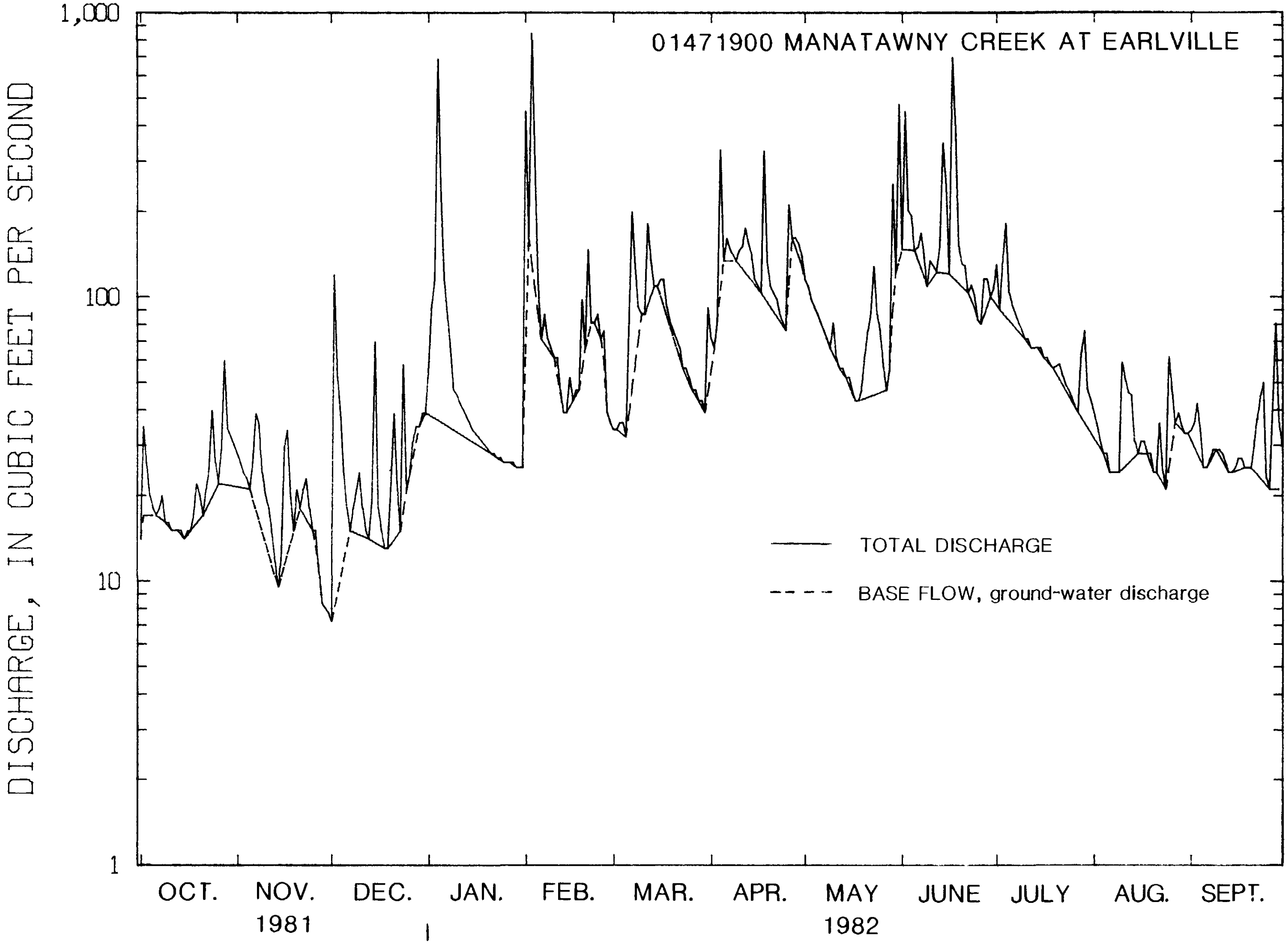


Figure 5f.--Hydrograph of mean daily streamflow and base flow, 1982 water year for Manatawny Creek at Earlville.

Table 3.--Summary information on gaging stations and streamflow
[mi^2, square mile; ft^3/s, cubic foot per second]

Station number	Station name	Location	Drainage area (mi^2)	Mean discharge (ft^3/s)	1982 Water year: Maximum daily discharge (ft^3/s)	Date of maximum discharge	Minimum daily discharge (ft^3/s)	Date of minimum discharge
01471700	Monocacy Creek at Limekiln	Lat. 40°20'35", long. 75°48'23", on upstream right-side wingwall of bridge on Oley Turnpike, 0.04 miles southwest of its intersection with Limekiln Road.	6.68	8.75	210	Feb. 3	0.81	Dec. 1
01471710	Limekiln Creek at Limekiln	Lat. 40°19'53", long. 75°47'34", on downstresm right-side wingwall of bridge on Limekiln Road, 1.08 miles southeast of its intersection with Oley Turnpike.	2.49	2.11	13	Feb. 3	.62	Mar. 3-6
01471800	Pine Creek near Manatawny	Lat. 40°24'42", long. 75°44'02", on upstream right-side wingwall of bridge on Lobachsville Road, 1.65 miles southwest of Pine Waters and 1.15 miles northwest of Pikeville.	9.70	12.8	167	Feb. 3	1.3	Nov. 30
01471835	Bieber Creek near Lobachsville	Lat. 40°24'12", long. 75°44'30", on upstream right-side wingwall of bridge on Bertolet Mill Road, 0.70 miles northeast of its intersection with Hoch Road.	9.08	13.2	425	Feb. 3	2.3	Oct. 15
01471845	Oysterville Creek at Manatawny	Lat. 40°23'08", long. 75°43'46", on left side of upstream center pier of bridge on Yoder Road, 0.13 miles southeast of its intersection with Oysterdale Road and 1.00 miles southwest of Pikeville.	9.29	13.2	130	Feb. 3 and June 17	1.6	Nov. 13
01471900	Manatawny Creek at Earlville	Lat. 40°10'05", long. 75°44'01", on downstream left-side wingwall of bridge on PA Route 562, 0.24 mi NW of its intersection with Powder Mill Road.	60.9	73.7	847	Feb. 3	7.2	Dec. 1
01471980	Manatawny Creek near Pottstown	Lat. 40°10'05", long. 75°44'01", on left bank about 180 feet upstream from bridge on Manatawny Street, 0.7 miles downstream from Ironstone Creek, 2.4 miles northwest of Pottstown, 3.1 miles upstream from mouth, and 4.7 miles southwest of Boyertown.	85.5	112	1,550	Feb. 3	21	Oct. 1,17

Flow Duration

A flow-duration curve shows the percentage of time that specified discharges were equaled or exceeded. It describes the flow characteristics of a stream throughout the range of discharge without regard to the sequence of occurrence. In this report, discharges have been divided by drainage area above the gage to facilitate comparison. Although the flow-duration curves for local streams (fig. 6) represents only the mean-daily discharges in the 1982 water year--a period of about average precipitation--they provide some indication of the variability of streamflow from basin-to-basin. A duration curve with a relatively steep slope--for example, Monocacy Creek at Limekiln (fig. 6a)--represents a stream whose total flow is variable, due largely to direct runoff. Flatter slopes, particularly at the lower end of the duration curve, indicate streamflow contributions mainly from ground-water storage in the basin. Thus, Limekiln Creek at Limekiln has relatively constant low streamflow sustained chiefly by releases from storage (fig. 6b).

The capacity of a basin to store ground water can be estimated from discharge ratios taken from the flow-duration curve. If Q_{25} represents the value of streamflow that is equaled or exceeded 25 percent of the time and Q_{75} represents the value that is equaled or exceeded 75 percent of the time, then the ratio $(Q_{25}/Q_{75})^{1/2}$ provides a measure of the ability of the basin to store water (Walton, 1970). Discharge ratios based on the flow duration curves of figure 6 are presented in table 4. Small ratios represent relatively permeable basins with large storage capacity; larger ratios indicate less-permeable basins with smaller storage capacity. Accordingly, the Limekiln Creek basin, which is underlain mostly by carbonate rocks, has the largest storage capacity, whereas the Monocacy Creek basin, which is underlain chiefly by noncarbonate rocks, has the smallest storage capacity.

Because the flow-duration curves shown in figure 6 represent only the discharge characteristics for the 1982 water year, they may not represent accurately the long-term probability distribution of streamflow. The nearest gaging station with a long-term flow-duration curve is Manatawny Creek near Pottstown (fig. 4). Because this station and the station at Earlville are on the same stream and both measure flow originating in similar terrain, the flow-duration curve for Manatawny Creek near Pottstown (fig. 7) can be used to approximate the general shape of the long-term flow-duration curve for Manatawny Creek at Earlville. Similarly, long-term flow-duration curves for the other local streams can be estimated by using historical discharge data for streams that drain basins that are similar in area, morphology, geology, and hydrology. However, conditions in the respective drainage areas, such as variations in vegetal cover, topography, land use, precipitation distribution, and releases of water from storage may cause some difference in the shape of the curves.

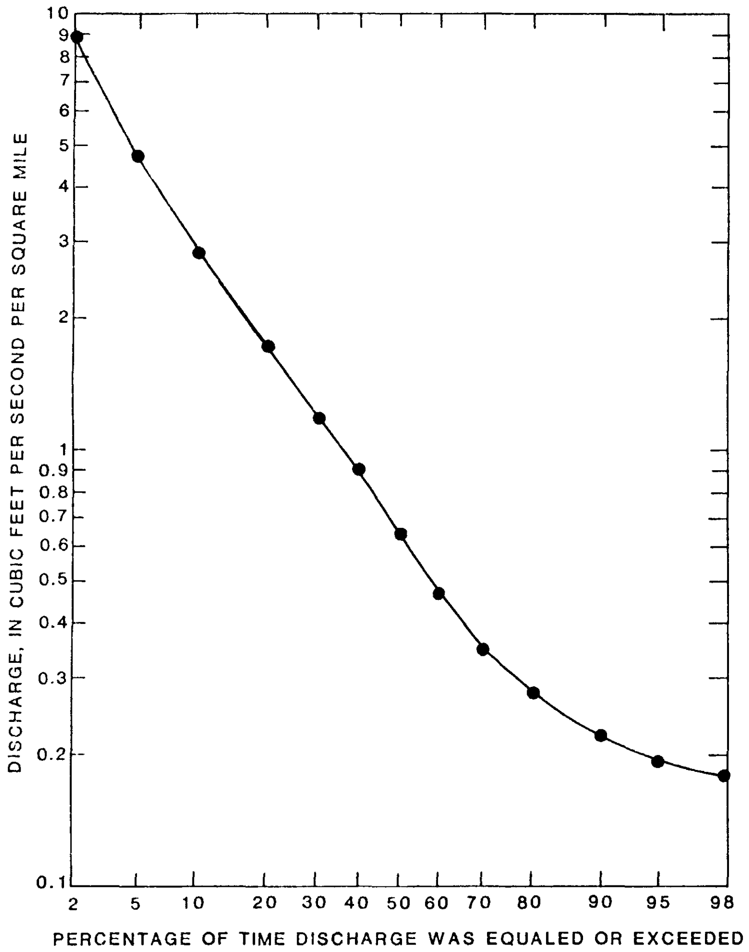


Figure 6a.--Duration curve of daily discharge for Monocracy Creek at Limekiln, 1982 water year.

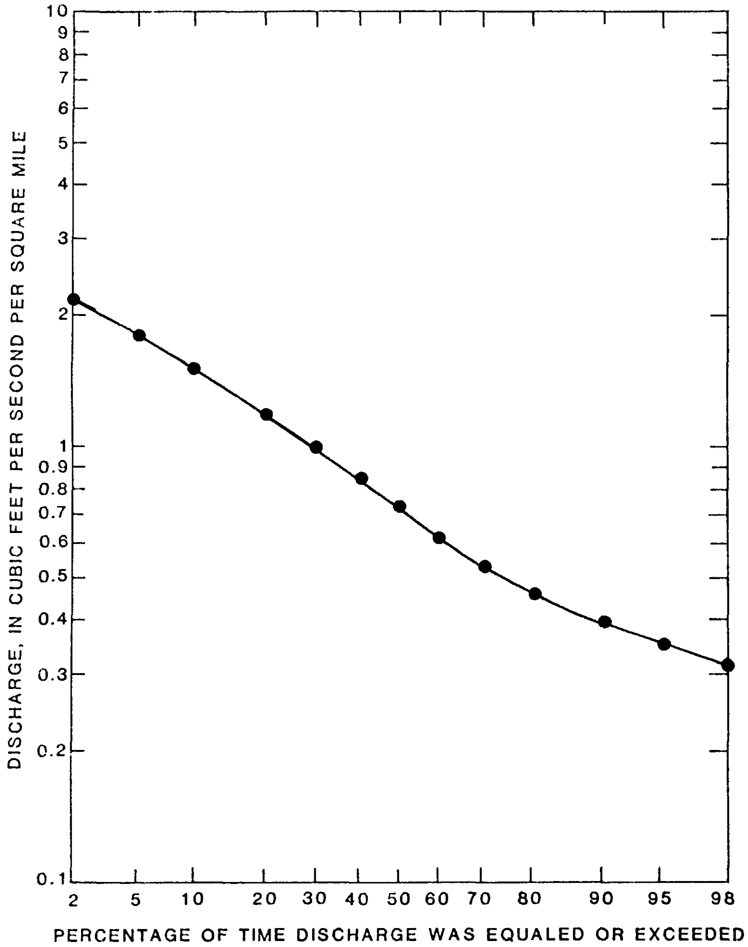


Figure 6b.--Duration curve of daily discharge for Limekiln Creek at Limekiln, 1982 water year.

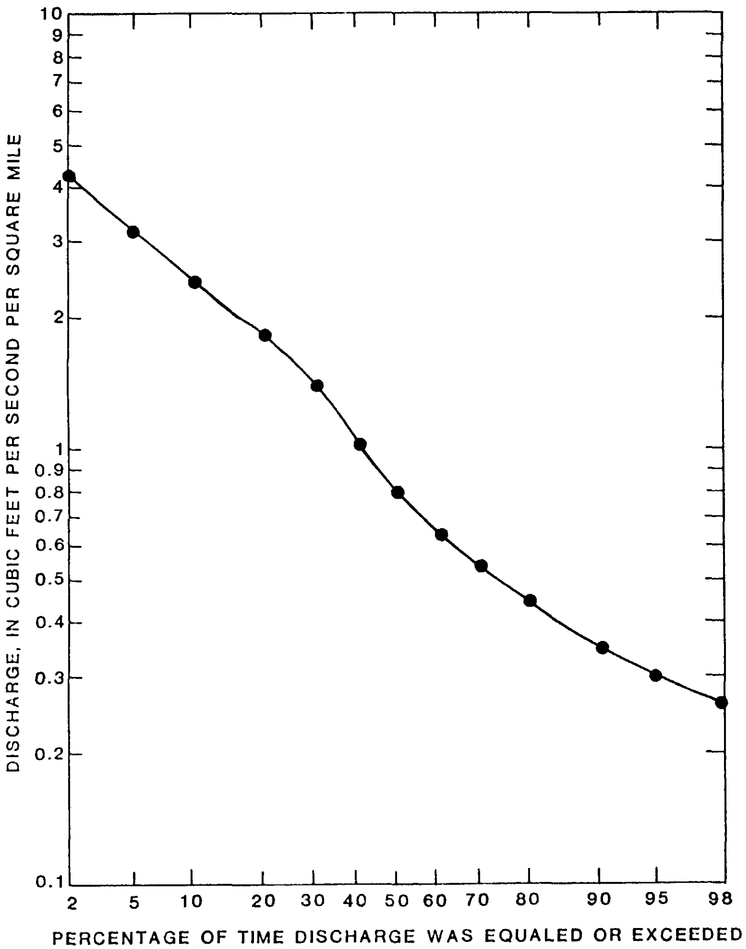


Figure 6c.--Duration curve of daily discharge for Pine Creek near Manatawny, 1982 water year.

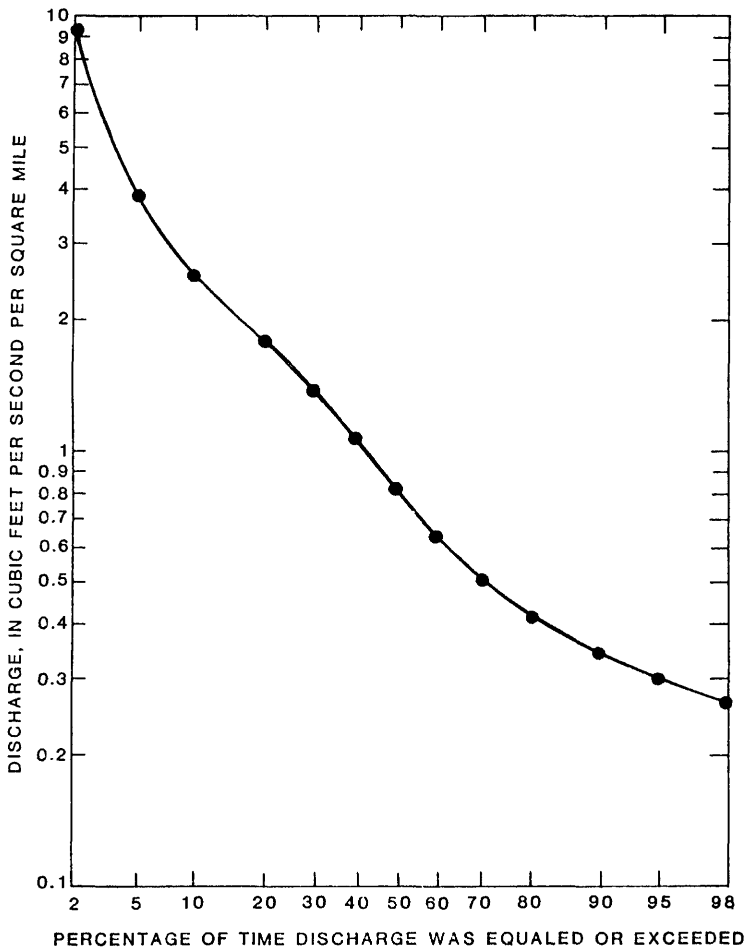


Figure 6d.--Duration curve of daily discharge for Bieber Creek near Lobachsville, 1982 water year.

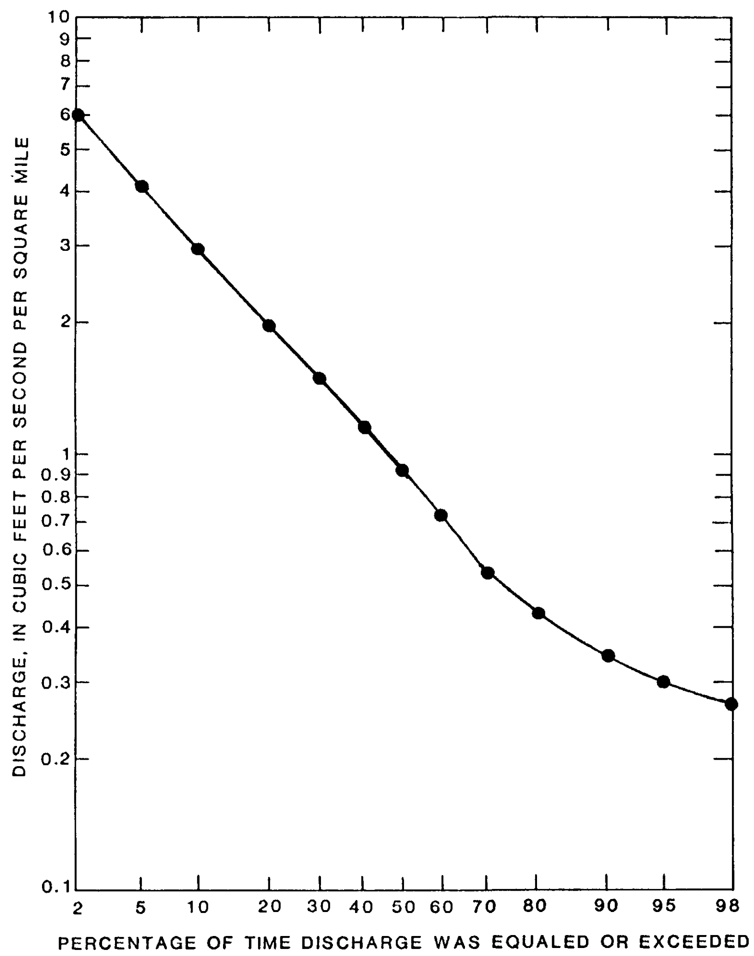


Figure 6e.--Duration curve of daily discharge for Oysterville Creek at Manatawny, 1982 water year.

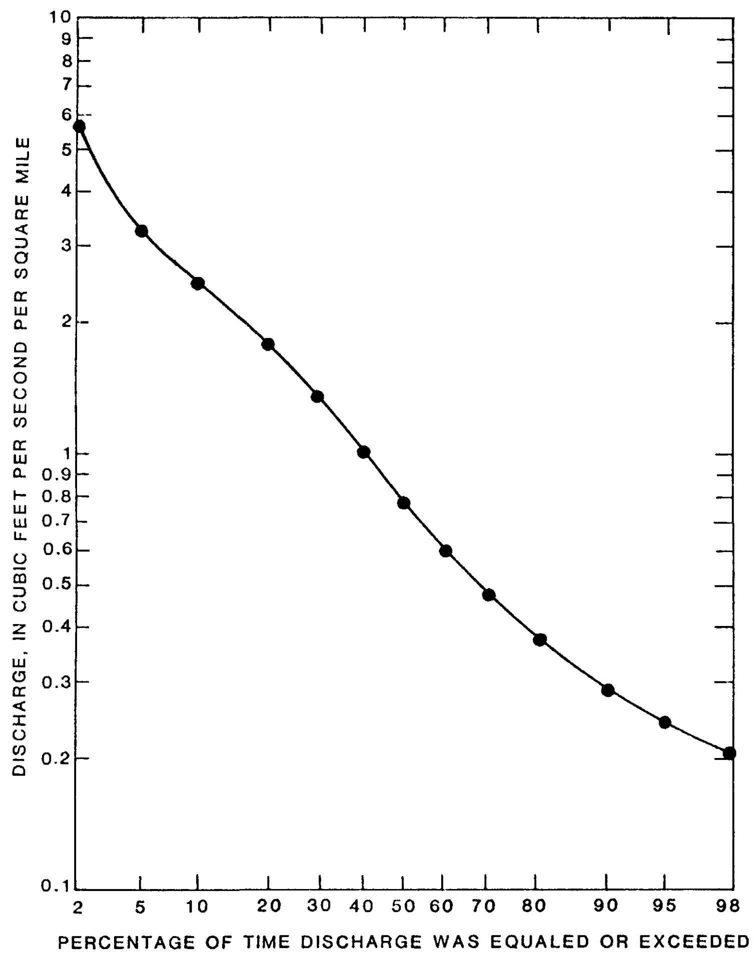


Figure 6f.--Duration curve of daily discharge for Manatawny Creek at Earlville, 1982 water year.

Table 4.--Discharge ratios for local streams, 1982 water year [Basins are listed in decreasing order of water-storage capacity]

Drainage basin	Discharge ratio[1] $(Q_{25}/Q_{75})^{1/2}$
Limekiln	1.53
Pine	1.77
Manatawny	1.83
Bieber	1.89
Oysterville	1.95
Monocacy	2.17

[1]Discharge ratio is the square root of Q_{25}, the streamflow that is equaled or exceeded 25 percent of the time, divided by Q_{75}, the streamflow that is equaled or exceeded 75 percent of the time.

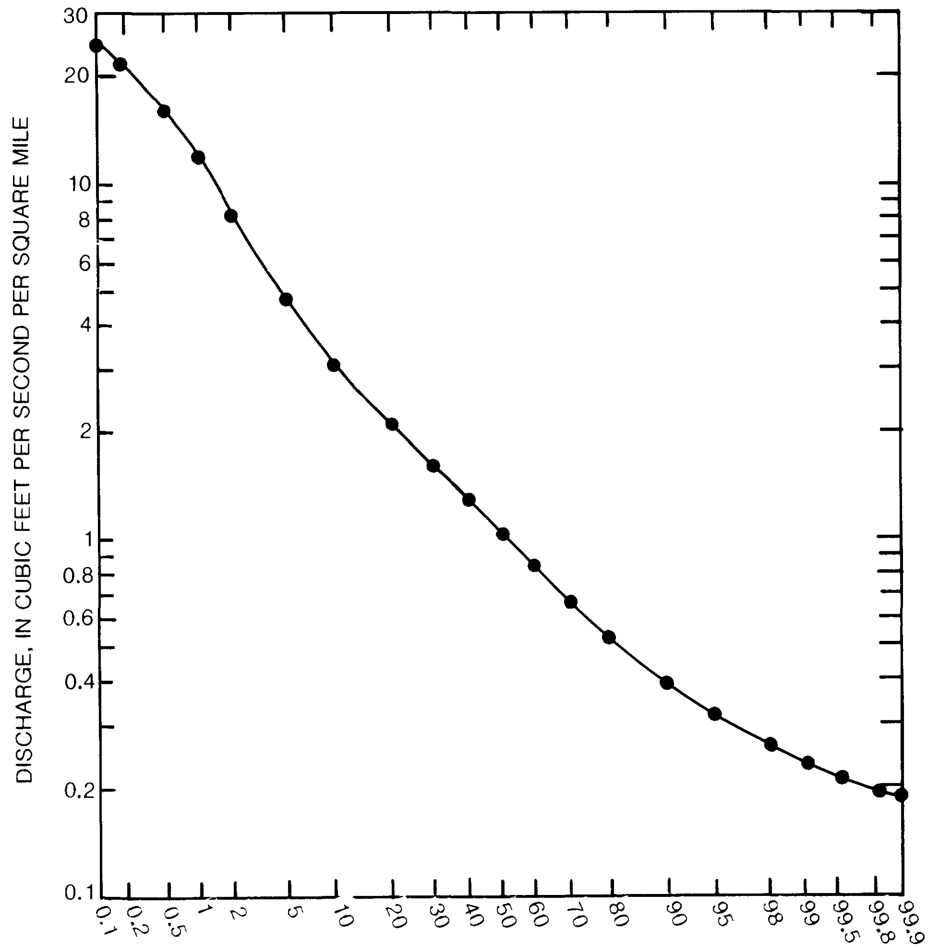


Figure 7.--Duration curve of daily discharge for Manatawny Creek near Pottstown, 1975-84 water years.

Quality

Six samples of surface water were collected on August 30, 1982, at project gaging stations during low streamflow. Figure 8 shows the location of the sites sampled. All samples were analyzed in the field for selected water-quality characteristics and in the laboratories of the U.S. Geological Survey for selected inorganic chemical species, nutrients, and bacteria. The results of these and several previous chemical analyses are given in table 15 (page 58).

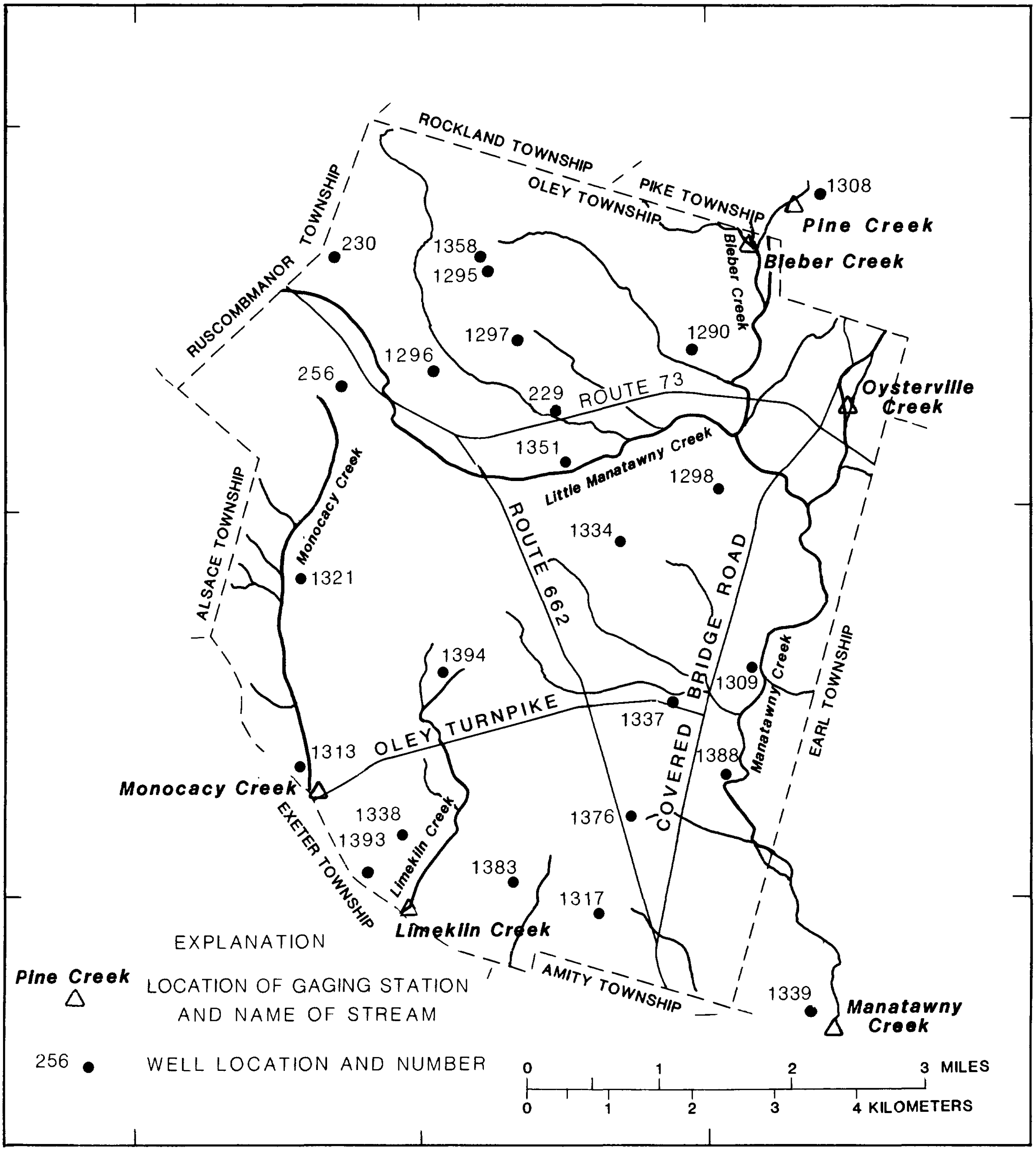


Figure 8.--Location of water-quality sampling sites.

Field Analyses

Specific conductance is a measure of a water's ability to conduct an electrical current; its value is proportional to the concentration of minerals dissolved in the water. Accordingly, large values of specific conductance represent high concentrations of dissolved minerals.

Specific conductance ranged from 105 to 560 µS/cm (microsiemens per centimeter at 25° Celsius) with a median of 228 µS/cm. Waters with low specific conductance represent drainage from basins that consist chiefly of crystalline rocks, such as the Bieber Creek basin, whereas waters with high specific conductance represent drainage from basins that are composed mainly of carbonate rocks, such as the Limekiln Creek basin.

The pH of a solution is a measure of hydrogen-ion concentration; it represents the degree of acidity or alkalinity of that solution. Values of pH from 0 to 7 indicate acidity, whereas values from 7 to 14 indicate alkalinity. A pH of 7 is neutral. The pH of water also is a measure of its reactive characteristics. Low values of pH, particularly below 4, indicate acidic, corrosive water that will tend to dissolve metals and other substances that they contact. Higher values, particularly above 8.5, represent alkaline waters that, on heating, will tend to form scale. The pH of water in gaged streams ranged from 7.7 to 8.8 and had a median of 8.0.

Surface-water temperatures fluctuate diurnally and seasonally as a result of changes in local air temperature. At the time of sampling, water temperatures ranged from 13.5 to 18.0°C and had a median of 15.0°C.

Alkalinity is a measure of the capacity of a water to neutralize acids and is related directly to the predominant rock type in a drainage basin. It was determined in the field by titrating a water sample to an endpoint pH of 4.5 with a standardized acid titrant. The alkalinity of surface water ranged from 28 to 210 mg/L and had a median of 85 mg/L.

Laboratory Analyses

Concentrations of selected chemical constituents in water samples collected during this study and analyzed by the laboratories of the U.S. Geological Survey, are summarized in table 5.

The maximum contaminant levels for potable water set by the U.S. Environmental Protection Agency (USEPA) are intended to assure the integrity of potable water supplies and provide adequate protection to water users. These maximum contaminant levels represent limiting concentrations for various constituents and are based either on the effects of those constituents on human health or on aesthetic considerations. None of the surface-water samples analyzed for this study (table 15) had any constituents that exceeded USEPA maximum contaminant levels (table 6).

Table 5.--Summary of laboratory determinations of water quality

[Quantity in parenthesis is number of values used in statistical computations; mg/L; milligrams per liter; µg/L, micrograms per liter; <, less than]

Statistical measure	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride dissolved (mg/L as Cl)	Fluoride dissolved (mg/L as F)	Silica dissolved (mg/L as SiO_2)	Dissolved solids sum of constituents (mg/L)	Nitrate (mg/L as N)	Iron dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
All ground-water samples (24)													
Range	110-1,152	25-280	4.7-110	2.4-25	<0.1-6.5	5.0-400	1.7-41	<0.1-1.7	7.8-20	147-934	<0.10-15	<3-1,400	<1-39
Median	265	64	20	6.0	1.2	36	11	0.2	12	269	2.6	12	4
Samples from carbonate aquifers (19)													
Range	200-1,152	39-280	4.7-110	2.4-25	<0.1-6.5	9.0-400	3.8-41	<0.1-1.5	8.1-18	185-934	<0.10-15	<3-1,400	<1-39
Median	290	68	22	6.0	1.4	37	12	0.2	11	279	3.3	12	4
Samples from noncarbonate sedimentary aquifers (4) and crystalline-rock aquifers (1)													
Range	110-340	25-72	7.3-19	3.4-9.3	0.2-1.4	5.0-120	1.7-11	0.1-1.7	7.8-20	147-325	<0.10-3.8	12-870	3-27
Median	190	32	13	5.3	0.5	30	5.0	0.3	14	162	<0.10	21	11
Samples from streams (6)													
Range	39-292	9.9-84	3.4-20	4.4-8.3	0.6-2.7	12-57	4.9-12	<0.1-0.1	8.4-20	75-350	0.34-8.3	9-85	3-22
Median	106	25	8.2	5.7	1.2	22	7.5	0.1	16	140	1.8	26	7

Table 6.--U.S. Environmental Protection Agency maximum contaminant levels for selected constituents in potable water

Constituent	Concentration (milligrams per liter)
Nitrate (as N)1/	10
Iron (Fe)2/	.3
Manganese (Mn)2/	.05
Sulfate (SO_4)2/	250
Total Dissolved Solids2/	500

1/Set by National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1985a)

2/Set by National Interim Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1985b)

GROUND-WATER RESOURCES

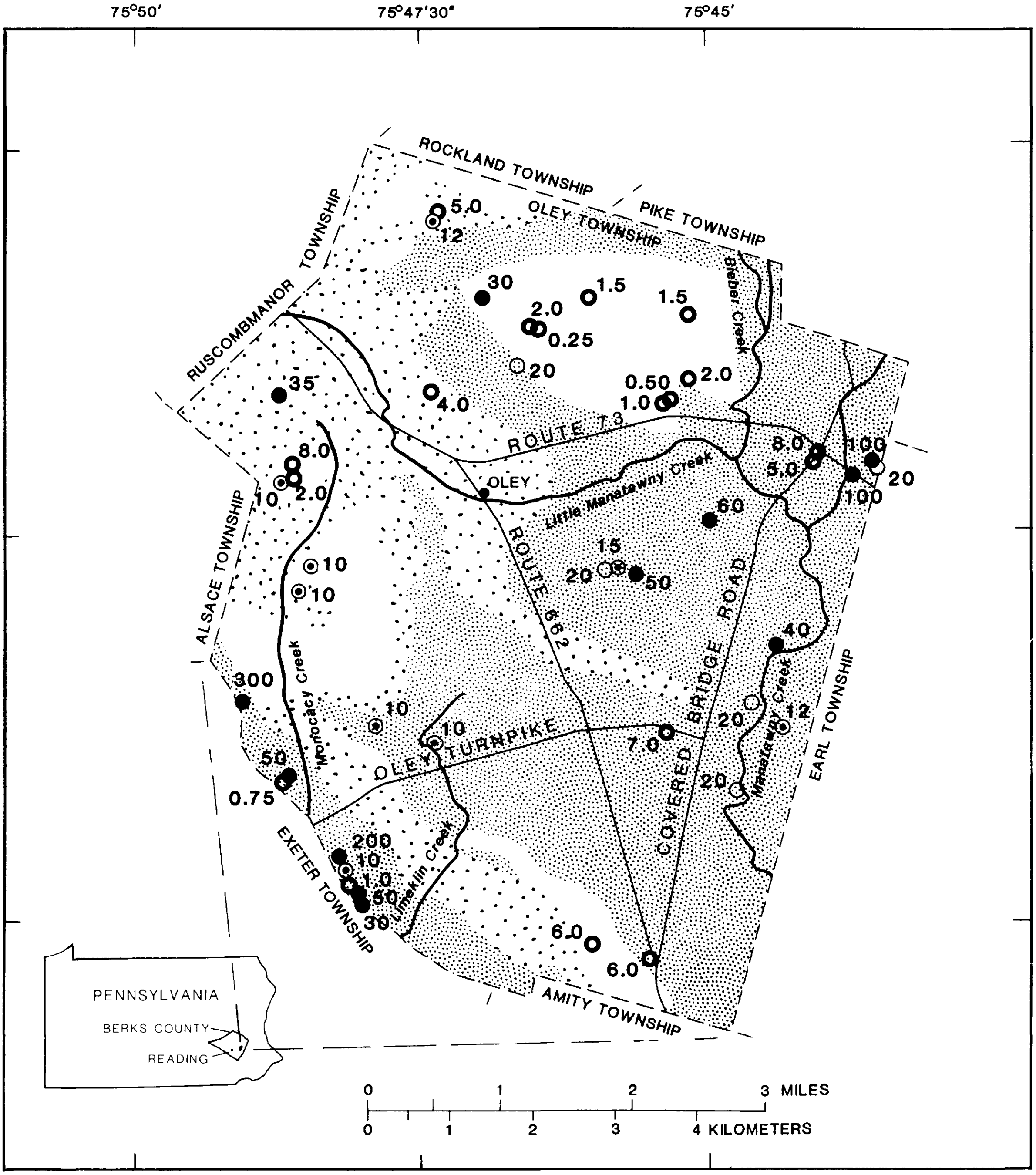
Occurrence and Movement

In Oley Township, most ground water is present in and moves along and through bedding planes and joints, faults, and other fractures. In carbonate rocks, some of these openings have been enlarged by solution, but most are only a fraction of an inch wide. Wood and MacLachlan (1978) reported that no more than 5 percent of all the wells that have been drilled in the carbonate rocks of Berks County have penetrated water-bearing openings as much as 1-ft wide. They also noted that fractures become closed with increasing depth. Wood and others (1972, p. 165), who worked in similar carbonate rocks in Lehigh County, reported that significant quantities of water were obtained from zones as deep as 600 ft below the land surface. They also noted that most fractures and solution openings became closed from 600 to 850 ft below land surface, and relatively little ground-water flow occurs below 850 ft. Thus, small quantities of water are encountered at depths of more than about 600 ft below land surface in carbonate rocks. In the shales, small quantities of water are encountered at depths of more than 300 to 400 ft below land surface.

Aquifer Characteristics

The geology and hydrology of each aquifer that crops out in Oley Township are discussed in this section, and the distribution of each unit is shown on plate 1. The generalized distribution of well yield is shown on Figure 9. Unless otherwise noted, the discussion is based on a report by Wood and MacLachlan (1978). Data for wells in Oley Township are too sparse to describe adequately the hydrology of most aquifers. For most aquifers, yields are given, but specific-capacity data given in Wood and MacLachlan (1978) have been omitted.

Where the term "adequate domestic supply" is used in the following section, it has been arbitrarily defined as 3 gal/min (gallons per minute) or more. This is enough water for most domestic uses, excluding lawn watering or other uses of a garden hose. With prudent use, some households get by on as little as 1 gal/min, whereas 6 gal/min is adequate for nearly all domestic uses. Dairy farms generally need a minimum of 10 gal/min. Irrigators and large public supplies usually require several hundred gallons per minute.



EXPLANATION

LOW YIELD--Median well yield less than 10 gallons per minute. Many wells fail to yield adequate domestic supplies

MODERATE YIELD --Median yield of nondomestic wells ranges from 10 to 50 gallons per minute. Most wells yield adequate supplies for domestic and farm use

HIGH YIELD--Median yield of nondomestic wells is greater than 50 gallons per minute. Many wells yield adequate supplies for public supply use

NUMBER IS YIELD OF DOMESTIC OR NONDOMESTIC WELL IN GALLONS PER MINUTE

- 0-9
- 10-19
- 20-29
- Greater than 29

Figure 9.--Generalized distribution of well yields.

Lithology and Well Yield

Diabase

The carbonate rocks and the Martinsburg Formation have been intruded by nearly vertical, dark-gray, diabase dikes of Early Jurassic or Late Triassic age. These dikes are about 5 to 100 ft wide.

Biesecker and others (1968) observed that well yields from the diabase range from 0.1 to 25 gal/min and the median is 5 gal/min. Yields are substantially influenced by the topographic setting of the wells. Failure to obtain domestic supplies is common near the crest of hills, whereas few wells on moderate slopes and in valleys fail to obtain domestic supplies. Few wells obtain water below 100 ft, because few fractures large enough to serve as conduits for ground water extend below this depth.

Brunswick Formation

The only lithology of the Brunswick Formation of Late Triassic age that crops out in Oley Township is fanglomerate, which is composed almost entirely of limestone and dolomite clasts up to 1 ft in diameter in a reddish-brown matrix. This formation is too limited in areal exent to be important and is probably less than 300 ft thick at the southern boundary of the township.

Well yields from the limestone fanglomerate differ greatly from outcrop to outcrop. Longwill and Wood (1965) give data on a single well (BE-107) in this fanglomerate. This well has a specific capacity of 5 (gal/min)/ft (gallons per minute per foot) of drawdown, suggesting that high yields are possible from wells in this unit.

Martinsburg Formation

The Martinsburg Formation of Late and Middle Ordovician age consists of thin-bedded, dark-gray, medium-gray to yellowish-brown weathering claystone slate. It contains minor thin interbeds of graywacke siltstone, carbonaceous slate, and dolomitic siltstone near the base. It is less than 500 ft thick in the township (MacLachlan, 1983).

Wood and MacLachlan (1978) reported that the median yield of nondomestic wells is 25 gal/min for all of northern Berks County. However, the yield of seven wells in Oley Township ranged from 0.25 to 30 gal/min and had a median yield of 6 gal/min. These wells had a median depth of more than 300 ft. The 30 gal/min yield for well BE-1295 is misleading because the 460-ft deep well was only pumped for 30 minutes, which produced 378 ft of drawdown. Thus, the well has a specific capacity of only 0.08 (gal/min)/ft of drawdown. Apparently, the Martinsburg is less permeable in Oley Township than elsewhere in the county and will barely yield adequate supplies for domestic use from wells that are several hundred feet deep.

Jacksonburg Limestone

The Jacksonburg Limestone of Middle Ordovician age consists of dark-gray, argillaceous limestone that is thick bedded and densely cleaved. It weathers to buff, fissile chips. This stratigraphic name is of Lehigh valley origin and is used according to local practice in the Oley Valley. However, the underlying beds appear to be of Lebanon Valley type, and the unit called Jacksonburg in this report probably is equivalent to the Hershey Formation. The thickness ranges from 90 to 300 ft (MacLachlan, 1983).

The Jacksonburg is one of the lowest-yielding carbonate rocks. Although it generally yields enough water for domestic use, the median yield of nondomestic wells is only about 15 gal/min.

Annville Limestone

The Annville Limestone of Middle Ordovician age consists of thick-bedded, medium-light to dark-gray, high-calcium limestone that is somewhat darker and less pure than the type Annville of Lebanon County. The thickness ranges from 0 to 135 ft. The Annville probably is permeable, but it is too thin to be important as an aquifer.

Hamburg sequence

The Hamburg sequence of Early Ordovician age consists of greenish-brown siltstone, claystone, and shale with interbeds of brown quartz-pebble graywacke conglomerate and limestone. The only unit of this sequence present in Oley Township is lithotectonic unit 6 of Wood and MacLachlan (1978). Its thickness is unknown but is probably less than 1,000 ft.

According to Wood and MacLachlan (1978), lithotectonic unit 6 is one of the highest yielding units in the Hamburg sequence in northern Berks County. They reported that the median yields of nondomestic and domestic wells are 140 gal/min and 30 gal/min, respectively. However, the only well with a known yield in Oley Township was 350 ft deep and had a yield of 4 gal/min and a specific capacity of only 0.01 (gal/min)/ft of drawdown. This suggests that yields from this unit may be lower in Oley Township than elsewhere in the county.

Beekmantown Group

From youngest to oldest, the Beekmantown Group of Middle and Early Ordovician age has been divided into the Ontelaunee, Epler, Rickenbach, and Stonehenge Formations. The Ontelaunee Formation (Middle and Lower Ordovician), which is 650 ft thick, consists of medium dark-gray, finely crystalline dolomite that is fairly pure at the top. Mottled beds of limestone compose about 50 percent of the medial part of the formation. Dark-gray beds of chert occur near the base. The Epler Formation (Lower Ordovician) consists of interbedded medium-gray limestone and dolomite with calcarenite lenses. Dark nodular chert is common in the dolomite. It is 800 ft thick. The Rickenbach Formation (Lower Ordovician) consists of gray cherty dolomite and subordinate limestone interbeds. It is darker and more coarsely crystalline toward the top. It is 560 ft thick. The Stonehenge Formation (Lower Ordovician) consists of medium-gray limestone that is cherty in the upper part with numerous nonshaly beds and laminations, intraformational conglomerate, and calcarenite lenses. The formation is 250 ft thick. Because the Beekmantown Group is poorly exposed in the northern part of the township, it has not been subdivided into formations there.

The Ontelaunee and Epler Formations are both good aquifers; median yields of nondomestic wells are 105 and 200 gal/min, respectively. Some wells in both formations yield 1,000 gal/min or more. No data are available from nondomestic wells that could be used to properly evaluate the Rickenbach and Stonehenge Formations. The scanty data available in Lebanon County (Meisler, 1963) suggest that both of these formations may yield large supplies of water to wells. Wells BE-1289, BE-1340, BE-1364, and BE-1290 drilled in the Beekmantown Group east of Oley Furnace had yields of only 0.5, 1, 1.5, and 2 gal/min, respectively. Either the Beekmantown is a very low permeability unit in that area or another carbonate-rock formation of low permeability has been incorrectly mapped as Beekmantown because of poor exposures.

Allentown Dolomite

The Allentown Dolomite of Early Ordovician and Late Cambrian age consists predominantly of gray dolomite to silty dolomite and usually is thick bedded with subordinate interbedded limestone. Algal laminite structures are common with some oolite and sharpstone conglomerate. The Allentown Dolomite, which is about 2,600 ft thick, tends to be more calcareous and shaly toward the base and may be older than the otherwise equivalent Conococheague Group.

The Allentown Dolomite is an excellent aquifer. The median yield of nondomestic wells is 200 gal/min, and many wells will yield 1,000 gal/min or more.

Conococheague Group

Only two formations of the Conococheague Group of Late Cambrian age are present--the Richland and the underlying Millbach. The Richland Formation consists of predominantly gray dolomite that is thick bedded, with subordinate interbeds of limestone that represent cyclical shallow-water to intertidal facies. Limestone is somewhat more abundant in the middle of the formation. The unit is dolomitic and sandy toward the base; it is 1,700 ft thick. The Millbach Formation consists of interbedded limestone and dolomite that is predominantly light-gray to occasionally pinkish-gray, especially toward the west. Algal structures and intraformational conglomerates are widely distributed; it is about 1,400 ft thick.

Both the Richland and Millbach are high-yield aquifers. The median yield of nondomestic wells in the Richland and Millbach Formations is 200 and 190 gal/min, respectively. Many wells in the Richland yield 1,000 gal/min or more.

Leithsville Formation

The Leithsville Formation of Middle and Early Cambrian age consists predominantly of gray dolomite with considerable amount of chert in the lower part; it is fissile in the upper part and is about 1,000 ft thick.

The formation typically is covered by a thicker overburden than are the other formations, and wells commonly require as much as 100 ft of casing. The median yield of nondomestic wells is 110 gal/min. The median yield of six domestic wells in Oley Township is 50 gal/min.

Hardyston Quartzite

The Hardyston Quartzite of Early Cambrian age consists of quartzose and feldspathic sandstones and quartzites. The unit has a conglomerate bed near the base; it is about 300 ft thick.

The median yield of nondomestic wells is 31 gal/min. A few wells located near the contact with the carbonate rocks may have yields of several hundred gallons per minute.

Granite gneiss

The granite gneiss of Precambrian age is light colored and medium grained. It consists chiefly of quartz and feldspar.

The median yield of nondomestic wells is 50 gal/min, and the median yield of 16 domestic wells in or near Oley Township is 12 gal/min. Low-yield wells may be encountered on hilltops.

Hornblende gneiss

The hornblende gneiss of Precambrian age is dark colored and medium grained. Yields of wells in these rocks are low. About 25 percent of the wells drilled in this unit fail to produce adequate supplies for domestic use.

Specific Yield

Specific yield in the zone of water-table fluctuation can be estimated from changes in water level in observation wells and baseflow. Natural water-level changes were measured in 19 wells for the 29-day period, June 22 through July 21, 1982, and baseflow was calculated at six streamflow-gages for the same 29-day period. The mean water-level decline for the 19 wells was 2.54 ft. The three wells in crystalline rock (granite gneiss), the three wells in noncarbonate sedimentary rock (shale), and the 13 wells in carbonate rocks had average declines of 3.20, 2.40, and 2.45 ft, respectively. Because the differences in the means for the various rock types are relatively small and the sample size for the granite gneiss and shale also is small, the average decline for all 19 wells was assumed to be a valid estimate of the water-level decline over the entire gaged area.

The percentage of noncarbonate sedimentary rock (table 2) ranges from 6 to 20 percent in the six basins. This range is too small to permit a valid calculation of specific yield for these units, but a specific yield of 1 percent was assumed as probably being typical of these rocks. Specific yield was then calculated to be 4.5 percent for the carbonate rocks of the Limekiln Creek basin, 93 percent of which is underlain by carbonate rock. A value for specific yield of 5 percent was calculated for the crystalline rocks using a similar procedure for the Pine Creek basin, 89 percent of which is underlain by crystalline rock.

The derived values of specific yield for each rock type were then used to calculate predicted baseflow for June 22 through July 21, 1982, at all six gages. The predicted baseflow was calculated by multiplying the drainage area underlain by each rock type (table 2) by the specific yield for that rock type and the average water-table decline and taking the sum for the three rock types.

Predicted and observed discharges are given in table 7. The relatively good agreement in four basins suggests that the specific yields of 4.5 percent for the carbonate rocks and 5 percent for the crystalline rocks are at least approximately correct. However, these values only apply to the zone of natural water-table fluctuation, and much lower values could be expected if the water table were to be lowered substantially. Furthermore, water-level declines may have been greater in the crystalline rocks than is assumed in the above analysis, and, if so, specific yield would be somewhat less than 5 percent.

The poor agreement between predicted and observed discharge for Oysterville Creek cannot be readily explained with the available data. The poor agreement between predicted and observed discharge for Monocacy Creek may reflect the fact that most of the carbonate rock that crops out in this basin is the Jacksonburg Limestone, which has a low permeability and almost certainly a lower-than-average specific yield compared with other carbonate rocks. The specific yield for this formation is probably about 1.5 percent.

Table 7.--Comparison of predicted and observed base flow for drainage basins, June 22 through July 21, 1982
[ft^3/s, cubic foot per second]

Drainage basin	Predicted discharge (ft^3/s)	Observed discharge (ft^3/s)
Monocacy	7.7	4.4
Limekiln	3	2.9
Pine	13	13
Bieber	11	10
Oysterville	11	19
Manatawny	72	80

Factors Affecting Well Yield

The well yield depends largely on the permeability, specific yield or storage coefficient, thickness and areal extent of the aquifer, sources of induced recharge, the length of the well that is open to the aquifer, the well diameter, and the efficiency of the well. Depth of saturated overburden, which is generally greatest in valleys, also affects well yield. When drilled, many wells in Oley Township appear to be artesian as they penetrate discrete water-bearing zones and water rises above the level at which it was encountered. However, the wells obtain most of their water by dewatering part of the aquifer in the vicinity of the well. Thus, many of the aquifers are more nearly water table than artesian. However, a few flowing artesian wells are present in Oley Township.

Topography has a significant effect on well yield. The highest median specific capacities are obtained from wells in valleys, and the lowest are obtained from wells on hilltops. Valleys are probably formed in areas of intense fracturing that are able to transmit more ground water than hilltop and hillside areas, where fewer fractures generally are present.

Specific capacities of nondomestic wells are higher than specific capacities of domestic wells by almost an order of magnitude. Part of the difference is due to the fact that the nondomestic wells are, on the average, deeper and penetrate more water-bearing zones than the domestic wells. Also, a disproportionate share of the nondomestic wells are in valleys, and wells located in valleys generally have higher specific capacities than those in other topographic settings. A small part of the difference can be attributed to the slightly larger diameter of the nondomestic wells.

Ground-Water Yields by Drainage Basin

The baseflow of streams per unit area of land surface provides a good indication of the practical limits of ground-water development for a particular basin. Such quantities, as determined from the water-budget computations (table 12), were used to estimate the average ground-water yields during the the 1982 water year from local drainage basins (table 8). Total water use in the study area averages only a very small percentage of total ground-water yield. Therefore, local ground-water resources can be further developed. The figures in table 8 are based on interpretations of yields from relatively large areas; therefore, they do not consider areal differences caused by variations in the water-yielding properties of the component rock types or seasonal differences in yield.

A conservative estimate of ground-water yield for the township is 0.5 $(Mgal/d)/mi^2$ (million gallons per day per square mile) (table 8). Thus, about 12 Mgal/d could be pumped from wells on a sustained basis.

Table 8.--Ground-water yields by drainage basin, 1982 water year

Drainage basin	Ground-water yield, 1982 water year (cubic feet per second per square mile)	Ground-water yield, 1982 water year (million gallons per day per square mile)
Monocacy	0.84	0.54
Limekiln	.74	.48
Pine	.91	.59
Bieber	.90	.58
Oysterville	1.00	.65
Manatawny	.73	.47

Water Levels

Fluctuations

The principal changes in water levels are seasonal. Water levels generally start to decline in March or April and continue to decline until late fall. Even though precipitation is greater during the summer than during the winter, less precipitation reaches the water table during the summer and fall because large amounts of water are evaporated from the soil and transpired by vegetation. Rain and snowmelt recharge the aquifers during the winter and early spring, and water levels generally rise during this period. Natural annual fluctuations of water levels in wells generally range from 3 to 20 ft.

Figure 10 shows typical hydrographs for four observation wells in the Oley Valley for 1982. The four hydrographs are very similar, although those for wells BE-256 and BE-1297 have somewhat sharper peaks. Despite the general pattern of water-level declines starting in March or April, substantial amounts of recharge took place during June as a result of higher-than-normal precipitation.

Water-table Configuration

The water table in Oley Township is the upper surface of the ground-water reservoir in the aquifers. The shape of this surface depends primarily on aquifer hydraulic properties, recharge, and discharge.

The configuration of the water table during April 13-15, 1982 is shown on the contour map (plate 2). The map was prepared chiefly from measured or estimated water levels in wells and quarries. Water-table altitudes were computed by subtracting depths to water below land surface from altitudes estimated from 7 1/2-minute topographic maps. Topography was also used as a guide in preparing the map. In general, the contour interval is 50 feet in the noncarbonate areas and 20 feet in the areas underlain by carbonate rocks. The

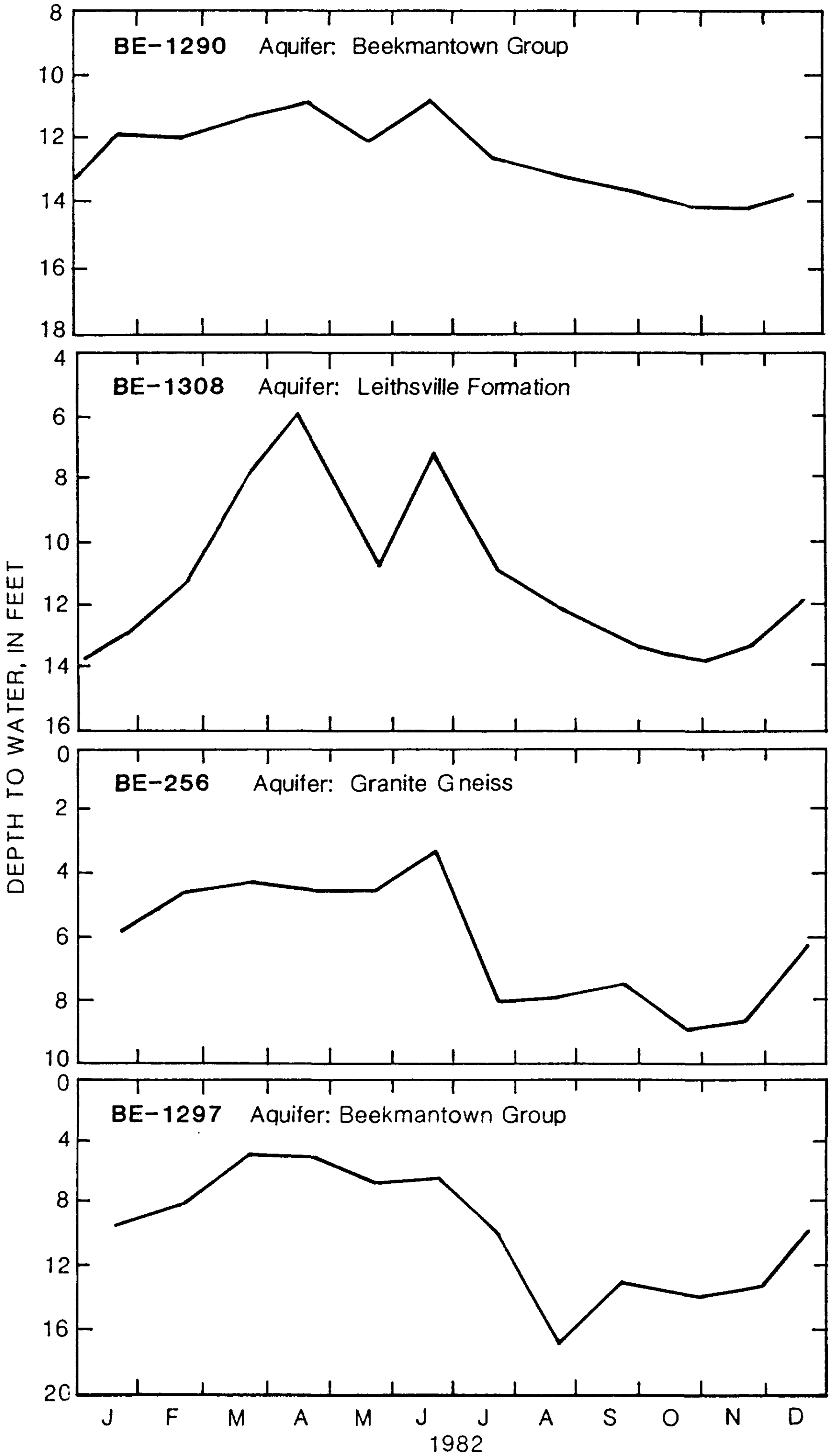


Figure 10.--Hydrographs for selected observation wells.

accuracy of the water-table contours is such that approximately 75 percent of all water levels can be expected to fall within one-half of the contour interval, except for those in areas of greater topographic relief in the western part of the township.

In unstressed noncarbonate aquifers, the water-table profile generally resembles the land-surface profile. Consequently, the altitude of the water table is highest on hilltops and ridges, and is lowest in valleys where it may intersect the land surface at streams, ponds, springs, and excavations. Precipitation infiltrates to the water table, moves downgradient from recharge areas along flow paths perpendicular to the water-table contour lines, and flows to points of discharge in the valleys. Water in these aquifers commonly travels less than a few thousand feet before it is discharged.

In unstressed carbonate aquifers, water may flow in directions contrary to those expected on the basis of topography. Water in these aquifers may travel several miles through solution features before it is discharged. Details of flow through the carbonate aquifers are more complex than could be ascertained from the limited water-level data and as represented by the water-table map. In fact, local flow may be in any direction. Ground-water levels seasonally may decline below stream levels, causing streamflow to leak downward into the ground-water reservoir. When ground-water levels rise above stream levels, the streams then receive ground-water discharge.

The prominent depressions on the water-table map are caused by ground-water withdrawals in the two active quarries. These quarries pump very limited quantities of water and have had relatively little effect on the hydrologic system, although substantial water-level declines have occurred in nearby wells, nearby springs have gone dry, and a small perennial stream has become intermittant. The effects are limited in areal extent because one of the quarries is entirely in the Jacksonburg Limestone, which has a low permeability, and the other is bounded on three sides by the Jacksonburg Limestone and Martinsburg Formation. Future expansion of the two active quarries is not apt to have large effects on water resources.

The water-table contour map (plate 2) may be used: (1) to determine the depth to water below land surface by subtracting the water-table altitude from the land-surface elevation; (2) to determine the direction of ground-water flow, as movement is from areas of high water-table elevation to areas of lower water-table elevation with the direction of flow approximately perpendicular to the water-table contour lines; (3) to ascertain the relative ability of the various aquifers to transmit water, as a wide contour-line spacing indicates a greater ability than a narrow spacing if recharge of all areas is uniform; (4) to estimate the velocity and quantity of ground-water flow; and (5) to delineate recharge and discharge areas.

Quality

The quality of ground water in Oley Township, as represented by limited sampling, is generally suitable for most uses. The water from most of the aquifers is the calcium bicarbonate type. In ground water--the chief source of potable supply--excessive hardness, locally elevated nitrate concentrations, and bacteria are the most significant water-quality problems.

Twenty-four samples of ground water were collected in August and September 1982. The ground-water samples were obtained from two shallow dug wells and 22 deeper drilled wells. Figure 11 shows the location of the sites sampled. The results of these and several previous chemical analyses are given in table 15 (page 58).

Field Analyses

Values of specific conductance, pH, temperature, and alkalinity measured in the field are summarized in table 9. The specific conductance of ground water from all aquifers in Oley Township measured in 1982 ranged from 255 to 1,750 µS/cm and had a median value of 465 µS/cm (table 9). Because of their relatively high solubility, the carbonate aquifers generally yield water with specific conductance significantly greater than water from other rock types. Table 9 shows that the median specific conductance of water from the carbonate aquifers is nearly twice as great as that from the other types of aquifers. High values of specific conductance may also be related to human activities that result in highly mineralized water reaching the ground-water reservoir, or locally deep faulting, which could allow more mineralized water to move upward from depth. Waters with relatively low specific conductance represent drainage from basins that consist chiefly of crystalline rocks, such as the Bieber Creek basin, whereas waters with high specific conductance indicate drainage from basins composed mainly of carbonate rocks, such as the Limekiln Creek basin.

Table 9.--Summary of field-determined characteristics of water quality
[Quantity in parenthesis is number of values used in statistical computations. µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; mg/L, milligrams per liter]

Statistical measure	Specific conductance µS/cm	pH (units)	Temperature °C	Alkalinity (mg/L as $CaCO_3$)
	All ground-water samples (24)			
Range	255-1,750	7.0-8.4	12.0-17.0	36-300
Median	465	7.4	13.0	190
	Samples from carbonate aquifers (19)			
Range	320-1,750	7.0-7.8	12.5-17.0	130-300
Median	540	7.4	13.0	190
	Samples (5) from noncarbonate sedimentary aquifers (4) and crystalline-rock aquifers (1)			
Range	255-520	7.2-8.4	12.0-17.0	36-230
Median	300	7.7	15.0	110

The pH of ground water from all aquifer types in Oley Township ranged from 7.0 to 8.4, and had a median value of 7.4. On the basis of limited sampling, water from the Martinsburg shale appears to be the most alkaline. The pH of ground water tended to be slightly lower than that of surface water. This difference results mainly from chemical changes that occur when ground water emerges from the subsurface and comes into direct contact with the atmosphere.

Ground-water temperatures ranged from 12.0°C to 17.0°C and had a median value of 13.0°C (table 9). As a practical matter, some homeowners use ground water as a medium for heating and cooling through the use of heat pumps. Unlike surface-water temperatures, which fluctuate daily and seasonally because of changes in local air temperature, ground-water temperatures fluctuate only a small amount annually.

The alkalinity of ground water in Oley Township ranged from 36 to 300 mg/L and had a median value of 190 mg/L (table 9). Water from the noncarbonate sedimentary and crystalline rocks has relatively low alkalinity, whereas water from the carbonate rocks has high alkalinity.

Laboratory Analyses

The hardness of water is largely a measure of the amount of calcium and magnesium in solution. Hard water reacts with soap, causing insoluble calcium and magnesium compounds to precipitate and diminish the formation of lather. Also, changes in temperature and pressure cause calcium and magnesium compounds to precipitate and form scale in pipes, hot water tanks, and other plumbing fixtures.

Hardness of ground water in Oley Township ranged from 110 to 1,152 mg/L and had a median value of 265 mg/L. Water from the carbonates commonly is hard because those rocks consist mostly of water-soluble calcium and magnesium carbonate. Water from the noncarbonate sedimentary rocks and the crystalline rocks typically is softer because those rocks contain much smaller amounts of calcium and magnesium minerals. However, other factors, such as residence time of the ground water, topography, land use, and human activities, may be as significant as geology in controlling hardness. Consequently, some areas of soft or hard water span several different geologic units. Ground-water movement across geologic contacts also may explain some of the lack of agreement between hardness and geologic contacts.

Figure 11 illustrates the general distribution of hardness. Most of the ground water in Oley Township has a hardness greater than 180 mg/L, and is very hard according to the classification proposed by Durfor and Becker (1964, p. 27).

A significant proportion of the water from aquifers that discharge into streams passes through only the shallow parts of the aquifers and is not in contact with soluble minerals as long as water in the deeper parts of the aquifers. Consequently, local stream water is commonly lower in dissolved solids and softer than ground water from deep wells.

Dissolved-solids concentrations in ground water from all aquifer types in Oley Township measured in 1982 are shown in figure 12. Concentrations ranged from 147 to 934 mg/L and had a median value of 269 mg/L (table 5). The dissolved-solids concentration in one sample from the carbonate Ontelaunee Formation exceeded the maximum contaminant level recommended by USEPA of 500 mg/L. Excessive amounts of calcium, magnesium, and sulfate are the principal cause of elevated dissolved-solids concentrations.

Iron concentrations in ground water in 1982 ranged from less than 3 μg/L (micrograms per liter) to 1,400 μg/L; concentrations in most of the samples were less than 30 μg/L. However, in one sample from the Ontelaunee Formation and another from the noncarbonate Hamburg sequence, iron concentrations exceeded the maximum contaminant level recommended by USEPA by 300 μg/L.

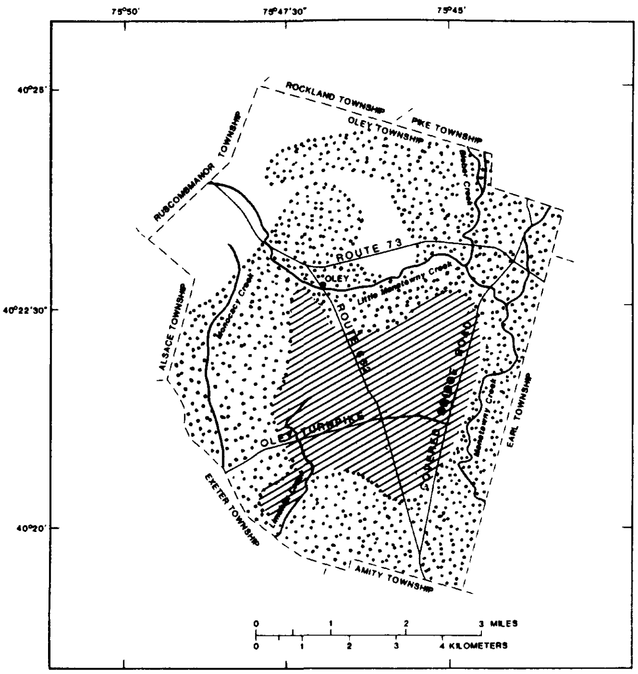
Sulfate concentrations, which ranged from 5.0 to 400 mg/L, had a median value of 36 mg/L. The sulfate concentration in one sample from the Ontelaunee Formation exceeded the maximum contaminant level recommended by USEPA of 250 mg/L.

Nitrate concentrations in ground water sampled in late August and early September 1982, a period of normal rainfall, are shown in figure 13. Concentrations ranged from less than 0.10 to 15 mg/L, and nitrate concentrations in water from three wells in carbonate rocks exceeded the USEPA maximum contaminant level of 10 mg/L (as nitrogen). Two of those wells are less than 100 ft deep; the depth of the third well is unknown. Nitrogen concentrations after rainfalls can be expected to increase several fold as contaminants wash off of impervious surfaces. Particularly in carbonate-rock areas, infiltration and overland runoff carrying nitrate from various sources may enter aquifers directly through solution cavities, sinkholes, and fractures. Nitrate at concentrations greater than 10 mg/L in drinking water may be toxic to children under 3 months of age by causing methemoglobinemia--a reduction of oxygen supply in the blood (USEPA, 1985a).

Fertilizers, barnyard wastes, and wastewater from on-site disposal systems are the chief sources of nitrate in ground water. Another likely source, although localized, is leakage of wastewater from sewers (exfiltration). Increased activity involving these principal sources will undoubtedly increase nitrate loads in ground water unless appropriate protective measures are adopted. Where practicable, such measures could include siting fertilized and livestock-raising areas as closely as possible to places of natural ground-water discharge, and implementing land-use practices that minimize infiltration.

Contamination of ground water by bacteria is a relatively common problem in Oley Township. Major sources of bacteria include barnyard wastes and wastewater from on-site disposal systems. When recharge water migrates through soil and rocks toward the ground-water reservoir, the bacteria it contains generally are filtered out. In parts of Oley Township, however, the unsaturated soil mantle is thin or even absent over solution cavities, sinkholes, and fractures. In such localities, bacteria-laden recharge water may flow directly to the water table with little reduction in the number of bacteria.

The standard test for biological quality is the determination of fecal coliform bacteria. In this study, fecal streptococci bacteria also were determined. These and similar bacteria originate in the gastrointestinal tracts of humans and animals; hence, they indicate unsanitary conditions when



EXPLANATION

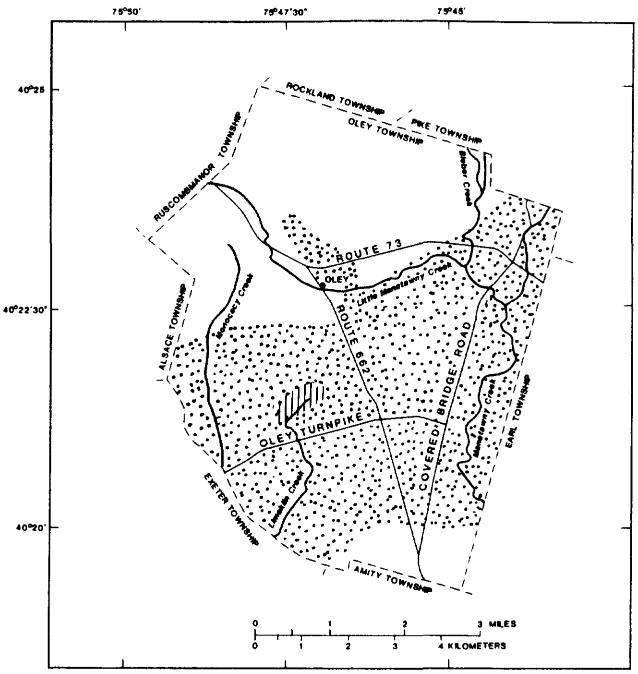
HARDNESS, IN MILLIGRAMS PER LITER

0-150

150-300

Greater than 300

Figure 11.--Hardness of ground water, 1982.



EXPLANATION

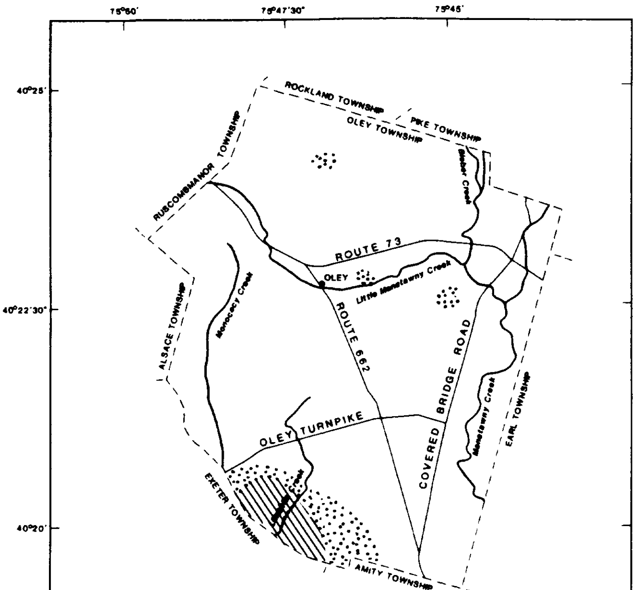
DISSOLVED SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER

0-250

250-500

Greater than 500

Figure 12.--Dissolved-solids concentration in ground water, 1982.



EXPLANATION

NITRATE CONCENTRATION, IN MILLIGRAMS PER LITER

0-5

5-10

Greater than 10

Figure 13.--Nitrate concentration in ground water, 1982.

present in a water supply. Fecal streptococci bacteria are pathogenic or disease-producing organisms. Fecal coliform bacteria are not pathogenic, but their presence suggests the possible presence of other microbiological species that are pathogenic. Therefore, complete absence of fecal coliform and fecal streptococci bacteria in potable water is highly desirable.

High-density housing with onlot waste water treatment in areas underlain by the more permeable carbonate rocks probably will produce serious ground-water problems--notably elevated nitrate concentrations and bacteria counts. Use of community sewage systems with a high degree of treatment will prevent most ground-water contamination.

Counts of fecal coliform bacteria in 24 ground-water samples measured in 1982 ranged from zero to more than 400 colonies per 100 milliters of sample; counts of fecal streptococci bacteria ranged from zero to 335 colonies per 100 milliliters (table 15) (page 58). Fecal coliform/fecal streptococci ratios suggest that most bacterial contamination of ground water in Oley Township originates from poultry and livestock wastes. However, the use of such ratios as indicators of contaminant source is limited, because the survival rate of fecal coliform bacteria in a preserved water sample is significantly less than that of fecal streptococci bacteria (Geldreich and others, 1968). Accordingly, the concentrations of fecal coliform and fecal streptococci bacteria presented in table 15 are minimum values. Fecal coliforms were detected only in samples from two shallow dug wells, whereas fecal streptococci bacteria were present in water from the two dug wells and from 10 deeper, drilled and cased wells (table 15). Bacteria counts in these, and undoubtedly many other wells that tap aquifers prone to contamination, can be expected to increase after rainy periods because of resultant percolation and infiltration. Wells that tap carbonate rocks are particularly susceptible, because bacteria-laden recharge water may enter these aquifers relatively unimpeded.

Selected Water-quality Problems and Common Remedies

When chemical constituents or bacteria are present in excess of recommended limits, it may be necessary to reduce or control concentrations so that water quality becomes acceptable. Table 10 lists the causes, sources, and significance of selected characteristics of and constituents in water. Table 11 presents selected methods for treating chemical constituents and bacteria that may be troublesome in the water of Oley Township.

Table 10.--Characteristics and constituents that affect water quality
[Modified from Heath (1983)]

Characteristic or constituent	Principal cause or source	Significance
Specific conductance	Substances that form ions when dissolved in water.	Most substances in water dissociate into ions that can conduct an electrical current. Consequently, specific conductance is a valuable indicator of the amount of material dissolved in water. The greater the conductivity, the more mineralized the water.
pH	Dissociation of water molecules and of acids and bases dissolved in water.	The pH of water is a measure of its reactive characteristics. Low values of pH, particularly below pH 4, indicate a corrosive water that will tend to dissolve metals and other substances that it contacts. High values, particularly above pH 8.5, represent an alkaline water that on heating will tend to form scale. The pH significantly affects the treatment and use of water.
Hardness	Calcium and magnesium dissolved in water.	Calcium and magnesium combine with soap to form an insoluble precipitate and thus hamper the formation of lather. Hardness also affects the suitability of water for use in steam boilers and water heaters.
Alkalinity	Carbonate and bicarbonate ions produced by the solution of carbonate rocks, mainly limestone and dolomite, by water containing carbon dioxide.	Controls the capacity of water to neutralize acids. Bicarbonates of calcium and magnesium decompose in steam boilers and water heaters to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, causes carbonate hardness.
Dissolved solids	Mineral substances dissolved in water.	Dissolved solids is a measure of the total amount of minerals dissolved in water and is therefore a very useful characteristic in the evaluation of water quality. Water containing less than 500 milligrams per liter is preferred for domestic use and for many industrial processes.
Iron (Fe) and Manganese (Mn)	Iron present in most soils and rocks; manganese less widely distributed.	Both are objectionable in food processing, dyeing, bleaching, ice manufacturing, brewing, and certain other industrial process. Cause staining of plumbing fixtures and laundry. USEPA regulations (1985b) recommend a maximum iron concentration of 300 micrograms per liter and a maximum manganese concentration of 50 micrograms per liter in drinking water supplies.
Sulfate (SO_4)	Dissolved from soils and rocks containing gypsum, pyrite, sulfides, and other sulfur compounds. Also contained in some industrial wastes.	In high concentrations, imparts a bitter taste to water and, at very high concentrations, has a laxative effect. When combined with calcium, forms a hard scale in steam boilers. USEPA regulations (1985b) recommended a maximum sulfate concentration of 250 milligrams per liter in drinking water supplies.

Table 10.--Characteristics and constituents that affect water quality--Continued
[Modified from Heath (1983)]

Characteristic or constituent	Principal cause or source	Significance
Nitrate (NO_3)	Present in fertilizers, sewage, soils, and in decaying organic matter.	Because nitrate is a nutrient, it enables growth of algae and other organisms which may produce undesirable tastes and odors. USEPA regulations (1985a) recommend a maximum nitrate concentration of 10 milligrams per liter (as nitrogen) in drinking water supplies, because concentrations in excess of that limit may cause methemoglobinemia in infants.
Fecal coliform and fecal streptococci bacteria	Originate in gastrointestinal tract of humans and animals.	Indicates contamination by human and/or animal wastes. Standard bacteriological tests for these indicator organisms are used to determine the biological suitability of a water for drinking purposes. Generally, when the ratio of concentration of fecal coliform bacteria to fecal streptococci bacteria is greater than two, contamination by human wastes is indicated; when the ratio is less than one, contamination by livestock or poultry wastes is likely. Fecal streptococci bacteria are themselves capable of causing disease.
Calcium (Ca) and Magnesium (Mg)	Soils and rocks containing limestone, dolomite, and gypsum.	These cations are the principal cause of hardness and of boiler scale and deposits in hot-water heaters. Small amounts of these constituents help to prevent corrosion of metals and other substances by otherwise aggressive waters. High concentrations of magnesium may have a laxative effect, particularly on new users of the water.
Sodium (Na) and Potassium (K)	Soils, rocks, some industrial wastes, and sewage.	More than 50 milligrams per liter sodium and potassium in the presence of suspended matter causes foaming, which accelerates scale formation and corrosion in boilers. In large concentrations, sodium may adversely affect persons with cardiac difficulties, hypertension, and certain other medical conditions. Depending on the concentrations of calcium and magnesium also present in the water, excessive sodium may be detrimental to certain irrigated crops.
Chloride (Cl)	Soils, rocks, some industrial wastes, and sewage.	In large amounts, increases corrosiveness of water. Concentrations in excess of 100 milligrams per liter impart a salty taste. USEPA regulations (1985b) recommend a maximum chloride concentration of 250 milligrams per liter in drinking water supplies.
Fluoride (F)	Small amounts dissolved from many soils and rocks. Added to many waters by fluoridation of public supplies.	Low concentrations of fluoride have beneficial effects on the structure and resistance to decay of children's teeth. Fluoride concentrations in excess of 6.0 milligrams per liter cause pronounced mottling of tooth enamel and disfiguration of teeth.
Silica (SiO_2)	Practically all soils and rocks.	In the presence of calcium and magnesium, silica forms a heat-conducting, hard glassy scale in boilers. Silica inhibits deterioration of zeolite-type water softeners and corrosion of iron pipes by soft water.

Table 11.--Selected methods of removing or reducing concentrations of chemical and bacteriological constituents from water

Problem constituent	Symptoms	Treatment processes
Hardness, Calcium (Ca) and Magnesium (Mg)	Forms scale in cooking utensils, pipes and plumbing fixtures; consumes soap.	1. Lime-soda treatment--chemical reactions convert most Ca and Mg to insoluble calcium carbonate and magnesium hydroxide. The resulting precipitate can then be removed by sedimentation and filtration. 2. Ion exchange--zeolite minerals of synthetic resin beads exchange sodium (Na) ions in their structure for Ca and Mg ions in the water. When their exchange capacity has been exhausted, they are regenerated by backflushing with a strong sodium chloride solution. The resin beads have a greater exchange capacity than the zeolite minerals.
Iron (Fe)	Forms reddish-brown stains on plumbing fixtures and laundry. May impart objectionable taste to food and beverages. A slimy deposit indicates the presence of iron bacteria.	1. Oxidation and filtration--aeration of water or treatment with chloride or potassium permanganate convert most Fe and Mn to insoluble precipitates which can then be removed by sedimentation and filtration. Aeration is commonly used when the water contains little organic matter; the chemical agents are used when large amounts of organic material are present, as in ground water containing iron bacteria or in surface water. The pH of water to be treated should be alkaline before Fe or Mn removal is attempted.
Manganese (Mn)	Same objectionable symptoms as iron, but generally forms brown or black stains. Removal is more difficult and commonly less complete than iron.	2. Oxidation and filtration through manganese green sand--the green sand liberates oxygen, which in contact with the water produces insoluble iron hydroxide and manganese oxide. When the available oxygen supply has been exhausted, the green sand is regenerated by backflushing a potassium permanganate solution through it. 3. Ion exchange (see above)
Pathogenic bacteria including fecal streptococci	Usually no symptoms displayed by water, although high bacteria counts may cause unusual odor or color.	1. Heating--Pasteurization by heating water to 161°F for 15 seconds or boiling kills most bacteria and viruses and does not impart objectionable odor or taste to water. 2. Chemical--Chlorine may be introduced into the water system at a concentration sufficient to kill bacteria after a contact time of approximately 30 minutes; other reagents that may be used are iodine and potassium permanganate. Chemical disinfection may impart objectionable odors or tastes to the water, but if desired, they can be removed by subsequently filtering the water through activated charcoal. 3. Ultraviolet light--Pass the water to within 1 to 5 inches of a quartz-mercury vapor lamp, which emits ultraviolet light. Depending on light intensity, the time of exposure required for complete disinfection may be as little as one second. This process does not impart objectionable odor or taste to water.

WATER BUDGETS

The hydrologic cycle is the continuous circulation of water in the atmosphere, in the soil and underlying rocks, and on the land surface, by the processes of condensation, precipitation, evapotranspiration, infiltration, and runoff. The movement of water through these components of the cycle is variable in both time and space, and is accompanied by changes in water quality. A sketch representing the hydrologic cycle under natural conditions is shown in figure 14. Several flowpaths result from human activities--particularly, pumping of water from wells, quarry dewatering, and regional treatment and disposal of wastewater.

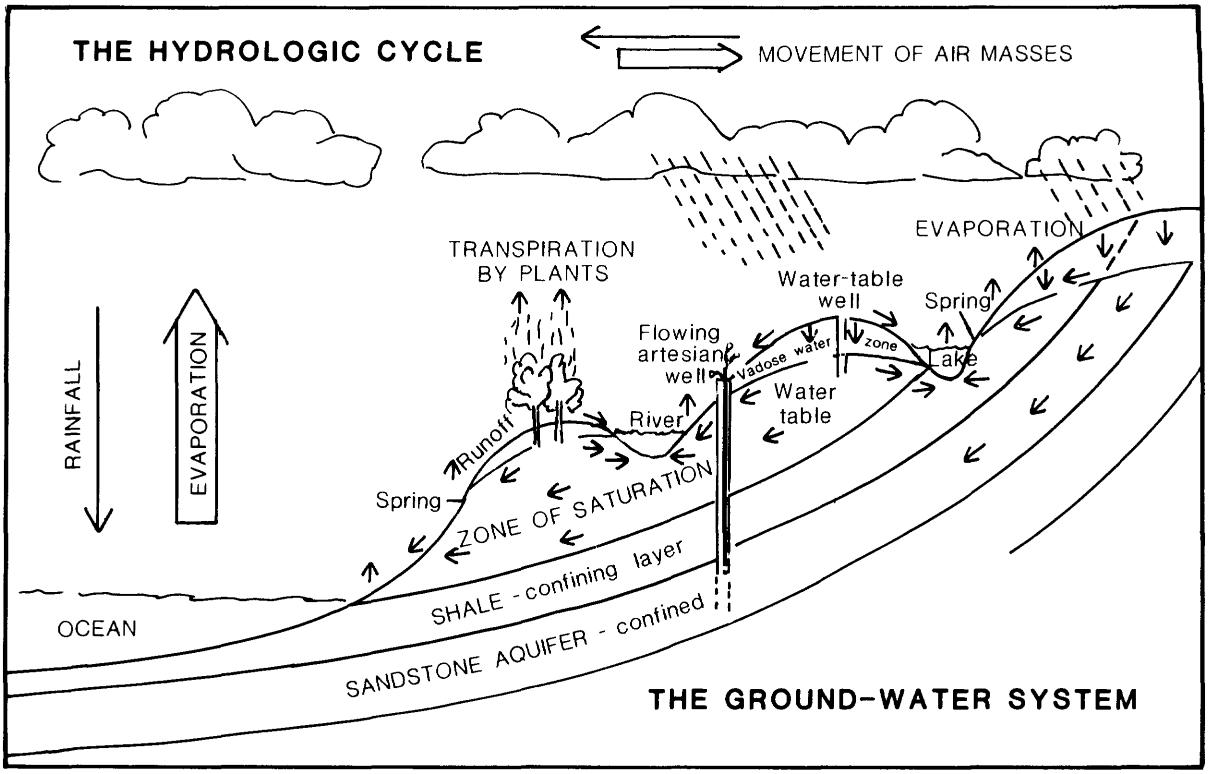


Figure 14.--The hydrologic cycle (after Newport, 1971).

Water enters the local hydrologic system as precipitation and leaves as surface runoff, ground-water flow and water vapor to the atmosphere (evapotranspiration). Part of the water entering the system moves out of the area relatively quickly by surface runoff, but that which remains for longer periods either evapotranspires or percolates underground and eventually discharges to streams of the Monocacy, Limekiln and Manatawny Creek basins.

Ground water is an important component of the local hydrologic system, as more than one-fourth of the precipitation infiltrates the land surface and moves slowly downgradient from areas of recharge. Eventually, ground water discharges to streams through many small seeps and springs. The average annual recharge, which can be considered to be the same as baseflow, is a rough estimate of the maximum amount of ground water available for consumptive use.

Ground-water use in excess of recharge will result in the progressive lowering of ground-water levels.

The components of the hydrologic cycle can be expressed quantitatively in the form of a water budget. Simply stated, a water budget is an accounting of all water entering and leaving a given area in a particular interval of time. It balances water entering the area as precipitation with water that leaves as streamflow and evapotranspiration, taking into account any changes in the volume of water in storage. A general equation representing this balance is:

$$\text{Water In} = \text{Water Out} \pm \text{Change in Storage}$$

Specifically, for this study:

$$P = Rs + Rg + ET + \Delta S + Ug, \qquad (1)$$

where:

P = precipitation,
Rs + Rg = total streamflow,
Rs = surface runoff,
Rg = ground-water discharge (baseflow)
ET = water lost by evapotranspiration,
ΔS = change in ground-water storage, and
Ug = ground-water flow across the area boundary (underflow).

Table 12 presents generalized annual water budgets for the 1982 water year for the six principal drainage basins in the study area. The records of the five nonrecording gages in Oley Township (fig. 3) provided estimates of local precipitation. During the 1982 water year, a period of approximately average rainfall according to records for nearby Reading, precipitation was distributed fairly evenly over the study area. Variation in amounts from station to station are chiefly the result of localized intense thundershowers of the later summer months.

Table 12.--Water budgets for principal drainage basins, 1982 water year

Drainage basin	Precipitation (P) (inches)	=	Surface runoff (Rs) (inches)	+	Ground-water discharge (Rg), (inches)	+	Evapotranspiration (ET) and underflow (Ug) (inches)
Monocacy	42.98a/	=	7.45	+	11.43	+	24.10
Limekiln	43.83b/	=	1.42	+	10.07	+	32.34
Pine	45.49c/	=	5.47	+	12.46	+	27.56
Bieber	45.49c/	=	9.53	+	12.13	+	23.83
Oysterville	45.37d/	=	5.60	+	13.70	+	26.07
Manatawny	42.44e/	=	6.47	+	9.96	+	26.01

Note: Precipitation measured at following gage sites:

a/Oley
b/Limekiln
c/Oley Furnace
d/Pleasantville
e/Yellow House

During the course of this study, ground-water levels changed little from one year to the next; consequently, in the water-budget computations, annual changes in ground-water storage are considered to be zero. For similar reasons, changes in surface-water storage are assumed to be negligible.

Streamflow in the six principal drainage basins was determined from records of the U.S. Geological Survey for the non-recording gages established for this investigation (fig. 4). The ground-water runoff or base-flow component of streamflow was computed for each station by a computer program modified from Pettyjohn and Henning (1979).

Table 13 presents summary information on ground-water runoff for the 1982 water year. The ground-water contribution to total discharge ranged from 56 percent in the Bieber Creek basin to 88 percent in the Limekiln Creek basin. Differences in the percentage that ground water contributes to total flow reflect primarily the effect of geology on hydrologic characteristics of the basins, although topography and land use may also be significant factors. The Bieber Creek basin is composed chiefly of noncarbonate sedimentary and crystalline rocks, whereas the Limekiln Creek basin is underlain predominantly by carbonate rocks (table 2). The other drainage basins consist of a mixture of these rock types (table 2).

Table 13.--Summary information on ground-water runoff

Discharge basin	Total discharge (inches)	Ground-water runoff (inches)	Percent of total discharge as ground-water runoff
Monocacy	18.88	11.43	60
Limekiln	11.49	10.07	88
Pine	17.93	12.46	70
Bieber	21.66	12.13	56
Oysterville	19.30	13.70	71
Manatawny	16.43	9.96	61

RELATION OF GROUND-WATER WITHDRAWALS TO STREAMFLOW

A series of four discharge measurements were made on 4.7-mi reach of Manatawny Creek from just below the confluence with Furnace Creek to the gage at Earlville (01471900) on January 14, 1983, during high baseflow. These measurements show approximately 15 ft^3/s (cubic feet per second) of water entering the stream--2 ft^3/s of tributary inflow, 1 ft^3/s of quarry discharge, and 12 ft^3/s of direct ground-water inflow. Most of the ground-water inflow appears to be in reaches where the stream flows over the Leithsville Formation. This illustrates that the stream is well connected to the more permeable carbonate aquifers. Because of this interconnection, nearly all ground-water pumpage has some adverse effect on streamflow. This effect will be small where water is returned to the ground near where it is pumped--for example, by seepage from drain fields of septic tanks. The effect will be large where water is exported from the basin in which it was pumped by sewer or water lines.

Although a ground-water yield for Oley Township of 12 Mgal/d (million gallons per day) was calculated from data given in table 8, pumping this amount would have major adverse effects on streamflow. Twelve million gallons per day (18.6 ft^3/s) is more than the flow of Manatawny Creek at Earlville (at the southern boundary of the township) for each of 41 days in the 1982 water year. If wells pumping 12 Mgal/d were located near Manatawny Creek, the stream would have gone dry on many of these 41 days. Placement of wells away from perennial streams would mitigate adverse effects, but would not eliminate them.

Therefore, although local ground-water resources can be developed further, the return of treated wastewater near or upstream from points of withdrawal may be a desirable course of action. Also, the effects of such development should be monitored to detect adverse effects on water levels and streamflow.

SUMMARY AND CONCLUSIONS

(1) Nearly all of the water in Oley Township comes from precipitation that falls within the 24-square mile township or from small streams--chiefly tributaries to Manatawny Creek--that flow into the township from adjacent areas.

(2) About half of the township, generally the southern and eastern parts, is underlain by highly permeable carbonate rocks, the most important of which are the Allentown Dolomite, Conococheague Group, Leithsville Formation, and part of the Beekmantown Group. Nondomestic wells in these units have median yields that range from 105 to 200 gal/min; some wells yield more than 1,000 gal/min. Large public supply wells can be developed in these units.

(3) Ground-water yield for the township is about 0.5 $(Mgal/d)/mi^2$. Thus, about 12 Mgal/d could be pumped from wells on a sustained basis. However, all pumping has some effect on streamflow and pumping this amount would substantially reduce streamflow. A series of discharge measurements made on Manatawny Creek on January 14, 1983, showed that the creek was gaining approximately 12 ft^3/s where it flowed over the Leithsville Formation. Thus, the stream is directly connected to the aquifers. The flow of 12 Mgal/d (18.6 ft^3/s) was less than Manatawny Creek at Earlville (at the southern boundary of the township) for 41 days in the 1982 water year. If wells pumping 12 Mgal/d were located near Manatawny Creek, the stream would have gone dry on many of these 41 days. Placing wells away from perennial streams would mitigate adverse effects, but would not eliminate them.

(4) Those parts of the township underlain by diabase, Martinsburg Formation, Jacksonburg Formation, hornblende gneiss, and perhaps the Hamburg sequence and the area mapped as Beekmantown Group east of Oley Furnace, are areas underlain by rocks of low permeability. Some wells in these areas will fail to yield sufficient quantities of water for small domestic supplies. These areas are not suited for extensive development of individual wells.

(5) Despite the drying up of some nearby springs and the substantial drawdowns in nearby wells, the two active quarries in Oley Township have had minor effects on streamflow and ground-water resources. The effects are limited in areal extent because one of the quarries is entirely in the Jacksonburg Limestone, which has a low permeability, and the other is bounded on three sides by the Jacksonburg Limestone and Martinsburg Formation. Future expansion of the two active quarries is not likely to produce large effects on the water resources.

(6) Water from the carbonate rocks is usually very hard. However, the most serious water-quality problems in the township are excessive nitrate concentrations and bacterial contamination. Three of 19 wells in carbonate rocks had nitrate concentrations in excess of the USEPA maximum contaminant level of 10 mg/L. Five of the 19 wells had fecal streptococci bacteria counts of more than 20 colonies per 100 milliliters. Fecal coliform/fecal streptococci ratios suggest that most of the contamination originates from poultry and livestock wastes. However, septic tanks may contribute to the problem. In any case, carbonate rocks are particularly susceptible to contamination, because bacteria-laden recharge water may enter these aquifers relatively unimpeded. High-density housing with on-lot wastewater treatment in areas underlain by the more permeable carbonate rocks has the potential for producing serious ground-water quality problems. Problems may be kept to a minimum where community sewage systems that provide a high degree of treatment are used.

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GLOSSARY

<u>Alkalinity</u>.--The capacity of a water for neutralizing an acid solution. Alkalinity in natural water is caused primarily by the presence of carbonates and bicarbonates.

<u>Allochthonous rocks</u>.--Rocks that have been moved a long distance from their original place of deposition by some tectonic process, generally related to overthrusting or recumbent folding, or perhaps gravity sliding.

<u>Aquifer</u>.--A formation, group of formations, or part of a formation from which water is collectable in usable quantities.

<u>Artesian aquifer</u>.--An aquifer in which ground water is confined under pressure greater than atmospheric by overlying, relatively impermeable strata. In a well penetrating such an aquifer, the water level will rise above the bottom of the confining bed.

<u>Base runoff</u>.--Sustained or fair-weather runoff. In most streams, base runoff is composed largely of ground-water discharge.

<u>Carbonate rock</u>.--A rock consisting of limestone and (or) dolomite.

<u>Discharge</u>.--The volume of water that passes a given point within a given period of time. The terms discharge, streamflow, and runoff represent water with the solids dissolved in and the sediment mixed with it.

<u>Drainage basin</u>.--A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

<u>Evapotranspiration</u>.--Evaporation of water from land and water surfaces plus the water transpired by vegetation.

<u>Fanglomerate</u>.--A rock composed of heterogeneous materials which were originally deposited in an alluvial fan but which since deposition have been cemented into solid rock.

<u>Flow-duration curve</u>.--A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

<u>Gage height</u>.--The water-surface elevation referred to some arbitrary gage datum.

<u>Gaging station</u>.--A particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are obtained.

<u>Hardness</u>.--A property of water which causes an increase in the amount of soap that is needed to produce foam or lather. Hardness is produced almost completely by the presence of calcium and magnesium salts in solution. Carbonate hardness is represented by the carbonate and bicarbonate salts of calcium and magnesium. Noncarbonate hardness is represented by all other

salts of calcium and magnesium. Hardness is expressed conventionally in terms of an equivalent quantity of calcium carbonate. The following scale may assist the reader in appraising hardness:

Degrees of hardness	Hardness range (mg/L)
Soft............................	0-60
Moderately hard.................	61-120
Hard............................	121-180
Very hard.......................	above 180

Hydrograph.--A graph showing stage, flow, velocity, or other property of water with respect to time.

Permeability.--A measure of the ability of a material to transmit water. Generally expressed as the flow of water in gallons per day through a cross-sectional area of one square foot under a hydraulic gradient of one foot at a temperature of 60°F.

pH.--Is a measure of the acidity or alkalinity of water. A pH of 7.0 indicates a neutral condition. An acid solution has a pH less than 7.0, and a basic or alkaline solution has a pH more than 7.0.

Runoff.--The part of the precipitation that appears in surface streams.

Specific capacity.--The yield of a well divided by the drawdown (pumping water level minus static water level) necessary to produce this yield. Usually expressed as gallons per minute per foot.

Specific conductance.--A measure of the ability of a water to conduct an electrical current. It is expressed in microsiemens per centimeter at 25°C. Pure water has a very small electrical conductance, but the conductance increases with increasing concentration of dissolved minerals.

Specific yield.--The volume of water free to drain from the rocks, expressed as a percentage of the total volume of the aquifer.

Storage coefficient.--The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Water-table aquifer.--A water table or unconfined aquifer is one in which the water table is the upper surface of the zone of saturation.

Water year.--The 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus the year that ended September 30, 1982 is called the "1982 water year."

TABLE 14.--RECORDS OF SELECTED WELLS IN OLEY TOWNSHIP AND VICINITY

EXPLANATION OF CODES: GEOLOGIC UNIT CODES ARE PRESENTED IN TABLE 1.
USE OF WATER: C, COMMERCIAL; H, DOMESTIC; I, IRRIGATION;
N, INDUSTRIAL; P, PUBLIC SUPPLY; S, STOCK; U, UNUSED
DATES: UNKNOWN MONTHS OR DAYS ARE SHOWN AS 00

LOCAL NUMBER	SITE-ID	OWNER	DRILLER	DATE COMPLETED	GEOLOGIC UNIT
BE- 229	402305075462701	OLEY TWP MUN AUTH.	--	07/13/57	364BKMN
230	402406075475601	OLEY TWP MUN AUTH.	C.S. GARBER AND SONS	04/00/62	377HRDS
256	402317075480401	SCHAEFFER, RONALD M.	KOHL BROS., INC.	06/17/57	000GRGS
257	402022075473801	ROHN, WILLIAM J.	KOHL BROS., INC.	02/03/64	364JKBG
453	402405075475502	OLEY WATER CO.	C.S. GARBER AND SONS	01/00/62	377HRDS
1288	402436075471701	SCHLEGEL, R.C.	KERMIT S. SNYDER	09/09/77	000GRGS
1289	402324075451501	GREBE	C.S. GARBER AND SONS	05/00/78	364BKMN
1290	402332075450601	OLEY VALLEY YOUTH LEAGUE	PHARES W. FRY	06/29/78	364BKMN
1292	402248075483301	HOFFMAN, EARL	C.S. GARBER AND SONS	09/00/80	000GRGS
1293	402247075483401	HOFFMAN, EARL	C.S. GARBER AND SONS	09/00/80	000GRGS
1295	402403075465101	TURNER, G.	C.S. GARBER AND SONS	11/00/80	361MRBG
1296	402325075472001	SEIDEL, WAYNE	PHARES W. FRY	05/22/81	364HMBG6
1297	402334075463601	GEISSENHAINER, R.	C.S. GARBER AND SONS	06/00/81	364BKMN
1298	402237075445501	KURTZ, L.	C.S. GARBER AND SONS	10/00/81	371ALNN
1299	402433075471901	BARTO, FORREST W.	C.S. GARBER AND SONS	08/05/77	000GRGS
1300	402350075462201	READINGER, JAMES	C.S. GARBER AND SONS	07/23/75	361MRBG
1301	402351075462801	RIBBLE, HOWARD E.	ELMER C. LENHART	04/09/68	361MRBG
1303	402300075433001	WALTERS, R.	C.S. GARBER AND SONS	10/00/78	374LSVL
1306	402302075440201	ANGSTADT, RUSSEL F.	C.S. GARBER AND SONS	02/22/77	371ALNN
1307	402303075440001	LABE, PAUL	DOUGLAS K. REIGNER	09/28/68	371ALNN
1308	402432075440201	LORAH, NED	ELMER C. LENHART	08/02/71	374LSVL
1309	402125075443301	MISIASZEK, M.	PETERSHEIM BROS.	10/19/78	371ALNN
1311	402117075442101	KULP, PERCIVAL	C.S. GARBER AND SONS	10/00/81	371ALNN
1312	402053075444201	WEIDNER, LESTER	C.S. GARBER AND SONS	02/21/77	371ALNN
1313	402051075483401	HOWARD, A.	C.S. GARBER AND SONS	03/00/78	364ONLN
1314	402052075483401	HOWARD, A.	KOHL BROS., INC.	00/00/54	364ONLN
1315	402014075480201	PENKUNAS, J.	PHARES W. FRY	06/05/78	367EPLR
1316	402020075480401	ABRAHAM, BRUCE	PETERSHEIM BROS.	10/00/78	367EPLR
1317	401950075455501	KARPINSKI, P.	C.S. GARBER AND SONS	04/00/79	361MRBG
1318	402008075475801	FLECK, PHILIP	PETERSHEIM BROS.	08/00/79	367EPLR
1319	401944075452601	LICHTENSTEIN, E.	C.S. GARBER AND SONS	09/00/79	371RCLD
1320	402109075471901	RENNINGER, H.	C.S. GARBER AND SONS	08/00/80	364ONLN
1321	402204075482701	HOFFMAN, BARRY	JACK HATMAKER	10/00/80	364JKBG
1322	402214075482201	DE TURK, M.	JACK HATMAKER	11/00/80	361MRBG
1323	402214075482202	DE TURK, M.	JACK HATMAKER	01/00/81	361MRBG
1325	402043075454901	SCHLEGEL, DANIEL	C.S. GARBER AND SONS	12/00/80	371RCLD
1326	402226075481901	HEFFNER, CARL	C.S. GARBER AND SONS	01/00/81	364JKBG
1327	402122075485601	SNYDER, J.	C.S. GARBER AND SONS	01/00/81	364ONLN
1328	402010075475901	WEIDENHAMMER, STEPHEN	PHARES W. FRY	10/20/77	367EPLR
1329	402113075474601	EASTERN INDUSTRIES INC.	EDWARD M. ARNOLD SR	08/01/73	364ONLN
1330	402255075434301	REIFSNYDER	C.S. GARBER AND SONS	07/00/81	374LSVL
1331	402152075450301	MAST, N.	C.S. GARBER AND SONS	06/00/79	371ALNN
1332	402152075445901	MAST, N.	--	--	371ALNN
1333	402216075454701	CUSTER, G.	C.S. GARBER AND SONS	06/00/79	364BKMN
1334	402216075454401	BERTOLET, G.	C.S. GARBER AND SONS	06/00/79	364BKMN

DEPTH OF WELL (FEET)	DEPTH CASED (FEET)	CASING DIAM- ETER (INCHES)	DEPTH TO FIRST OPENING (FEET)	ALTITUDE OF LAND SURFACE (FEET NGVD)	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GAL/MIN/FT)	USE OF WATER	LOCAL NUMBER
220	--	6	--	350	--	--	60	--	P	BE- 229
120	92	6	--	485	47	04/00/62	120	2.8	P	230
500	37	8	46	530	7.92	12/15/81	--	.14	H	256
--	32	6	57	300	2	02/03/64	20	.06	H	257
220	--	6	--	485	--	--	1.5	.01	U	453
242	41	6	86	590	40	09/09/77	5	.03	H	1288
340	41	6	150	350	30.68	12/15/81	.50	.00	H	1289
300	72	6	140	355	14.45	12/15/81	2	.01	C	1290
420	44	6	60	440	7.08	12/15/81	2	.00	U	1292
380	44	6	95	440	8	09/00/80	10	.03	S	1293
440	30	6	180	460	37.05	12/31/81	30	.08	H	1295
350	42	6	180	430	24.75	12/15/81	4	.01	H	1296
249	41	6	203	410	65	06/00/81	20	.11	H	1297
62	41	6	43	330	23.28	12/13/81	60	1.5	H	1298
140	27	6	85	580	60.72	12/14/81	12	.16	H	1299
440	23	6	220	465	125	07/23/75	.25	.00	H	1300
305	38	6	15	455	35	04/09/68	2	.01	H	1301
122	66	6	90	340	20	12/17/81	100	1	H	1303
260	61	6	69	330	69	02/22/77	5	.03	H	1306
300	22	6	26	330	--	--	8	--	C	1307
92	36	6	16	375	13.86	12/17/81	22	.63	H	1308
165	66	6	85	300	60	10/19/78	20	.80	H	1309
298	42	6	70	300	52	10/00/81	12	.05	H	1311
180	54	6	60	280	8	02/21/77	20	.12	H	1312
528	180	6	300	320	100	03/00/78	.75	.00	H	1313
160	15	6	--	310	52.48	12/24/81	50	--	U	1314
150	20	6	65	325	55	06/05/78	10	.10	H	1315
344	40	6	342	310	40	10/00/78	200	.66	H	1316
249	42	6	56	390	22.01	12/31/81	6	.03	H	1317
140	68	6	120	325	50	08/00/79	50	--	H	1318
298	40	6	71	305	115	09/00/79	6	.03	H	1319
200	43	6	107	345	102.47	12/31/81	10	.09	H	1320
120	21	6	10	360	2.02	12/31/81	10	.34	H	1321
304	16	6	60	440	65	11/00/80	10	.04	I	1322
300	14	6	60	440	28	01/00/81	10	.04	I	1323
268	40	6	95	360	65.43	12/31/81	--	--	H	1325
438	37	6	230	375	30	01/00/81	--	--	H	1326
378	50	6	70	370	1.78	12/29/81	300	.86	H	1327
350	100	6	220	325	60	10/20/77	1	.00	H	1328
500	21	6	216	375	--	--	10	--	N	1329
98	84	6	88	330	11	07/00/81	100	1.2	H	1330
120	99	5	108	320	35	06/00/79	50	.56	H,S	1331
59	--	6	--	300	25.60	12/23/81	--	--	U	1332
198	21	6	89	360	62	06/00/79	20	.15	H	1333
260	29	6	95	360	30	06/00/79	15	.06	H	1334

TABLE 14.--RECORDS OF SELECTED WELLS IN OLEY TOWNSHIP AND VICINITY--(continued)

EXPLANATION OF CODES: GEOLOGIC UNIT CODES ARE PRESENTED IN TABLE 1.
USE OF WATER: C, COMMERCIAL; H, DOMESTIC; I, IRRIGATION;
N, INDUSTRIAL; P, PUBLIC SUPPLY; S, STOCK; U, UNUSED

LOCAL NUMBER	SITE-ID	OWNER	DRILLER	DATE COMPLETED	GEOLOGIC UNIT
1337	402113075451801	SCHLEGEL, RICHARD	C.S. GARBER AND SONS	00/00/65	367EPLR
1338	402023075473601	ROHN, WILLIAM J.	KOHL BROS., INC.	00/00/74	364JKBG
1339	401910075440301	TRUMBORE TRAILER PARK	C.S. GARBER AND SONS	06/28/77	371ALNN
1340	402323075451601	HART, JOHN W.	PETERSHEIM BROS.	06/00/79	364BKMN
1349	402413075445801	ANGSTADT, DANIEL	--	--	364BKMN
1350	402304075444301	KURTZ, OMAR	--	--	371ALNN
1351	402247075461301	COKER, JAMES	--	--	364BKMN
1352	402247075463301	HOPKINS, LLOYD	--	--	364HMBG6
1353	402309075463601	HELWIG, JOHN	--	--	364BKMN
1354	402413075461801	HEINBACH, WILFRED	--	--	361MRBG
1355	402413075461701	HEINBACH, WILFRED	--	--	361MRBG
1356	402403075455901	LUNT, DOROTHEA	C.S. GARBER AND SONS	00/00/57	361MRBG
1357	402405075454401	LUNT, DOROTHEA	--	--	364BKMN
1358	402412075465301	ANGSTADT, DONALD	--	--	364BKMN
1359	402408075465301	ANGSTADT, DONALD	--	--	361MRBG
1360	402433075472701	ROTHENBERGER, FRANCIS	--	--	000HBLD
1361	402328075460801	HOWARD, LEROY	--	--	361MRBG
1362	402348075453301	RICHARD, RALPH	--	--	364BKMN
1363	402354075450501	HOCH, MARK	--	--	364BKMN
1364	402355075450701	HOCH, MARK	--	--	364BKMN
1365	402355075450501	HOCH, MARK	--	--	364BKMN
1366	402253075482901	MOXON	--	--	000GRGS
1367	402357075481601	LEVENGOOD, DANIEL	--	--	377HRDS
1368	402321075483601	MOXON	--	00/00/61	000GRGS
1370	402238075443401	ZOOK, LLOYD	--	--	371ALNN
1375	402035075451001	SHELLEY, DONALD	--	--	371RCLD
1376	402028075454001	FISHER, FRANK	C.S. GARBER AND SONS	00/00/51	371RCLD
1377	402214075453201	PETERSHEIM, ELMER	--	00/00/66	364BKMN
1378	402148075442201	WAGNER, HENRY	--	--	374LSVL
1379	402128075443801	SZARKO, FRANK	--	--	371ALNN
1380	402058075443301	HAUP, GERALD	--	--	371ALNN
1381	402034075470101	BASHORE, TERRY	--	--	367EPLR
1382	402015075461901	CHAPPELL, ROBERT	--	--	361MRBG
1383	402003075463701	PEIFER, ANDREW	--	--	364JKBG
1384	402043075482101	HETRICK, MERRILL	--	--	364ONLN
1385	402045075475801	SNYDER, JOHN	--	--	364JKBG
1386	402134075482201	KOCH, ROBERT	--	--	361MRBG
1387	402141075484301	SITTLER, ROBERT	--	--	361MRBG
1388	402046075445001	SCHERBNER, PAUL	--	--	371ALNN
1389	402114075455001	MOYER, JAKE	--	--	367EPLR
1390	402115075452401	TURCZINSKI	--	--	367EPLR
1391	402039075450701	STRUNK, HAROLD	--	--	371RCLD
1392	401944075463801	LAPP	--	--	364JKBG
1393	402007075475701	KENT, ANDREW	ROBERT D. GRANT	07/00/76	367EPLR
1394	402125075471401	EASTERN INDUSTRIES INC.	--	--	364ONLN
1420	402411075480701	OLEY TWP MUN AUTH.	--	00/00/68	377HRDS

DEPTH OF WELL (FEET)	DEPTH CASED (FEET)	CASING DIAM-ETER (INCHES)	DEPTH TO FIRST OPENING (FEET)	ALTITUDE OF LAND SURFACE (FEET NGVD)	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GAL/MIN/FT)	USE OF WATER	LOCAL NUMBER
340	95	5	--	320	46.11	12/31/81	7	--	H,S	1337
--	--	6	--	315	17.20	12/31/81	--	--	H	1338
90	74	6	76	265	27	06/28/77	100	1.6	H	1339
424	42	6	250	350	70	06/00/79	1	--	H	1340
--	--	--	--	380	9.74	04/15/82	--	--	U	1349
--	--	--	--	325	10.83	04/15/82	--	--	U	1350
15	--	--	--	360	8.16	04/14/82	--	--	U	1351
--	--	--	--	390	7.83	04/14/82	--	--	S	1352
--	--	--	--	375	12	--	--	--	H	1353
90	--	6	--	425	10.27	04/15/82	--	--	U	1354
--	--	--	--	420	8.48	04/15/82	--	--	U	1355
225	--	6	--	415	--	--	1.5	--	H	1356
--	--	--	--	390	13.18	04/15/82	--	--	H	1357
--	--	6	--	450	22.21	04/14/82	--	--	H	1358
--	--	6	--	450	14.30	04/14/82	--	--	H	1359
30	--	--	--	550	18.80	04/15/82	--	--	H	1360
--	--	6	--	375	8.87	04/14/82	--	--	H	1361
--	--	--	--	365	6.70	04/15/82	--	--	H	1362
--	--	--	--	375	3.49	04/15/82	--	--	H	1363
--	--	--	--	375	70	04/15/82	1.5	--	S	1364
--	--	--	--	375	13.11	04/15/82	--	--	S	1365
135	--	--	--	470	--	--	8	--	H	1366
30	--	--	--	480	10.43	04/14/82	--	--	U	1367
85	--	6	--	570	--	--	35	--	H	1368
110	--	--	--	325	--	--	--	--	H	1370
20	--	--	--	310	17.60	04/13/82	--	--	--	1375
136	--	6	--	320	8.11	04/13/82	65	--	H	1376
260	240	--	--	340	28.07	04/13/82	--	--	--	1377
60	--	--	--	305	13.64	04/14/82	40	--	--	1378
200	--	--	--	315	16.49	04/14/82	--	--	--	1379
180	--	--	--	305	13.32	04/14/82	--	--	--	1380
342	--	--	--	275	6.09	04/14/82	--	--	--	1381
--	--	--	--	370	4.82	04/14/82	--	--	--	1382
15	--	--	--	355	1.63	04/14/82	--	--	--	1383
--	--	--	--	285	17.28	04/14/82	--	--	--	1384
13	--	--	--	330	4.28	04/14/82	--	--	--	1385
--	--	--	--	350	.68	04/14/82	--	--	--	1386
110	--	--	--	360	23.16	04/14/82	--	--	--	1387
86	--	--	--	295	5.94	04/15/82	--	--	--	1388
--	--	--	--	330	35.34	04/15/82	--	--	--	1389
25	--	--	--	310	17.55	04/15/82	--	--	--	1390
49	--	--	--	305	16.73	04/14/82	--	--	--	1391
--	--	--	--	305	9.39	04/14/82	--	--	--	1392
72	10	6	--	315	50	07/00/76	30	--	H	1393
165	--	6	--	370	--	--	--	--	S,H	1394
330	220	6	220	560	--	--	--	--	P	1420

TABLE 15.--CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS AND STREAMS

EXPLANATION OF ALPHABETIC PREFIXES ON SELECTED FECAL STREPTOCOCCI VALUES: E, ESTIMATED VALUE; K, RESULTS BASED ON COLONY COUNT OUTSIDE THE ACCEPTABLE RANGE (NON-IDEAL COLONY COUNT)

LOCAL WELL NUMBER OR IDENTIFIER	DATE OF SAMPLE	GEO-LOGIC UNIT	SPE-CIFIC CON-DUCT-ANCE (µS)	pH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	COLI-FORM, FECAL, 0.45 UM-MF (COLS./ 100 ML)	STREP-TOCOCCI, FECAL, KF AGAR (COLS. PER 100 ML)	HARD-NESS (MG/L AS CACO3)	CALCIUM, DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
BE- 229	82-08-25	364BKMN	320	7.2	12.5	4.8	<1	K1	156	41	13
230	82-08-25	377HRDS	300	7.6	12	7.7	<1	<1	152	31	18
256	82-08-25	000GRGS	280	7.7	17	.7	<1	<1	110	32	7.3
1290	82-08-24	364BKMN	440	7.7	13.5	4.5	<1	<1	224	55	21
1295	82-08-24	361MRBG	255	8.1	15	1.3	<1	<1	116	25	13
1296	82-08-24	364HMBG6	520	7.2	16.5	2.2	<1	<1	25B	72	19
1297	82-08-24	364BKMN	390	7.7	13	1	<1	<1	182	58	9
1298	82-08-31	371ALNN	560	7.2	12.5	9.1	<1	K2	304	69	32
1308	82-08-24	374LSVL	395	7.5	12.5	.9	<1	54	199	40	24
1309	82-08-31	371ALNN	540	7.2	13	.5	<1	K5	298	70	30
1313	82-09-08	364ONLN	700	7.6	12.5	.0	<1	K1	244	63	21
1317	82-09-01	361MRBG	380	8.4	13	.2	<1	37	183	55	11
1321	82-08-25	364JKBG	440	7.6	15	.7	<1	<1	214	66	12
1334	82-08-31	364BKMN	675	7	13.5	6.3	<1	<1	359	76	41
1337	82-09-01	367EPLR	600	--	12.5	1	<1	81	345	72	40
1338	82-08-26	364JKBG	640	7.1	17	6.5	<1	22	324	110	12
1339	82-09-01	371ALNN	360	7.5	13.5	9.5	<1	<1	190	40	22
1351	82-09-07	364BKMN	380	7.4	12.5	--	>400	E335	168	44	14
1358	82-08-24	364BKMN	380	7.8	13.5	8.5	<1	<1	192	39	23
1376	82-09-01	371RCLD	600	7.4	13.5	.9	<1	<1	330	68	39
1383	82-09-07	364JKBG	490	7.1	12.5	--	28	160	257	95	4.7
1388	82-08-31	371ALNN	580	7.2	14	5.4	<1	<1	293	71	28
1393	82-08-26	367EPLR	580	7.2	13	8.7	<1	<1	282	80	20
1394	82-09-08	364ONLN	1750	7.1	13	5.8	<1	<1	1152	280	110
BIEBER CR NR LOBACHSVILLE	82-08-30	--	150	8	14.5	10.3	--	--	58	14	5.6
LIMEKILN CR AT LIMEKILN	82-08-30	--	560	7.7	14	10.1	--	--	292	84	20
MANATAWNY CR AT EARLVILLE	78-12-19	--	280	8.2	2	--	--	--	--	--	--
	82-08-30	--	285	8.8	18	12.2	--	--	136	33	13
MONOCACY CR AT LIMEKILN	82-08-30	--	340	8	17	8.5	--	--	149	46	8.3
OYSTERVILLE CR AT MANATAWNY	82-08-30	--	170	8.4	16	10.3	--	--	76	17	8.1
PINE CR NR MANATAWNY	70-05-14	--	99	7.7	17	--	--	--	32	8.2	2.9
	71-05-04	--	93	7.9	11	--	--	--	29	7.4	2.5
	75-04-23	--	88	--	10.5	--	--	--	--	--	--
	75-09-17	--	100	6.9	12	11.2	--	--	43	6.4	6.5
	82-08-30	--	105	7.8	13.5	10.1	--	--	39	9.9	3.4

SODIUM, DIS- SOLVED (MG/L AS NA)	POTAS- SIUM, DIS- SOLVED (MG/L AS K)	ALKA- LINITY FIELD (MG/L AS CACO3)	SULFATE, DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	FLUO- RIDE, DIS- SOLVED (MG/L AS F)	SILICA, DIS- SOLVED (MG/L AS SIO2)	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)	IRON, DIS- SOLVED (UG/L AS FE)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)
6.1	.3	140	17	8.7	.1	14	190	.010	1.2	<.010	10	16
3.4	1.4	140	5	4.1	.2	15	162	<.010	3.8	.010	27	3
7.9	.5	86	30	5	1.7	20	156	<.010	<.10	<.010	21	11
2.4	1.1	200	27	6.1	.3	13	246	<.010	3.3	<.010	6	4
5.3	1	110	22	1.7	.3	13	147	<.010	<.10	<.010	12	11
9.3	.2	230	65	6	.3	14	325	<.010	<.10	<.010	870	27
6	<.1	160	38	3.8	.2	16	225	<.010	<.10	<.010	180	17
3.3	2	190	37	12	<.1	9.8	279	<.010	15	<.010	19	1
7.6	2	180	25	23	.2	9.6	239	<.010	.25	<.010	12	15
3	1.5	260	32	11	.2	9.9	314	<.010	1.4	<.010	20	5
25	.4	130	180	12	1.5	18	400	<.010	.11	<.010	1400	39
4.8	.2	36	120	11	.1	7.8	243	2.10	1.1	<.010	17	4
6.9	.3	150	61	12	<.1	11	261	.250	.25	<.010	13	7
12	1.2	300	44	22	<.1	11	402	.010	3.4	<.010	17	<1
19	2.2	260	82	32	.2	13	428	.080	2.6	<.010	10	<1
3.2	.4	230	40	21	.2	8.5	333	<.010	15	<.010	9	5
3.1	1.8	150	18	5.7	.1	12	193	<.010	7.3	.010	18	<1
6.2	2.9	130	19	12	<.1	9.3	185	<.010	7.6	.030	<3	4
3.6	1.4	160	9	9.5	.3	12	194	<.010	6	<.010	7	<1
14	2	240	74	41	.2	14	402	.020	1.2	<.010	20	1
2.9	.5	200	36	10	.1	8.1	277	<.010	8.2	.020	<3	9
6	6.5	230	50	18	.2	11	329	<.010	9.9	.080	8	1
5.8	1.3	220	26	15	.1	10	290	<.010	13	<.010	12	2
10	2.6	190	400	7	.2	10	934	<.010	2.7	<.010	<3	2
6	.9	50	13	6	.1	20	96	<.010	1	.020	85	7
4.4	1.5	210	57	12	<.1	8.4	350	.020	8.3	<.010	9	3
--	--	--	--	--	--	--	--	--	--	--	--	--
6	1.3	100	29	9	.1	12	175	.020	2.7	.030	11	5
8.3	2.7	110	32	12	.1	17	210	.180	3.9	.070	16	22
4.7	1	70	12	4.9	.1	14	106	.060	.34	<.010	51	7
--	--	21	24	4.7	--	--	--	--	--	--	--	--
--	--	19	14	4.8	--	--	--	--	--	--	--	--
--	--	19	14	4	--	--	--	--	--	--	--	--
--	--	30	12	5	--	--	--	--	--	--	--	--
5.4	.6	28	14	5.1	.1	20	75	<.010	.44	<.010	35	7