GEOHYDROLOGY OF THE FURNACE CREEK BASIN AND VICINITY, BERKS, LANCASTER, AND LEBANON COUNTIES, PENNSYLVANIA

By L. DeWayne Cecil

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4218

Prepared in cooperation with

MILLCREEK TOWNSHIP

Harrisburg, Pennsylvania

1988

DEPARTMENT OF THE INTERIOR

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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 units	By	To obtain metric units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	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]	0.2070	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 square mile ($Mgal/mi^2$)	1,461	cubic meter per square kilometer (m^3/km^2)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	0.0169	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)

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

The Furnace Creek basin is an area of 8.95 square miles, about three-fourths of which is underlain by metamorphic rocks of low permeability. Reported yields for 14 wells in these rocks range from 1 to 60 gal/min (gallons per minute), with a median of 7.5 gal/min.

The northern part of the study area consists of highly permeable carbonate rocks. Nondomestic wells in these rocks typically yield from 200 to 300 gal/min and one well yields 1,200 gal/min.

Ground-water discharge from a 4.18-square-mile drainage area underlain by Precambrian granitic and hornblende gneiss averaged 868,000 gallons per day per square mile from October 1983 through September 1985. Thus, as much as 3,630,000 gallons per day could be pumped from wells in this area on a sustained basis. However, pumping this amount would have major adverse effects on streamflow.

A water-budget analysis for March 1984 to February 1985 showed that precipitation was 52.16 inches, streamflow was 26.38 inches, evapotranspiration was 29.29 inches, ground-water storage decreased by 5.94 inches and diversions made by Womelsdorf-Robesonia Joint Authority for water supply totaled 2.43 inches. Precipitation during this period was above normal.

Four of 18 wells sampled for water quality had iron, manganese, or nitrate concentrations above the U.S. Environmental Protection Agency's recommended limits. The crystalline rocks in the study area yield soft to moderately hard water that is generally acidic.

INTRODUCTION

A study of the water resources of the Furnace Creek basin in Berks, Lancaster, and Lebanon Counties, Pennsylvania, was conducted by the U.S. Geological Survey in cooperation with Millcreek Township from October 1982 through September 1985. No previous work covered this area in detail. The Furnace Creek basin is 10 to 15 miles from Reading, and the area's population is expected to grow substantially. Ground-water pumpage is expected to increase as population increases. Because much of the rock in the basin has a very low permeability and specific yield, interference between wells may become a serious problem. Also, runoff available to a public-supply reservoir will decline. Although all water resources in the area were studied, the primary focus was on the geohydrology of the area, particularly the low-permeability crystalline rocks of South Mountain. A glossary of some of the terms used in this report is at the end of the text.

Purpose and Scope

The purpose of this report is to describe the occurrence, availability, and quality of ground water and surface water in the Furnace Creek basin and vicinity (fig. 1), and to characterize the geohydrology.

Data on precipitation and ground-water level fluctuations were collected principally by volunteer observers. Four nonrecording gages were installed to determine spatial and temporal distribution of precipitation. One streamflow-gaging station was established in October 1982 to measure surface-water flow from the metamorphic rocks of South Mountain. Seventy-five wells were inventoried to obtain information on the occurrence and availability of ground water. Water levels were measured monthly in 13 of these wells. Eighteen ground-water and two surface-water samples were analyzed to obtain information on water quality.

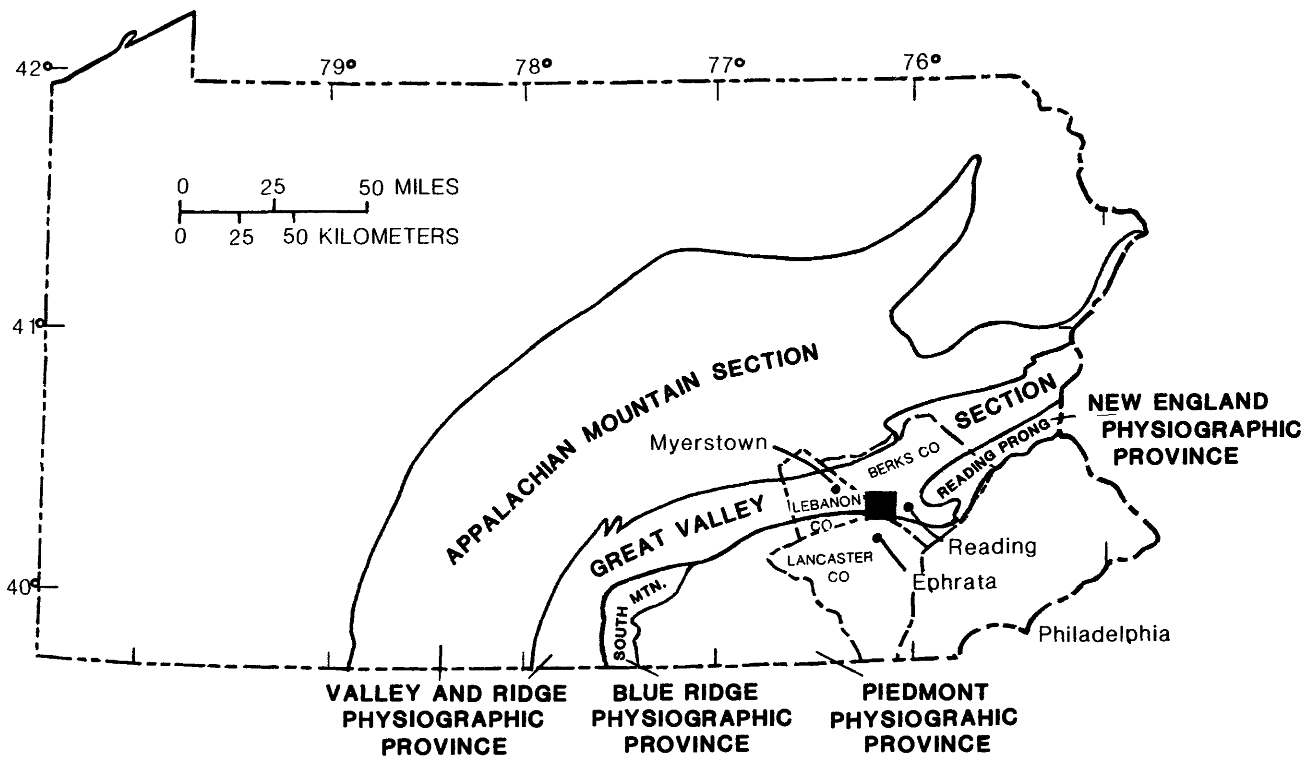


Figure 1.--Location of study area in southeastern Pennsylvania.

Acknowledgments

The author is indebted to the many individuals who provided assistance and information essential for the successful completion of this study. Special thanks are given to the many volunteer observers, particularly Mr. David W. Schreffler, who gave freely of their time to collect and provide hydrologic data. Steve Hirschritt, Randy Weitzel, Jerry Royer, Willard Noll, and Charles Minnick also made monthly ground-water level measurements.

Sincere thanks are given to Glen Eberle and Bill Conrad of the Womelsdorf-Robesonia Joint Authority (WRJA), Kerry Weaver of Richland Borough, and Sam Hoover of the Newmanstown Water Company for providing data. The author also gratefully acknowledges the cooperation of the many individuals who kindly permitted access to their wells for the collection of data essential to this study.

Well-Numbering System

The well-numbering system used in this report consists of two parts: (1) a two-letter abbreviation that identifies the county in which the well is located; and (2) a sequentially assigned number. All wells mentioned in this report are in Berks, Lancaster, or Lebanon counties and are identified by the abbreviations BE, LN, and LB, respectively. The only cited well located in Lancaster County is LN-1683. Locations of selected wells, with the prefixes BE, LN, and LB omitted from the local well number, are shown on plate 1.

The site-identification number given in table 11 has 15 digits. 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 a sequential number assigned to distinguish among sites located within a common 1-second grid block.

DESCRIPTION OF AREA

Location and Physiography

Furnace Creek drains 8.95 mi^2 (square miles) in Berks, Lancaster, and Lebanon Counties, Pennsylvania, and is a tributary to Spring Creek, which is a tributary to the Schuylkill River. This study also incorporates data from areas immediately adjacent to the basin, including the borough of Womelsdorf (fig. 2). Although a small part of Lancaster County is in the study area, this investigation focuses mainly on Berks and Lebanon Counties. The total study area is approximately 30 mi^2. Reading, the nearest major city, is about 11 miles to the northeast.

The study area is in two physiographic provinces. The northern one-third is in the Lebanon and Lehigh Valleys, which are part of the Great Valley section of the Valley and Ridge physiographic province. The southern two-thirds consist of South Mountain, which is an extension of the Reading Prong of the New England physiographic province.

Land-surface elevations range from approximately 350 feet above sea level in the Great Valley section, to higher than 1,300 feet on South Mountain--an extension of the Reading Prong. The area is not extensively farmed because of the rugged terrain and poor soil that covers the igneous and metamorphic rocks. Most of the mountain is wooded, and no major towns are located there. The boroughs of Womelsdorf and Robesonia lie in the carbonate valley in the northern part of the area.

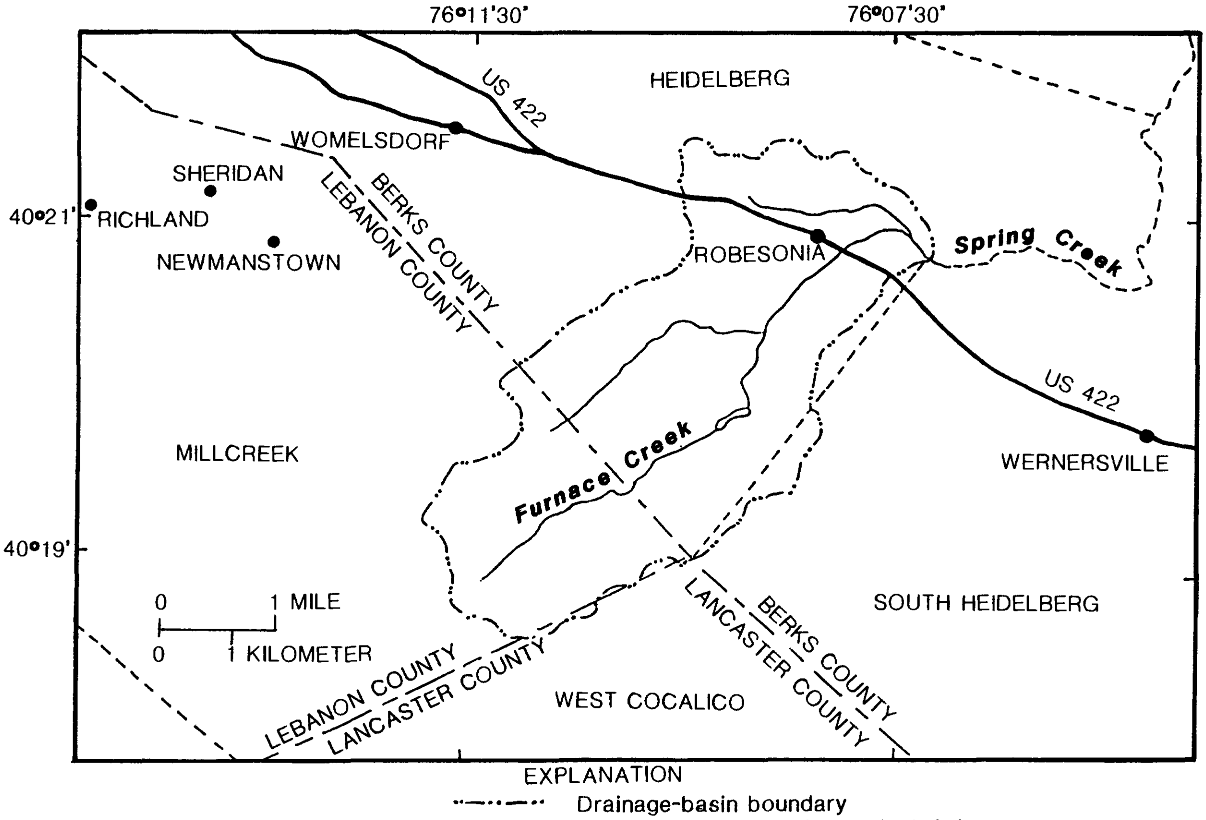


Figure 2.--The Furnace Creek drainage basin and vicinity.

Climate

The climate of the Furnace Creek basin and vicinity is classified as humid continental and is characterized by significant annual temperature ranges with hot summers and associated moderate to high humidity and cold winters dominated by low humidity air masses. A typical growing season has a duration of 200 days.

The 1951-80 normal monthly temperatures for the NOAA (National Oceanic and Atmospheric Administration) station in Ephrata provide an adequate estimate for temperatures in the study area (fig. 3). Ephrata is 8 miles south of the Furnace Creek basin. The 1951-80 normal temperature at Ephrata ranged from a minimum of -6.0° C (21.2° F) in January, to a maximum of 29.3° C (84.8° F) in July.

Four nonrecording precipitation gages (fig. 4) were read daily from March 1984 to February 1985 by volunteer observers. The average precipitation for these sites was 52.16 inches, or 8.66 inches more than the 1951-80 normal for Ephrata, indicating a wet year. The 1951-80 normal precipitation for Ephrata is 43.50 inches (table 1). No data are available for the NOAA station at Ephrata for March 1984 through February 1985.

A comparison of precipitation for the same period at the NOAA station 11 miles to the northeast in Reading also indicates that this was a wet year. The 1951-80 normal for Reading is 42.68 inches, and the total precipitation at Reading for March 1984 through February 1985 was 49.24 inches, or 6.56 inches above the normal. Although precipitation was slightly greater in May

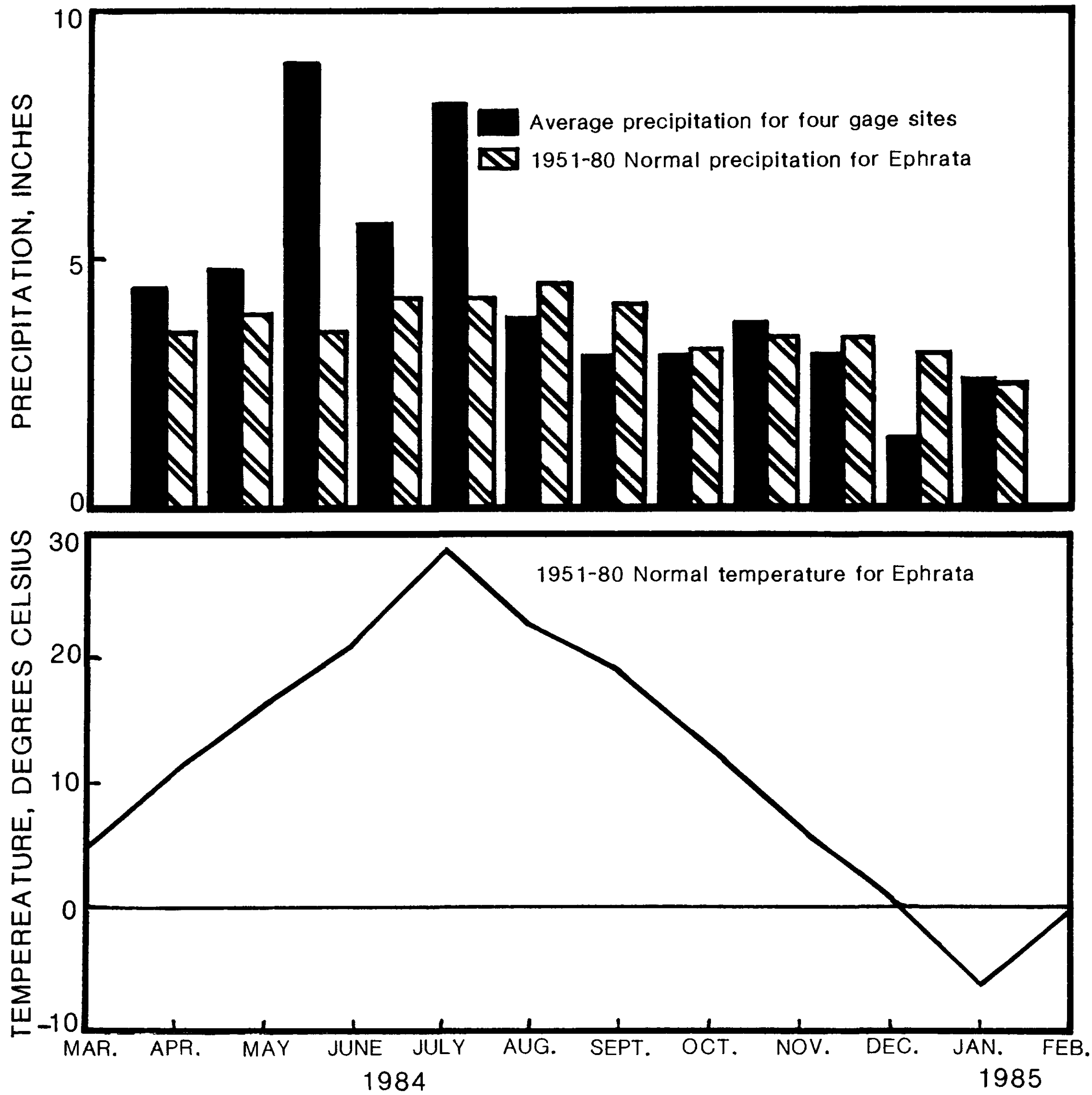


Figure 3.--Meteorological data for Furnace Creek basin and Ephrata.

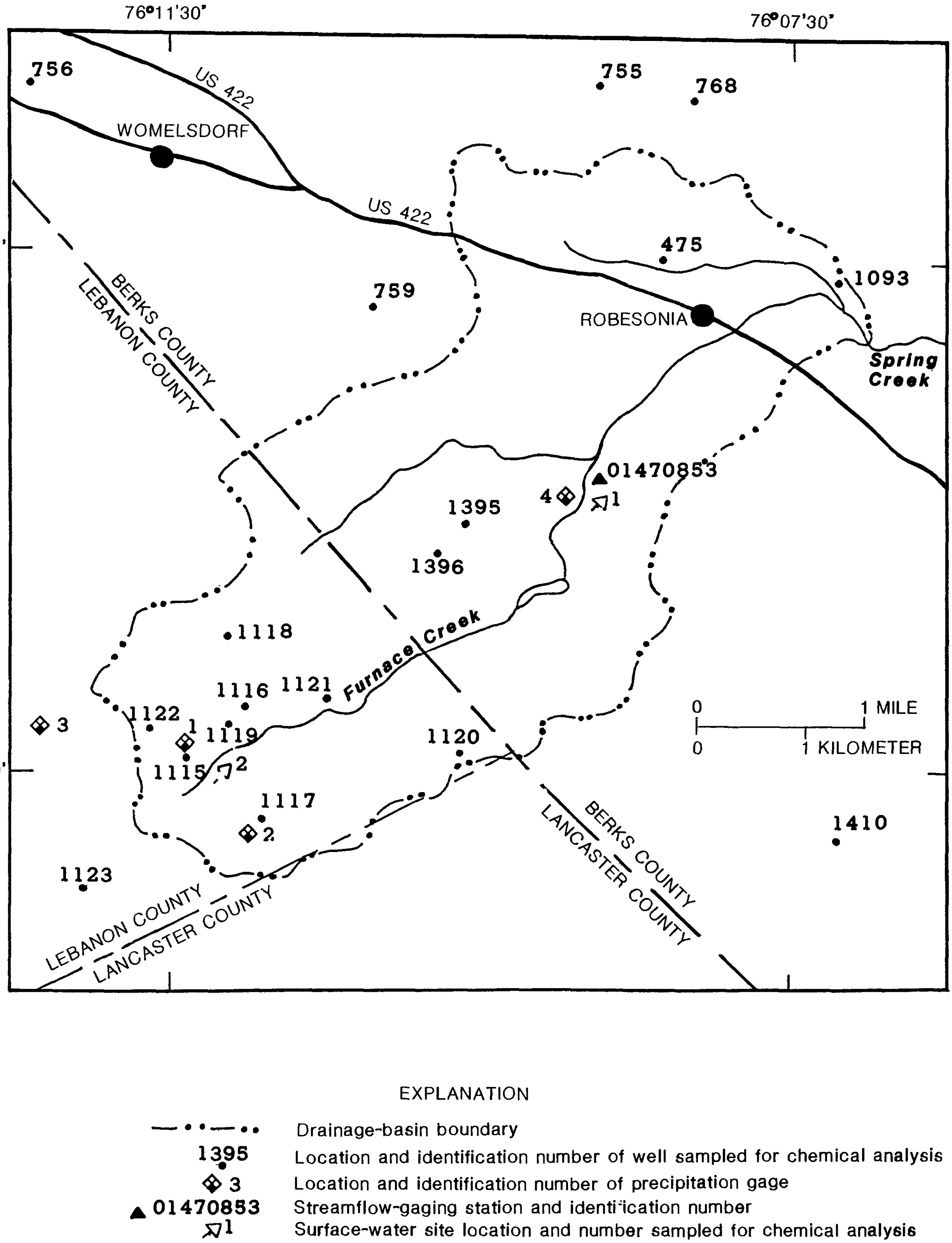


Figure 4.--Location of data-collection sites.

and July than in other months, long-term records for Ephrata indicate that precipitation is distributed fairly evenly throughout the year. There are no 1951-80 normal temperature data available for the NOAA station in Reading; therefore, the NOAA station in Ephrata was selected for a long-term comparison in this investigation.

Table 1.--Monthly precipitation for March 1984 - February 1985 for Furnace Creek basin compared to the 1951-80 normal precipitation at Ephrata. Location of precipitation gages are shown on figure 4
[Precipitation is in inches]

	Furnace Creek basin					Ephrata
Month	Gage 1	Gage 2	Gage 3	Gage 4	Mean of four gages	(1951-80 Normal)
1984						
March	[1]4.77	[1]4.63	[1]4.07	4.02	4.37	3.54
April	4.61	4.81	4.61	4.86	4.72	3.88
May	10.32	7.35	9.10	8.84	8.90	3.53
June	5.28	5.88	5.10	6.35	5.65	4.19
July	8.18	8.28	8.27	7.53	8.07	4.20
August	4.07	3.56	3.84	3.54	3.75	4.47
September	2.85	3.39	2.67	3.05	2.99	4.05
October	3.19	4.06	1.70	3.07	3.01	3.16
November	3.49	3.64	3.84	3.73	3.68	3.42
December	2.80	2.74	3.97	2.71	3.05	3.42
1985						
January	1.51	1.94	1.17	0.98	1.40	3.11
February	2.83	2.74	2.33	2.38	2.57	2.53
TOTAL	53.90	53.02	50.67	51.06	52.16	43.50

[1] Partially estimated from NOAA daily precipitation data from stations at Ephrata and Myerstown.

Geology

A description of the geologic units in the study area is given on plate 1. Unless otherwise noted, the following discussion is taken from Meisler (1963). The predominant surfacial feature is South Mountain, an uplift that has exposed a Precambrian core flanked by Paleozoic sedimentary rocks on the north and west and by down-faulted Triassic rocks to the south. The uplift appears to be a great plate of crystalline rocks, consisting of the Hardyston Quartzite and minor carbonate rocks, thrust over the carbonate rocks that form a part of the Great Valley physiographic province (MacLachlan and others, 1975). South

Mountain is an extension of the Reading Prong of the New England physiographic province and has a total relief exceeding 1,000 feet. It makes up approximately 75 percent of the surface area of the basin. It is underlain by gneisses that have been intruded by metadiabase dikes (sheet-like bodies of igneous rock that cut across the bedding or structural planes of the host rock). The Hardyston Quartzite of Early Cambrian age forms the high ridges that border South Mountain to the north.

Distinct rock assemblages of similar age but different composition are termed sequences. Rocks of the Lebanon Valley and the Lehigh Valley sequences dominate the valleys in the northern part of the study area. The rocks are in a system of major thrust slices or large overturned folds (nappes). The beds commonly dip steeply and are sometimes overturned in both sequences with high-angle faults and thrust faults common.

The Lebanon Valley sequence is dominately carbonate rocks that lie in the Lebanon nappe to the north of South Mountain. The upper half of the sequence, extending from the lowest member of the Martinsburg Formation (Upper and Middle Ordovician) to the Snitz Creek Formation (Upper Cambrian) is present.

The Lehigh Valley sequence consists of a Lower Cambrian basal quartzite with a large thickness of shallow-water Cambrian and Lower Ordovician limestones and dolomites that grade upward to a Middle Ordovician shale. Only the lowest two formations of the sequence--the Hardyston Quartzite and overlying Leithsville Formation--are present.

One unit of the Hamburg sequence is present. Throughout the Great Valley physiographic province, the Hamburg sequence consists of a series of litho-tectonic units that are mapped as units 1 to 8 in possible ascending order of superposition. Lithotectonic unit 3 has been mapped in the study area. The age of Hamburg sequence rocks has not been fully resolved, but unit 3 is probably of Middle Ordovician age (Berg and others, 1983). Thickness of these units are unknown, and their origin and structure are complex.

Table 2 lists the geologic units in the study area 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. (If a rock unit includes more than one series designation, the youngest is coded). The second part, or next four characters, is an abbreviation for the name of the geologic unit. The third part, if used, is a single character that denotes the lithology or stratigraphic position of the geologic unit. For example, 361MRBGL denotes a geologic unit that is in the Upper Ordovician Series (361), is called the Martinsburg Formation (MBRG), and stratigraphically is the lower member (L) of the Martinsburg Formation. The aquifer codes appear in the column "aquifer code" in the records of selected wells (table 11) and in the water-quality table (table 12).

Table 2.--Aquifer codes for geologic units

System or Series	Geologic unit	Aquifer code
Upper and Middle Ordovician	Martinsburg Formation, lower member	361MRBGL
Middle Ordovician	Jacksonburg Limestone	364JKBG
	Hershey and Myerstown Limestones, undivided	364HRSY
Middle and Lower Ordovician	Ontelaunee Formation	364ONLN
	Epler Formation	367EPLR
Upper Cambrian	Richland Formation	371RCLD
Middle and Lower Cambrian	Leithsville Formation	374LSVL
Lower Cambrian	Hardyston Quartzite	377HRDS
Precambrian	Granite gneiss	000GRGS
	Hornblende gneiss	000HBLD

GEOHYDROLOGY

Hydrologic Cycle

The hydrologic cycle is the continuous circulation of water in the atmosphere, in the soil and underlying rocks, and on the Earth's surface. The processes in this cycle are condensation, precipitation, evapotranspiration, infiltration, and runoff. A sketch representing the hydrologic cycle under natural conditions is shown in figure 5. Human activities change these flow paths by pumping water from wells, by regional treatment and disposal of wastewater, and by the construction of dams and reservoirs.

All water enters the local hydrologic system as precipitation and leaves as surface runoff, ground-water discharge and underflow, diversion by public water suppliers, and as water vapor through evapotranspiration. Part of this water moves out of the area relatively quickly as surface runoff. Some that remains for a longer period percolates underground, moves through the ground-water system, and eventually discharges to streams.

An estimate of the maximum amount of ground water available for consumption is the average annual recharge (equivalent to average annual base flow). Ground water is an important component of the local hydrologic cycle, as more than 34 percent of the total precipitation infiltrates the land surface and percolates to the ground-water system. This water then moves relatively slowly downgradient from areas of recharge to areas of discharge where it seeps into streambeds and becomes base flow. This 34 percent represents the base flow contribution to the total water budget for March 1984 through February 1985. When long-term ground-water pumping exceeds recharge, the result commonly is the progressive lowering of ground-water levels.

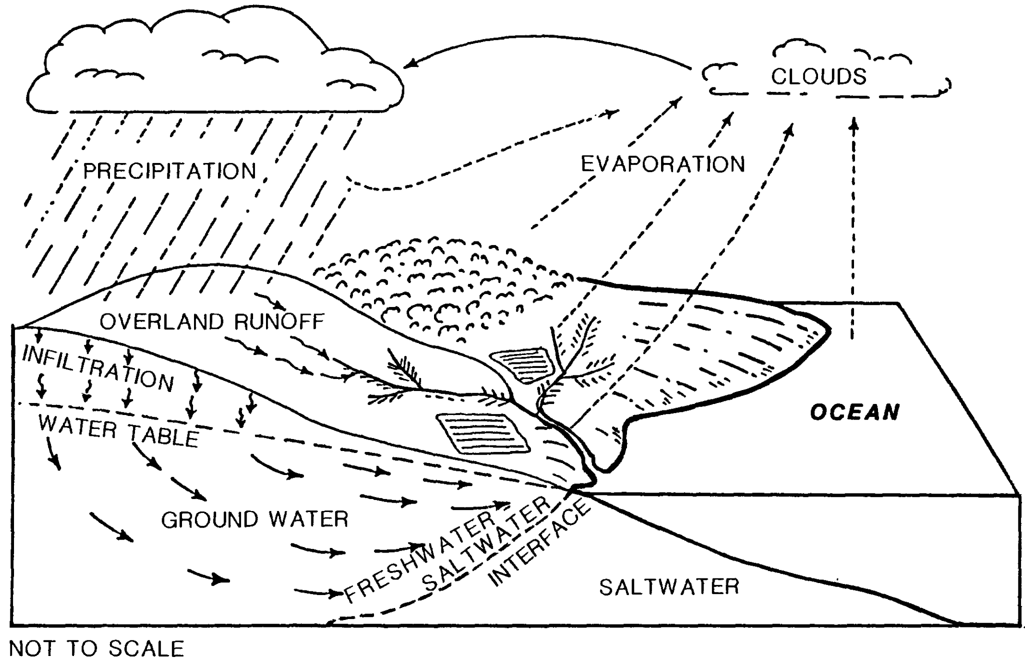


Figure 5.--Hydrologic cycle (from Heath, 1983).

Surface Water

Streamflow and Base Flow

Nearly all precipitation not evaporated or transpired by plants leaves the Furnace Creek basin as streamflow. Figure 4 shows the location of a continuous-record streamflow-gaging station (U.S. Geological Survey number 01470853) established in 1982. The drainage area upstream from this station is 4.18 mi^2. Annual discharge at this station averaged 25.19 inches per year for 1983-85. Table 3 gives mean monthly stream discharge with diversions from the Furnace Creek reservoir by the WRJA added to monthly stream discharge.

A hydrograph of mean daily streamflow and base flow during the 1984 water year (October 1, 1983 to September 30, 1984) is shown in figure 6. The solid line represents the total discharge of Furnace Creek upstream of the gaging station and the dashed line indicates the ground-water discharge to the stream (base flow) determined by the local minima hydrograph-separation technique of Pettyjohn and Henning (1979). Precipitation at the NOAA station at Reading was 21.33 inches greater than the 1951-80 normal of 42.68 inches. The ground-water contribution to total streamflow for that period was 68 percent. The 1985 water year was one of slightly below-normal precipitation (41.69 inches). The ground-water contribution for that period was 78 percent.

Table 3.--Monthly discharge for Furnace Creek at Robesonia
[units are inches]

	1983	1984	1985	Mean
January	0.83	1.75	1.19	1.26
February	1.84	3.23	2.09	2.39
March	4.38	3.19	1.58	3.05
April	8.25	4.32	0.96	4.51
May	3.89	3.90	1.78	3.19
June	1.59	2.92	0.66	1.72
July	0.57	3.46	0.56	1.53
August	0.44	1.73	0.43	0.87
September	0.35	1.26	0.79	0.80
October	0.98	0.91	1.57	1.15
November	2.14	1.20	1.11	1.48
December	4.95	2.11	2.65	3.24
TOTAL	30.21	29.98	15.37	25.19

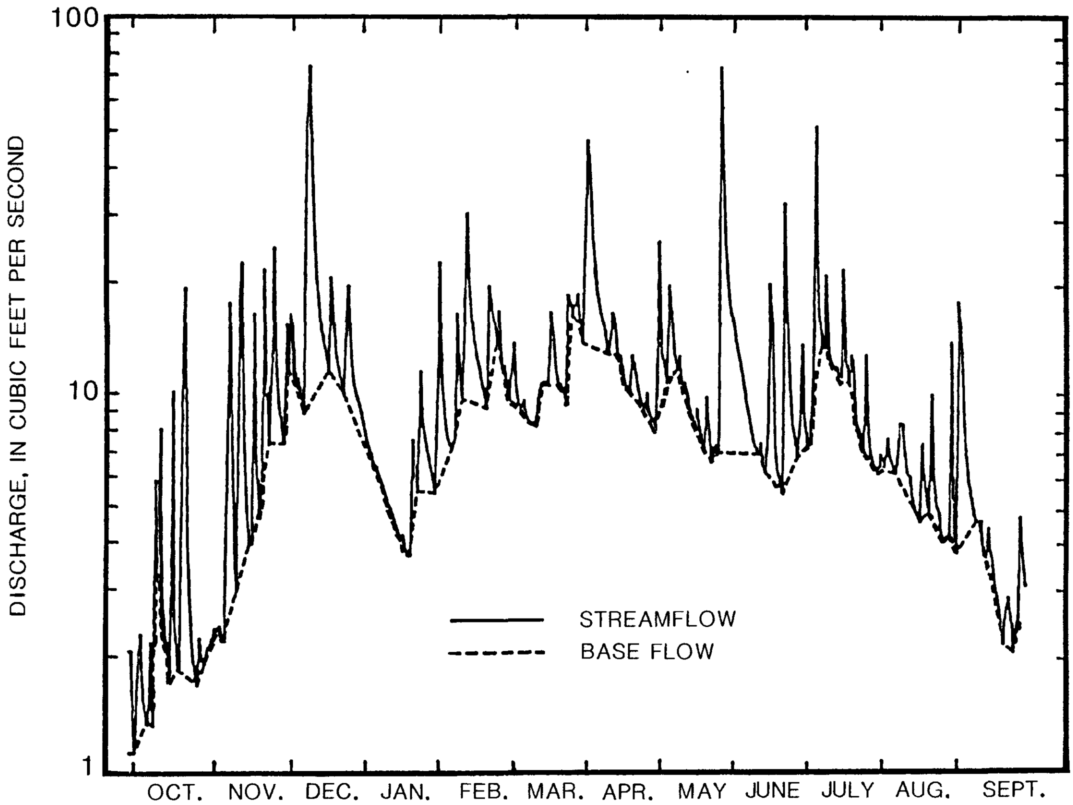


Figure 6.--Hydrograph of mean daily streamflow and base flow, Furnace Creek at Robesonia, 1984 water year.

Flow Duration

A flow-duration curve shows the percentage of time that specified discharges are equaled or exceeded over the entire range of discharge, without considering the sequence of occurrence. Duration curves with steep slopes represent streams that have variable flows generally attributable to intermittent periods of direct runoff. Duration curves with flatter slopes indicate streamflow contributions chiefly from ground-water discharge within the basin. Figure 7 shows the flow duration for three water years (1983-85) for Furnace Creek at Robesonia. This duration curve accounts for diversions by the WRJA. The slope of the curve is relatively flat, indicating that the streamflow contributions in the Furnace Creek basin are chiefly from ground-water storage. Hydrograph separations show an average of 69 percent of streamflow is ground-water discharge. Therefore, Furnace Creek has relatively constant low streamflow sustained mainly by ground-water discharge.

The capacity of a basin to store ground water can be estimated from discharge ratios taken from the flow-duration curves. If P25 represents the value of streamflow equaled or exceeded 25 percent of the time, and P75 represents the value of streamflow equaled or exceeded 75 percent of the time, then the discharge ratio $(P25/P75)^{1/2}$ provides a measure of the capacity of a basin to store ground water (Walton, 1970). A discharge ratio and flow-duration statistics for the Furnace Creek basin are given in table 4. Small discharge ratios represent relatively permeable basins with large storage capacity, and large ratios indicate less permeable basins with small storage capacity. In Berks County, the Limekiln Creek basin (fig. 8), which is composed chiefly of carbonate rocks, has a relatively small discharge ratio (large storage capacity), 1.53, whereas the Monocacy Creek basin, which is underlain mainly by noncarbonate rocks, has a relatively large discharge ratio (small storage capacity), 2.17 (Paulachok and Wood, 1988). The discharge ratio for Furnace Creek at Robesonia, which consists of noncarbonate rocks, is 2.06, indicating a basin with small storage capacity.

Ground-water discharge for three water years (1983-85) exceeded 317,000,000 gallons per square mile per year. This is about 868,000 gallons per day per square mile. Theoretically, about 3,630,000 gal/d (gallons per day) could be pumped on a sustained basis from the 4.18 mi^2 area of Furnace Creek basin. However, pumping this amount would have major adverse effects on streamflow. If wells pumping this amount were located near Furnace Creek, the stream would go dry because of the diversion of base flow.

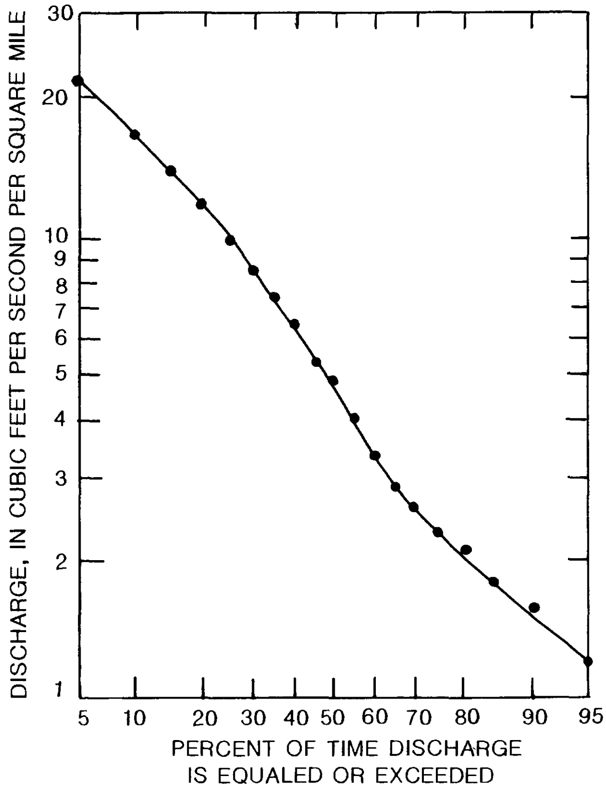


Figure 7.--Flow-duration curve for Furnace Creek at Robesonia, 1983-85 water years.

Table 4.--Flow-duration statistical characteristics for Furnace Creek, 1983-85 water years [ft^3/s, cubic feet per second]

	Discharge ft^3/s	Discharge ratio
P95	1.2	P25 = 9.8 ft^3/s
P90	1.6	P75 = 2.3 ft^3/s
P85	1.8	
P80	2.1	ratio = $(P25/P75)^{1/2}$
P75	2.3	= 2.06
P70	2.6	
P65	2.9	
P60	3.4	
P55	4.0	
P50	4.8	
P45	5.6	
P40	6.5	
P35	7.4	
P30	8.5	
P25	9.8	
P20	11.9	
P15	13.8	
P10	16.2	
P05	21.6	

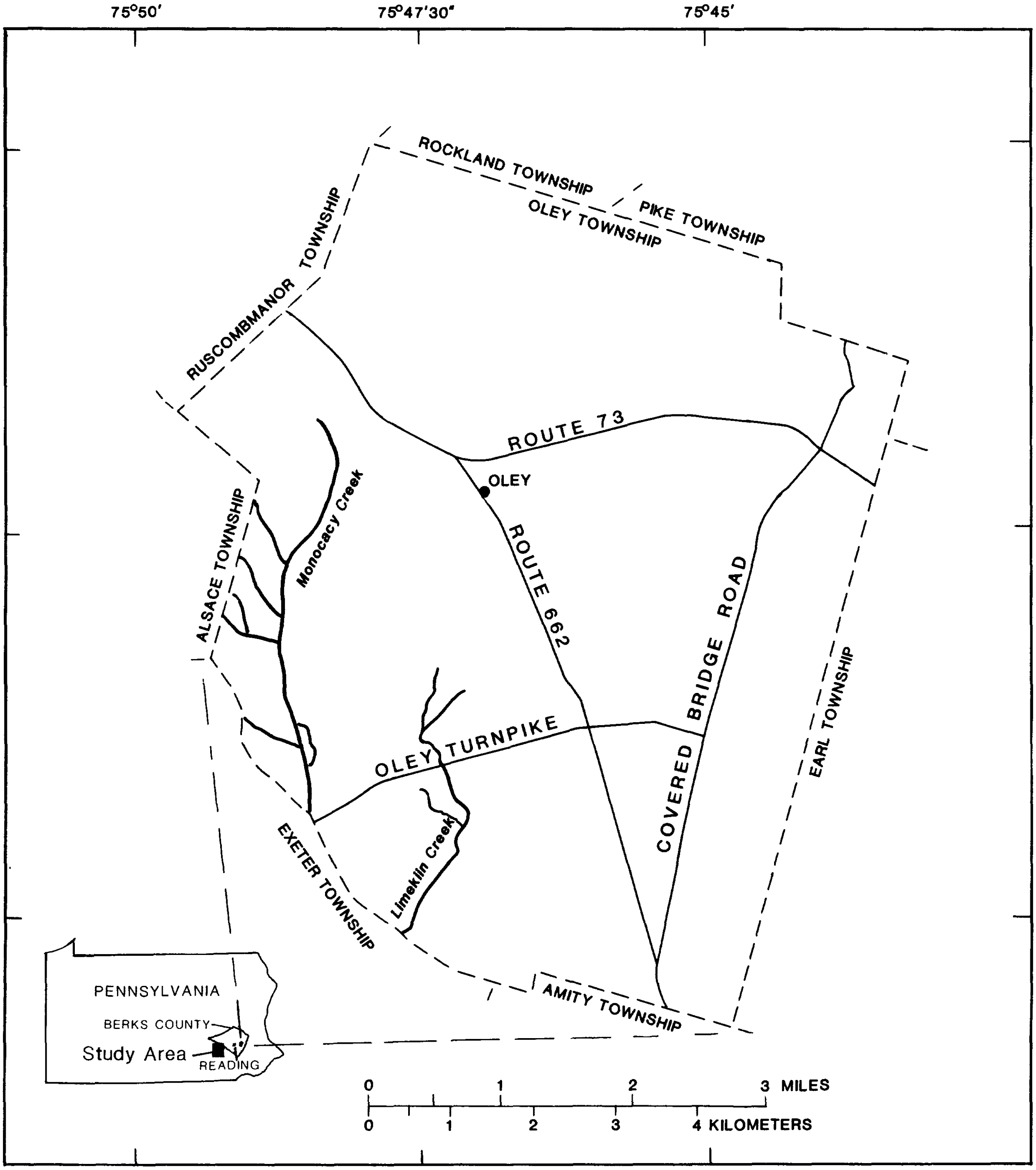


Figure 8.--Location of Limekiln Creek and Monocacy Creek, Berks County.

Ground Water

Well Yield and Specific Capacity

Well yields depend primarily on permeability, specific yield (or storage coefficient), thickness and areal extent of the aquifer, sources of induced recharge, the size and number of water-bearing openings encountered, well diameter and efficiency, and depth of saturated overburden. Most ground water in the study area occurs in and moves through secondary openings along bedding planes and joints, faults, and fractures. Thus, geologic structure also is a significant factor affecting well yield.

At the time a well is completed, the driller estimates the yield of the well by measuring the rate at which water must be removed from the well in order to lower the water level to near the bottom of the well. This is generally the reported yield. Several factors limit the accuracy of this estimate: (1) the higher the yield, the more difficult it becomes to lower the water level to the bottom of the well; and (2) these tests are usually too short (1 hour or less) to accurately represent well yield.

Generally, well yields are greater in areas of intensively fractured bedrock. In the carbonate rocks, fractures may be enlarged by solution. Solution openings in carbonate rock in Berks County as large as 1 foot have been reported by Wood and MacLachlan (1978). However, they also noted that fractures generally become closed with increasing depth, and openings in most carbonate units are only a fraction of an inch wide. Table 5 lists the number of wells reported to penetrate water-bearing zones for specific depth ranges. The greatest number of water-bearing zones for all units were penetrated within 200 feet of land surface. Wood and others (1972, p. 165) noted that most fractures in carbonate rocks in Lehigh County become closed between 600 and 850 feet below land surface, and relatively little ground-water flow takes place below 850 feet.

Table 5.--Number of wells penetrating a water-bearing zone reported for a specified depth range
Some wells penetrate more than one water-bearing zone reported for a specified range

Unit	Total number of wells	Depth range, (feet)											
		0-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	>500	Deepest Zone
Martinsburg Formation, lower member	4	2	2	1	1	1	0	0	0	0	0	0	246
Epler Formation	10	3	2	3	2	2	1	0	0	0	0	0	293
Richland Formation	10	1	5	4	3	0	0	2	0	0	1	1	515
Leithsville Formation	2	0	0	1	1	0	0	0	0	0	0	0	113
Hardyston Quartzite	4	1	1	2	2	1	0	0	0	0	0	0	270
Granite gneiss	1	0	1	1	0	0	0	0	0	0	0	0	111
Hornblende gneiss	6	0	3	2	2	0	0	0	0	0	0	0	440

Deeper wells do not necessarily produce more water. For example, wells BE-336 and BE-356 in the Epler Formation have depths of 660 and 345 feet, respectively. The land-surface elevation for BE-336 is 420 feet above sea level, and for BE-356 the land-surface elevation is 438 feet. The reported yields are 100 gal/min for BE-336 and 1,200 gal/min for BE-356. In this case, the shallower well (BE-356) has a much higher reported yield, even though the two wells have similar topographic position and are completed in the same aquifer.

Specific capacity is the yield of a well per unit of drawdown. It is determined by pumping a well at a constant rate for a given period of time. The pumping rate of a given well, discharge, and pumping time all affect specific capacity. Generally, specific capacities are highest for wells located in valleys and lowest for wells on hilltops. Table 11 lists specific capacities for 27 wells in the study area. One nondomestic well in the Epler Formation, BE-596, has a specific capacity of 275 (gal/min)/ft (gallons per minute per foot); a nondomestic well in the hornblende gneiss on South Mountain, LB-1125, has a specific capacity of 0.04 (gal/min)/ft. The type of aquifer in each case also is a factor. The Epler Formation is more permeable than the hornblende gneiss.

Specific capacities are less than 1.0 (gal/min)/ft for 70 percent of the wells. The median specific capacity for domestic wells is 0.1 (gal/min)/ft. For nondomestic wells the median specific capacity is 0.85 (gal/min)/ft, nearly an order of magnitude higher than for domestic wells. Some of this difference is attributable to the generally large (greater than 6 inches) diameter of nondomestic wells, which are drilled for the largest yield obtainable, whereas most domestic wells have 6-inch diameters and are drilled until a suitable domestic yield is obtained. Some of this difference is also because nondomestic wells are generally deeper and penetrate more water-bearing zones than domestic wells. In addition, many of the nondomestic wells are located in valleys.

The geohydrology of each important aquifer in the study area is discussed in this section. Only those units listed in table 2 are covered in detail because they are the ones areally extensive enough to be considered for development. Unless otherwise noted, the discussion is taken from Paulachok and Wood (1988) for those units in Berks County, and from Royer (1983) for the units in Lebanon County. Adequate domestic supply has been arbitrarily defined as 3 gal/min or more. This yield should be adequate for normal domestic use, excluding lawn and garden watering. Six gal/min is adequate for nearly all normal domestic uses. With careful use, some households can operate on as little as 1 gal/min (Paulachok and Wood, 1988).

Lebanon Valley sequence

Martinsburg Formation.--Only the lower member of the Martinsburg Formation, a dark-gray shale, is present. The low hills to the north of Robesonia are underlain by the Martinsburg Formation to a maximum thickness of approximately 400 feet.

Yields should be adequate for domestic supply. Four domestic wells have reported yields ranging from 7 to 20 gal/min with a median yield of 13 gal/min. Well depths range from 140 to 300 feet with a median depth of 198 feet. Three of these wells have specific capacities of 0.036, 0.08, and 0.15 (gal/min)/ft.

Jacksonburg Limestone.--The Jacksonburg Limestone is a thick-bedded argillaceous limestone. A small valley that borders the northern edge of the Furnace Creek basin is underlain by the Jacksonburg Limestone. One domestic well has a reported yield of 35 gal/min. One nondomestic well has a reported yield of 10 gal/min and a specific capacity of 1.0 (gal/min)/ft.

Hershey and Myerstown Limestones, undivided.--The Hershey Limestone is a thin-bedded argillaceous limestone. The Myerstown Limestone is a thin-bedded crystalline limestone. Reported yields are 15 to 20 gal/min in Berks County (Wood and MacLachlan, 1978). Specific capacities for two wells in Lebanon

County were 11 and 12 (gal/min)/ft (Meisler, 1963). Two nondomestic wells in the study area have reported yields of 30 and 45 gal/min; one of these wells has a specific capacity of 0.33 (gal/min)/ft.

Beekmantown Group.--Only two formations of the Beekmantown Group--the Ontelaunee and underlying Epler Formations--are present. The boroughs of Robesonia and Womelsdorf are underlain primarily by these formations. Both are excellent aquifers. The Ontelaunee Formation is a crystalline dolomite interbedded with limestone. It is about 300 feet thick. One well in the Ontelaunee Formation in the study area has a reported yield of 80 gal/min and a depth of 154 feet. The Ontelaunee Formation is considered to be an excellent aquifer throughout the Great Valley section of the Valley and Ridge physiographic province with reported yields of 3 to 1,000 gal/min (Paulachok and Wood, 1988). In Lebanon County reported yields for 14 wells range from 3 to 750 gal/min with a median of 11 gal/min for domestic wells and 200 gal/min for nondomestic (Royer, 1983).

The Epler Formation also is a dolomite interbedded with limestone. It is about 800 feet thick. The Epler is a very important aquifer in the study area. The reported yields of 13 wells range from 8 to 1,200 gal/min. The median yield for eight nondomestic wells is 275 gal/min. The median yield for five domestic wells is 10 gal/min.

Conococheague Group.--Three formations of the Conococheague Group are present: in descending order they are the Richland, Millbach, and Snitz Creek Formations. Only the Richland Formation is of great enough areal extent to be important. The Richland Formation is chiefly a thick-bedded dolomite that is interbedded with limestone and oolitic chert. It is about 1,000 feet thick. It is a very productive aquifer, with reported yields of 13 wells ranging from 6 to 500 gal/min. The median reported yield for domestic and nondomestic wells is 20 and 150 gal/min, respectively. Specific capacities for four nondomestic wells range from 0.3 to 85 (gal/min)/ft, with a median of 2.8 (gal/min)/ft; for two domestic wells, specific capacities are 0.1 and 0.4 (gal/min)/ft.

Lehigh Valley sequence

Leithsville Formation.--The Leithsville Formation consists predominately of crystalline dolomite that has considerable amounts of chert in the lower part. It extends along the base of South Mountain northwest of the Furnace Creek basin. The Leithsville Formation is approximately 1,000 feet thick and is more deeply weathered than the other formations. Wells commonly require over 100 feet of casing. For example, casing depths for wells LB-1045 and LB-1046 are 107 and 156 feet, respectively. Three nondomestic wells have reported yields of 300, 100, and 100 gal/min. Two of these nondomestic wells have specific capacities of 0.8 and 1.2 (gal/min)/ft.

Hardyston Quartzite.--The Hardyston Quartzite consists of sandstones and quartzites with a conglomerate bed near the base. It is 250 to 600 feet thick and forms a steep slope on the northern perimeter of South Mountain. These rocks dip at angles from 30 to 50 degrees to the northwest. One domestic well has a reported yield of 3 gal/min and the median reported yield for four nondomestic wells is 60 gal/min. Specific capacities for two nondomestic wells are 0.35 and 0.41 (gal/min)/ft.

South Mountain metamorphic rocks

The metamorphic rocks on South Mountain include metadiabase, granitic gneiss, and hornblende gneiss. Gneisses are coarse-grained, banded rocks formed during high-grade regional metamorphism. Reported yields for 14 wells in these crystalline rocks range from 1 to 60 gal/min, with a median of 7.5 gal/min.

The metadiabase is shown as dikes on the geologic map (Plate 1). Generally, metadiabase is a low-yielding water unit. No wells are completed in metadiabase in the study area.

Granite gneiss is light colored and medium grained. It consists chiefly of quartz and feldspar of igneous origin. The reported yields for three domestic wells range from 3 to 12 gal/min and the reported yield for one nondomestic well is 6 gal/min. One domestic well has a specific capacity of 0.1 (gal/min)/ft.

The hornblende gneiss is dark colored and medium grained. It may include some rocks of sedimentary origin. Four nondomestic wells have reported yields that range from 3 to 20 gal/min, and a median of 5 gal/min. Specific capacities for two of these wells are 0.04 and 0.16 (gal/min)/ft. The range of reported yields for six domestic wells is 1 to 60 gal/min, with a median yield of 12 gal/min. Specific capacities for two domestic wells are 0.04 and 0.2 (gal/min)/ft.

Summary of well yield and specific capacity

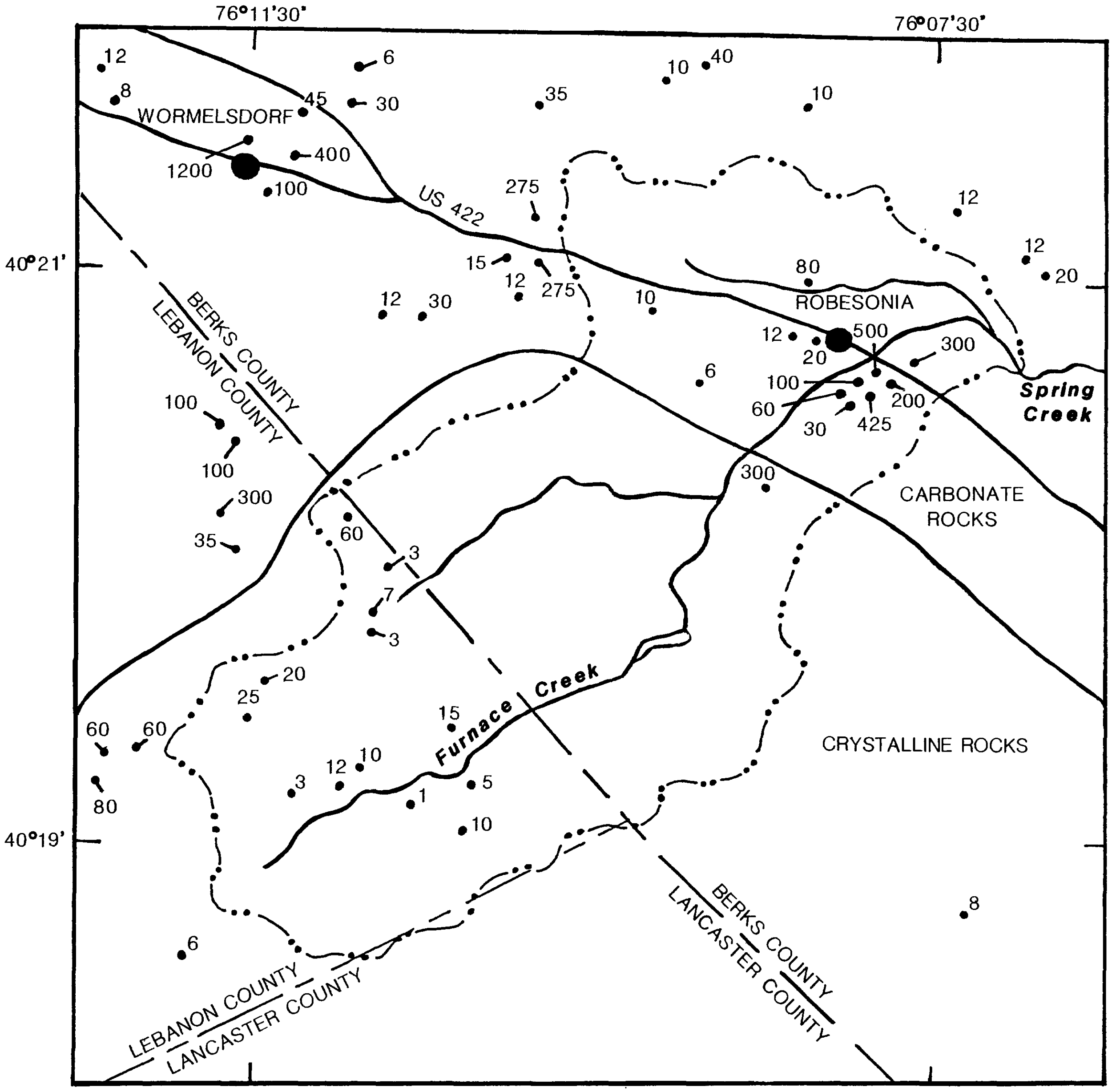
Well yields are shown in figure 9. Reported well yield, depth, and casing depths for domestic and nondomestic wells is summarized in table 6. Reported well yield and depth can be used to evaluate an aquifer's suitability for various domestic and nondomestic needs. If 25 percent of reported well yields for an aquifer, such as the Epler and Richland Formations, exceed 100 gal/min, then that aquifer is adequate for the development of municipal and industrial supplies. Well and casing depth data can be used to estimate probable drilling costs.

Wells in all the carbonate and crystalline aquifers have reported yields adequate for domestic needs. However, no wells in the crystalline rocks have reported yields adequate for industrial or commercial use.

Water-Level Fluctuations

Water levels have a seasonal trend, generally declining during the growing season when evapotranspiration is high. Rain and snowmelt recharge the aquifers during late fall, winter, and early spring, and water levels generally rise. Typical annual water-level fluctuations range from 3 to 20 feet.

Hydrographs for three observation wells (wells LB-1117, LB-1122, and LB-1115) are shown in figure 10. The three hydrographs show the same trend with water levels generally declining throughout the summer months and rising in the late fall and early winter. A rise in water levels during the summer months is due to higher-than-normal precipitation recharging the ground-water system. Well LB-1122 is in an aquifer that is more responsive to recharge, resulting in sharper peaks than either LB-1115 or LB-1117, which are in different aquifers.



EXPLANATION

- 12 Domestic well location and reported yield in gallons per minute
- 30 Nondomestic well location and reported yield in gallon per minute
- Generalized contact between crystalline and carbonate rocks
- Drainage-basin boundary

Figure 9.--Well yields in the Furnace Creek basin and vicinity.

Table 6.--Summary of well yield, well depth, and casing depth
[gal/min, gallons per minute; a dash indicates no value reported]

Unit	Type of well[1]	Number of wells	Reported yield (gal/min)		Reported yield (gal/min): yield exceeded by indicated percentage of wells			Well depth (feet)		Casing depth (feet)	
			Range	Median	25	50	75	Range	Median	Range	Median
Martinsburg Formation	D	4	6-20	12	19	11	5	150-300	195	27-41	-
Jacksonburg Limestone	D	1	35	-	-	-	-	36	-	-	-
	N	1	10	-	-	-	-	86	-	23	-
Hershey and Myerstown Limestones, undivided	N	2	30-45	-	-	31	-	80-180	-	-	-
Ontelaunee Formation	N	1	80	-	-	-	-	154	-	-	-
Epler Formation	D	5	8-12	10	11	9	8	112-220	175	22-122	65
	N	7	15-1,200	275	399	274	99	90-345	220	20-94	43
Richland Formation	D	5	6-300	20	299	19	7	46-336	137	42-205	154
	N	9	12-500	150	424	199	59	60-660	190	42-114	60
Leithsville Formation	N	3	100-300	100	-	99	-	135-360	173	107-156	-
Hardyston Quartzite	D	1	3	-	-	-	-	280	-	-	-
	N	4	35-80	60	36	59	-	212-700	494	40-152	125
Granitic gneiss	D	3	3-12	10	-	9	-	110-120	-	42	-
	N	1	6	-	-	-	-	220	-	68	-
Hornblende gneiss	D	6	1-60	12	24	14	4	120-501	160	41-145	47
	N	4	3-20	5	19	6	2	140-640	300	27-68	52

[1] D is for domestic wells; N is for nondomestic wells

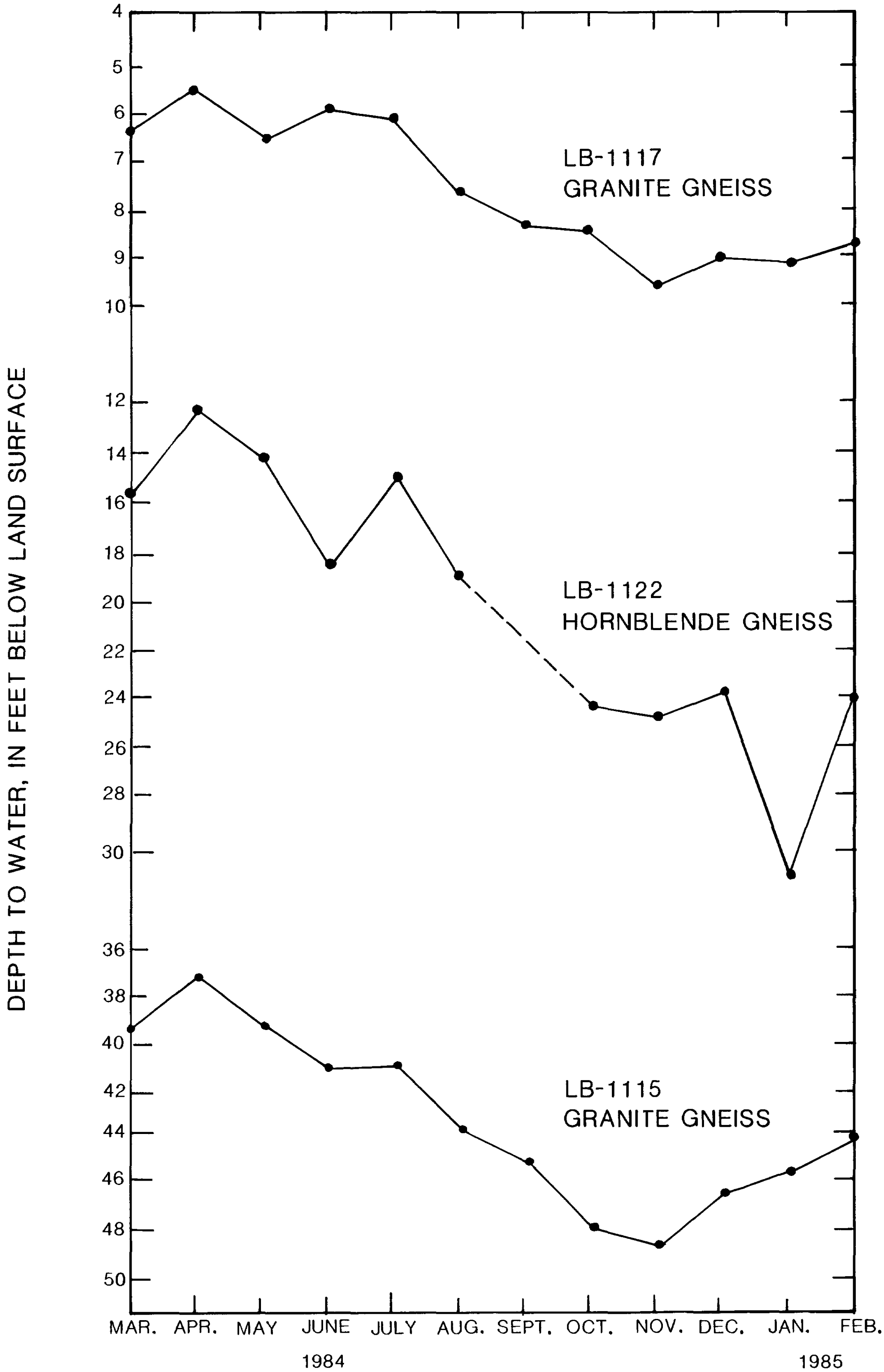


Figure 10.--Hydrographs for selected observation wells.

Water Budget

A water budget is an estimate of the quantity of water entering and leaving an area for a given period of time. The water budget balances water entering the area as precipitation with water leaving as streamflow, exported water, and evapotranspiration, taking into account any changes in storage. The water budget can be expressed as:

$$P = SF + ET + DS + DIV,$$

where:

P = precipitation,

SF = streamflow (overland runoff and ground-water discharge or base flow),

ET = evapotranspiration,

DS = change in ground-water storage, and

DIV = diversions by WRJA

The water budget for March 1984 through February 1985 was estimated for the 4.18-mi^2 drainage basin above the streamflow-gaging station on Furnace Creek. Soil moisture generally is at field capacity during the winter. The period for the water budget begins and ends in winter, therefore, the change in soil moisture is assumed to be negligible. The change in surface-water storage in Furnace Creek reservoir was assumed to be zero for the same period. Information on daily diversions and surface-water storage in Furnace Creek reservoir was supplied by the WRJA. The mean water-level change of -5.5 feet in four observation wells was multiplied by a specific yield for granitic rocks of 9 percent to estimate the change in ground-water storage (Olmsted and Hely, 1962, p. A-18); this is the average gravity yield of the zone of water-table fluctuations for crystalline rocks. After all other components in the water budget were calculated, the residual was assumed to be evapotranspiration.

The water budget for March 1984 to February 1985, expressed in inches of water is:

$$P = SF + ET + DS + DIV$$
$$52.16 = 26.38 + 29.29 - 5.94 + 2.43$$

Precipitation for this period was 19.9 percent above the 1951-80 normal for Ephrata (table 1), indicating a wet year. The evapotranspiration for this period, 29.29 inches, also is higher than it would be in a normal year because of this increased precipitation. The streamflow number in the water budget, 26.38 inches, does not include diversions as supplied by the WRJA. A decline in ground-water storage during March 1984 to February 1985 probably was due to high water levels in March 1984.

Public Water Supply

Three public-water suppliers (table 7) obtain all or part of their water from the Furnace Creek basin or from nearby wells and springs in the same units that crop out in the basin. These public suppliers withdraw an average of 0.67 Mgal/d (million gallons per day) from ground-water and surface-water sources.

Table 7.--Public-water suppliers in Furnace Creek basin and vicinity
[Mgal/d, million gallons per day]

Public water supplier	Source of supply	Aquifer	Average daily withdrawal (Mgal/d)
Womelsdorf-Robesonia Joint Authority	1 well 2 springs 1 reservoir	Leithsville Formation Hornblende gneiss	0.54
Newmanstown Water Authority	1 well 5 springs	Leithsville Formation	.01
Richland Borough	3 wells 1 spring	Hardyston Quartzite	.12

The WRJA supplies water to the boroughs of Womelsdorf, Robesonia, and Sheridan. This public water-supply system consists of: (1) well LB-723 with a reported yield of 300 gal/min, which is used for emergency supply only; (2) two springs that supply an average of 65,000 gal/d; and (3) a reservoir on South Mountain from which the WRJA diverts an average of 477,000 gal/d. Table 8 lists the annual ground-water and surface-water use by the WRJA for 1973-86. In 1986, the WRJA had 1,592 residential, 15 commercial, and 2 industrial customers.

The Newmanstown Water Authority obtains water from five springs and one well. The springs provide an average of 9,700 gal/d. The well (LB-699) is an alternative source utilized during periods of low spring flow. The Newmanstown Water Authority supplies 420 residential customers.

Richland Borough uses three wells and one spring to supply 563 residential customers. The three wells are used during periods of low spring flow. The wells, LB-700, LB-702, and LB-1124, have reported yields of 60, 60, and 80 gal/min, respectively. The spring provides an average of 120,000 gal/d.

A comparison of ground-water withdrawals by public suppliers for 1969 and 1979 is shown in table 9. The borough of Wernersville, located approximately 3 miles east of the Furnace Creek basin, is experiencing expansion from the Reading area. Ground-water use by the Wernersville Municipal Authority from 1969 through 1979 increased 573.1 percent or 1 Mgal/d. The water use in 1979 is about double the current combined ground-water and surface-water usage by the WRJA, which is 0.54 Mgal/d.

Table 8.--Annual ground-water and surface-water withdrawals by the Womelsdorf-Robesonia Joint Authority, 1973-86
[units are millions of gallons]

Period	Furnace Creek Reservoir	Springs	Total
June 1973 - May 1974	148.3	39.5	187.8
June 1974 - May 1975	194.2	22.1	216.3
June 1975 - May 1976	174.3	12.8	187.1
June 1976 - May 1977	173.8	18.3	192.1
June 1977 - May 1978	181.5	24.6	206.1
June 1978 - May 1979	200.7	38	238.7
June 1979 - May 1980	173.2	33.5	206.7
June 1980 - May 1981	190	26.3	216.3
June 1981 - May 1982	202	25.4	227.4
June 1982 - May 1983	166.5	15	181.5
June 1983 - May 1984	168.5	18.3	186.8
June 1984 - May 1985	160	16.8	176.8
June 1985 - May 1986	129.7	18.8	148.5

Table 9.-Comparison of ground-water withdrawal by public suppliers for 1969 and 1979

Public water supplier	Ground-water withdrawal[1] (million gallons per day)			Percentage change
	1969	1979	Change	
Wernersville Municipal Authority	0.156	1.050	+0.894	+573.1
Womelsdorf-Robesonia Joint Authority	.200	.150	-.050	- 25.0
Newmanstown Water Authority	.100	.100	0	0
Richland Borough	.080	.080	0	0

[1] From R. E. Wright Associates, Inc., 1982.

Water Quality

The quantities and kinds of substances in water determine its quality and potential uses. Elevated concentrations of nitrate and chloride also may indicate contamination by human activities. Elevated nitrate concentrations may be caused by animal waste, sewage, or excessive use of fertilizers. Elevated chloride concentrations may be caused by sewage, industrial waste, or road salt.

The quality of ground water and surface water in the Furnace Creek basin and vicinity generally is suitable for most uses. Elevated concentrations of iron, manganese, and nitrate are the most significant water-quality problems in ground water, which is the chief source of potable supply.

Eighteen ground-water and two surface-water samples from the study area were analyzed. Figure 4 shows the locations of the water-quality sampling sites. The samples were analyzed in the field for selected chemical and physical properties, and in the laboratories of the U.S. Geological Survey for selected inorganic chemical species and nutrients.

Hardness of water is a measure of the amount of calcium and magnesium in solution. Qualitatively, hardness represents the soap-consuming capacity of water. Hard water reacts with soap, causing calcium and magnesium compounds to precipitate, which in turn, lessens the amount of lather produced. Water from the carbonate rocks commonly is hard, because those rocks consist of calcium and magnesium carbonates, which are very soluble. According to the classification proposed by Durfor and Becker (1964, p. 27), the water sampled on March 20, 1984, from nine wells in crystalline rock, ranged from soft (0 to 60 mg/L as $CaCO_3$) to moderately hard (61 to 120 mg/L as $CaCO_3$) (table 10).

Field Analysis

Specific conductance, pH, and hardness were measured in the field for this study (table 10). All wells sampled are in noncarbonate aquifers.

The pH of a solution is a measure of the hydrogen-ion concentration, and it represents the level of acidity or alkalinity of the solution. A pH of 7.0 is regarded as neutral; values greater than 7.0 indicate alkaline water and values less than 7.0 indicate acidic water. In general, the pH of water also is a measure of potential reactivity. Values of pH below 4.5 generally indicate water that may tend to dissolve metals and other substances that it contacts. Higher values, generally above 8.5, indicate alkaline waters that may form scale in pipes. The pH of ground water from the noncarbonate aquifers ranged from 5.3 to 6.4. Water from the granitic and hornblende gneiss is acidic.

Specific conductance is a measure of a fluid's ability to conduct an electrical current and is proportional to the concentration of dissolved solids in the fluid. Therefore, high values of specific conductance represent elevated concentrations of dissolved solids. The specific conductance of ground water from the noncarbonate aquifers ranged from 50 to 320 μS/cm (microsiemens per centimeter at 25° Celsius) with a median of 140 μS/cm.

Table 10.--Field determination of pH, specific conductance, and hardness in ground water, March 20, 1984 [μS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; a dash indicates no value reported]

Well number	Aquifer	pH (units)	Specific conductance μS/cm	Hardness (mg/L as $CaCO_3$)
BE-1395	Granitic gneiss	5.3	320	86
LB-1115	Granitic gneiss	5.9	130	34
LB-1116	Granitic gneiss	6.3	195	68
LB-1117	Granitic gneiss	6.2	100	51
LB-1119	Granitic gneiss	6.3	270	103
LB-1120	Granitic gneiss	5.4	140	51
LB-1121	Hornblende gneiss	6.3	200	68
LB-1122	Hornblende gneiss	5.3	110	34
LB-1123	Granitic gneiss	6.4	50	-

Laboratory Analysis

Physical properties and concentrations of selected chemical constituents of water samples collected during this study are summarized in table 12. The dissolved constituents that exceeded U.S. Environmental Protection Agency (1986) limits for potable water were iron, manganese, and nitrate. All samples collected for this analysis were below the USEPA recommended limit of 500 mg/L for dissolved solids in drinking-water supplies (U.S. Environmental Protection Agency, 1986).

Iron concentrations in ground water ranged from less than 10 μg/L (micrograms per liter) to 720 μg/L. The iron concentrations in the two surface water samples were 40 μg/L and 20 μg/L. Two wells sampled (BE-1395 and BE-756), exceeded the limit of 300 μg/L recommended by USEPA.

Manganese concentrations in ground-water ranged from less than 10 μg/L to 60 μg/L. The manganese concentrations in the two surface water samples were less than 10 μg/L and 10 μg/L. Only one well sampled (BE-768) exceeded the limit of 50 μg/L recommended by USEPA.

Nitrate concentrations in ground water ranged from 0.07 to 13.3 mg/L. Water from one well (BE-755) exceeded the maximum contaminant level of 10 mg/L recommended by USEPA. This well is 128 feet deep in the carbonate rocks and is at a farm. In carbonate-rock terrains, overland runoff and infiltration can transport nitrate from various sources directly into the aquifer through sink-holes, solution features, or fractures. Fertilizers and barnyard wastes are the most likely sources of nitrate.

Summary of Water-quality Problems

When chemical constituents exceed recommended levels, it may become necessary to control or reduce concentrations so that water quality is acceptable. Elevated concentrations of iron and manganese may cause staining of plumbing fixtures and laundry. Maximum recommended limits in drinking water are 300 μg/L for iron and 50 μg/L for manganese (U.S. Environmental Protection Agency 1986). Processes that use ion-exchange reactions generally can reduce elevated concentrations of iron and manganese; for example synthetic resin beads exchange sodium (Na) ions in their structure for iron and manganese ions in water.

Elevated concentrations of nitrate may enable the growth of other organisms that produce objectionable odors and tastes. The maximum contaminent level for nitrate in drinking water is 10 mg/L (U.S. Environmental Protection Agency, 1986). To prevent nitrate pollution, several appropriate protective measures may be adopted. These measures include (1) siting livestock-raising and fertilized areas as closely as possible to places of natural ground-water discharge (2) proper spacing between wells and on-site septic systems; and (3) implementing land-use practices that minimize nitrate infiltration.

SUMMARY

The southern two-thirds of the study area is underlain by low-permeability granitic and hornblende gneiss. Fourteen wells in these rocks have reported yields adequate for domestic use; median yields are 8 gal/min for granitic gneiss and 7.5 gal/min for the hornblende gneiss. The median reported yield for all 14 wells is 7.5 gal/min. However, no wells in either unit have reported yields adequate for industrial or commercial use. An aquifer test conducted on well LB-1125 in the hornblende gneiss indicated a specific capacity of 0.04 (gal/min)/ft.

The northern one-third of the study area is underlain by highly permeable carbonate rocks, the most important of which are the Epler, Richland, and Leithsville Formations. Wells in these units have median yields that range from 10 to 275 gal/min, and one well yields 1,200 gal/min. Wells in all of the carbonate aquifers have reported yields adequate for domestic needs.

Ground-water discharge from a 4.18-square-mile drainage area underlain by low-permeability metamorphic rocks, averaged 868,000 gallons per day per square mile from October 1983 through September 1985. Thus, as much as 3,630,000 gallons per day could be pumped from wells in this area on a sustained basis. However, pumping this amount would have major adverse effects on streamflow.

A water-budget analysis for March 1984 through February 1985 showed that precipitation was 52.16 inches, streamflow was 26.38 inches, evapotranspiration was 29.29 inches, ground-water storage decreased 5.94 inches, and surface-water diversions made by the Womelsdorf-Robesonia Joint Authority for water supply totaled 2.43 inches. Precipitation during this period was above normal.

Water-quality problems in the Furnace Creek basin and vicinity are caused by elevated concentrations of iron, manganese, and nitrate. Four of 18 wells sampled for water quality had iron, manganese, or nitrate concentrations above U.S. Environmental Protection Agency recommended limits.

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GLOSSARY

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

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

Base flow.--Sustained or fair weather flow. In most streams, base flow is composed largely of ground-water discharge.

Carbonate rock.--A rock consisting of limestone and (or) dolomite.

Discharge.--The total fluids measured. The terms discharge, streamflow, and runoff represent water with the solids dissolved in it and the sediment mixed with it.

Drainage basin.--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.

Evapotranspiration.--Evaporation of water from land and water surfaces plus the water transpired by vegetation.

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

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

Hardness.--A property of water that 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.

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 in 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° Celsius. 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.

Water year.--The 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ended September 30, 1985, is called the "1985 water year."

Table 11.--Records. of selected wells

Explanation of codes: Aquifer codes are presented in table 2. [Use of water: C, Commercial; H, Domestic; I, Irrigation; J, Industrial (Cooling); N, Industrial; P, Public supply; S, Stock; U, Unused; Z, Other. A dash indicates no value reported.]

Local well number	Site-ID	Owner	Contractor	Date well constructed	Aquifer code
		Berks County			
BE-25	402204076122201	Williams	--	01-01-25	367EPLR
28	402104076080301	Ruth	--	01-01-25	371RCLD
73	402143076110501	Fox	--	01-01-25	367EPLR
74	402139076111001	Williams & Moyer	--	01-01-25	371RCLD
335	402053076074501	Caron Spinning Co.	0561	12-14-59	371RCLD
336	402057076074601	Caron Spinning Co.	0561	04-28-60	371RCLD
337	402056076073901	Caron Spinning Co.	0561	05-12-61	371RCLD
338	402057076074401	Caron Spinning Co.	0561	04-28-61	371RCLD
339	402054076074701	Caron Spinning Co.	0561	06-28-61	371RCLD
340	402049076074201	Caron Spinning Co.	0561	10-25-60	371RCLD
341	402048076074401	Caron Spinning Co.	0561	02-20-61	371RCLD
356	402156076112101	Marco Electric Mfg. Co.	0561	10-15-49	367EPLR
475	402132076083201	Master	0561	04-20-39	364ONLN
476	402156076112401	Marco Electric Mfg. Co.	0561	07-10-46	367EPLR
592	402223076105201	Womelsdorf Borough	0561	10-17-68	361MRBGL
596	402128076094401	Inter-Continental Wire Co.	0561	01-28-67	367EPLR
597	402126076094701	Inter-Continental Wire Co.	0561	01-25-67	367EPLR
598	402126076094501	Inter-Continental Wire Co.	0561	01-21-67	367EPLR
631	402207076111501	Womelsdorf Mfg. Co.	0561	08-17-66	364HRSY
754	402218076090801	Rienicher	0561	09-26-67	367EPLR
755	402220076085801	Geisinger	0271	01-01-76	367EPLR
756	402206076122501	Wise	0561	12-21-59	367EPLR
759	402114076101601	Delp	0561	10-22-69	371RCLD
760	402059076084101	Harman	0561	09-27-65	371RCLD
761	402113076092101	Bechtel	0109	09-03-67	367EPLR
763	402105076080601	Yoder	0561	11-14-45	371RCLD
764	402136076074501	Bright	0561	10-04-65	361MRBGL
765	402217076075901	Brubacker	0118	--	364HMBG3
766	402209076100001	Stauffer	0319	--	364JKBG
767	402147076095101	Conner	-200	01-01-67	364MRBGL

Table 11.--Records of selected wells--Continued

Explanation of codes, continued: Contractor: 0109, R.H. Stanley; 0128, R.D. Grant; 0188, C.S. Garber & Sons; -200, C. Brendel; 0271, J.H. Mays; 0319, Myers Brothers; 0561, Kohl Brothers; 1271, Gill Inc.; 1328, Fisher's; 1258, F.R. Sensenig, 0319, J. Bucci

Local well number	Depth of well (feet)	Bottom of casing (feet)	Diameter of casing (in.)	Top of open interval (feet)	Altitude of land surface (feet)	Water level (feet)	Date water level measured	Discharge (GPM)	Specific capacity (gal/min)/ft	Primary use of water
25	220	—	6	—	410	30	01-01-25	8	—	H
28	46	—	6	—	430	25	01-01-25	20	—	H
73	90	—	8	—	415	—	—	100	—	Z
74	400	—	—	—	430	—	—	—	—	U
335	250	—	—	—	424	—	—	30	—	U
336	660	42	12	191 315 495 515	420	38	04-28-60	100	.89	U
337	60	57	10	58	417	30	05-12-61	300	—	U
338	63	54	8	55 61	418	24.00	04-28-61	500	—	U
339	80	71	5.8	80	422	26.50	03-21-72	60	—	U
340	260	97	8	147 165	422	38	10-25-60	200	4.8	U
341	190	114	6	145 164	424	46	11-25-70	425	85	U
356	345	94	10	293	438	65	10-15-49	1200	100	U
475	154		8		440	0.00	11-19-70	80	.80	R
476	283	38	8		445	67	07-10-46	400	5.1	U
592	300	41	6	160 246	350	7.00	01-08-69	6	.036	H
596	95	58	6.25	64	478	36	01-30-67	275	275	U
597	300	43	6.25	206	485	36	01-25-67	15	.06	U
598	220	20	10	110 179 216	485	44	11-18-70	275	39	J
631	180	—	6.25		382	33.00	11-01-70	45	.33	N
754	140	22	6	52 110	415	62.00	09-01-67	10	.13	H
755	128	—	6	—	410	48	11-13-70	40	—	S
756	189	33	5.6	180	397	20.14	10-31-72	12	—	H
759	134	125	6.25	130	500	44.79	10-31-72	30	.38	H
760	336	205	4.25	336	495	90.00	09-27-65	6	.10	H
761	112	97	6.25	112	535	71.71	11-02-72	10	—	H
763	142	60	5.5	—	425	43.20	11-02-72	12	.30	I
764	200	27	6.25	50	507	23.00	11-19-70	12	.08	H
765	140	—	6.00	—	440	17.04	11-02-72	—	—	S
766	36	—	6.00	—	460	17.40	11-02-72	35	—	H
767	190	—	6	—	540	30.70	11-02-72	—	—	H

Table 11.--Records of selected wells--Continued

Explanation of codes: Aquifer codes are presented in table 2. [Use of water: C, Commercial; H, Domestic; I, Irrigation; J, Industrial (Cooling); N, Industrial; P, Public supply; S, Stock; U, Unused; Z, Other. A dash indicates no value reported.]

Local well number	Site-ID	Owner	Contractor	Date well constructed	Aquifer code
768	402213076082401	Duncan	0561	08-25-47	364JKBG
770	402127076071501	Heiniman	0561	05-01-59	371RCLD
817	402208076111001	Yarn Manufacturers	--	01-01-68	364HRSY
1093	402125076071301	Eiceman	0271	01-01-64	361MRBGL
1205	402112076102501	Huber	0561	05-01-59	371RCLD
1395	402005076093001	Ressler	--	--	000GRGS
1396	401955076094201	Ressler	--	--	000GRGS
1410	401803076071101	Stopper	0188	01-01-75	000HBLD
1433	402114076100301	Brubaker	0188	01-01-83	371RCLD
1434	402118076094601	Plempel	--	01-01-82	356EPLR
1435	402047076101401	Bashore	0218	01-01-84	377HRDS
1436	402115076102501	Bond	--	01-01-81	371RCLD
1437	402114076103401	Navozny	--	01-01-78	371RCLD
1438	402016076082601	Hill	0188	01-01-81	371RCLD
		Lancaster County			
LN-1683	401834076091901	Wiest	--	01-01-78	000GRGS
		Lebanon County			
LB-699	402011076115501	Newmanstown Water Co.	0561	10-23-63	377HRDS
700	401918076122801	Richland Borough	0561	01-01-18	377HRDS
702	401917076122301	Richland Borough	0561	02-03-59	377HRDS
723	402025076115501	Womelsdorf-Robesonia	0561	01-01-31	374LSVL
1042	402014076105801	Sweigart	1271	11-19-81	000HBLD
1045	402041076114301	C. M. Davia Assoc.	0188	11-01-80	374LSVL
1046	402042076114401	C. M. Davia Assoc.	0188	11-01-80	374LSVL
1048	401924076113701	Oliviera	0561	11-14-75	000HBLD
1049	401909076105401	Harris	0561	06-03-77	000GRGS
1050	401932076113001	Dutchland Laboratory Animals	0561	03-01-79	000HBLD
1051	401904076102301	Harris	1328	08-17-77	000HBLD
1052	401905076100701	Ulrich	0561	06-02-79	000HBLD
1053	401852076095801	Levan	--	01-01-75	000GRGS
1091	402005076105901	Eagles Peak Campground	1328	08-01-81	000HBLD

Table 11.--Records of selected wells--Continued

Explanation of codes, continued: Contractor: 0109, R.H. Stanley; 0128, R.D. Grant; 0188, C.S. Garber & Sons; -200, C. Brendel; 0271, J.H. Mays; 0319, Myers Brothers; 0561, Kohl Brothers; 1271, Gill Inc.; 1328, Fisher's; 1258, F.R. Sensenig, 0319, J. Bucci

Local well number	Depth of well (feet)	Bottom of casing (feet)	Diameter of casing (in.)	Top of open interval (feet)	Altitude of land surface (feet)	Water level (feet)	Date water level measured	Discharge (GPM)	Specific capacity (gal/min)/ft	Primary use of water
768	86	23	6	--	430	34.40	11-19-70	10	1.0	S
770	140	42	6	61 132	490	59.00	11-03-66	12	.15	H
817	80	--	6.00	--	400	7.00	04-01-71	30	--	N
1093	150	--	6.00	--	485	--	--	20		H
1205	138	130	5.5	50 135	486	25.35	7-25-73	12	--	H
1395	--	--	--	--	950	10.78	11-21-84	--	--	U
1396	--	--	--	--	1000	--	--	--	--	H
1410	120	41	6	--	920	37.61	03-30-83	8	--	H
1433	--	--	6	--	510	37.07	03-01-84	--	--	H
1434	175	122	6	--	510	60.7	11-01-84	12.0	--	H
1435	280	--	6	220 270	900	166.14	11-01-84	3	--	H
1436	--	--	--	--	480	16.16	11-30-84	--	--	H
1437	--	--	6	--	475	26.98	11-30-84	--	--	H
1438	--	183	6.25	--	660	29.34	11-01-84	300	--	H
1683	--	--	--	--	960	33.40	11-01-84	--	--	H
699	212	40	6.25	92 140 190	680	0.0	10-23-63	35	.35	P
700	310	125	8	--	820	--	--	60	--	P
702	678	152	6	18 38 205	880	5.00	02-03-59	60	.41	P
723	360	--	--	--	620	--	--	300	--	P
1042	145	145 140	4.00 6.00	143	640	135	11-19-81	60	--	H
1045	135	107	6.00	113	550	52	11-01-80	100	1.20	A
1046	173	156	6.00	158	550	50.00	11-01-80	100	0.81	A
1048	137	50	6.00	58 74 113	1240	10.00	11-14-75	25	0.20	H
1049	120	42	6.00	68 111	950	3.83	09-03-81	12	0.10	H
1050	140	68	6.00	82	1210	12.00	03-01-79	20	0.16	S
1051	501	63	6.00	190 440	950	--	--	1	--	H
1052	180	43	6.00	86	955	38.00	06-02-77	5	0.4	H
1053	--	--	--	--	1010	--	--	10	--	H
1091	640	60	6.00	184	1070	--	--	3	--	C

Table 11.--Records of selected wells--Continued

Explanation of codes: Aquifer codes are presented in table 2. [Use of water: C, Commercial; H, Domestic; I, Irrigation; J, Industrial (Cooling); N, Industrial; P, Public supply; S, Stock; U, Unused; Z, Other. A dash indicates no value reported.]

Local well number	Site-ID	Owner	Contractor	Date well constructed	Aquifer code
1115	401902076111401	Schreffler	--	01-01-72	000GRGS
1116	401911076105001	Vecchio	--	--	000GRGS
1117	401828076104501	Hirschritt	--	--	000GRGS
1118	401937076110001	Gehmn	--	--	000HBLD
1119	401955076100001	Harris	--	--	000GRGS
1120	401855076250001	Weitzel	--	--	000GRGS
1121	401911076102001	Royer	--	--	000HBLD
1122	401909076114601	Minnick	--	--	000HBLD
1123	401804076121301	Parkinson	--	--	000GRGS
1124	401914076122801	Richland Borough	--	--	377HRDS
1125	401951076104401	Eagles Peak Campground	0319	--	000HBLD
1126	401956076103201	Eagles Peak Campground	0319	--	000HBLD
1127	401943076111001	Bachman	--	--	000HBLD
1128	401946076110701	Hickernell	--	--	000HBLD
1129	401931076101301	Nathan	0319	01-01-81	000HBLD
1130	401819076115301	Phares Shirt	1258	01-01-84	000GRGS

Table 11.--Records of selected wells--Continued

Explanation of codes, continued: Contractor: 0109, R.H. Stanley; 0128, R.D. Grant; 0188, C.S. Garber & Sons; -200, C. Brendel; 0271, J.H. Mays; 0319, Myers Brothers; 0561, Kohl Brothers; 1271, Gill Inc.; 1328, Fisher's; 1258, F.R. Sensenig, 0319, J. Bucci

Local well number	Depth of well (feet)	Bottom of casing (feet)	Diameter of casing (in.)	Top of open interval (feet)	Altitude of land surface (feet)	Water level (feet)	Date water level measured	Discharge (GPM)	Specific capacity (gal/min)/ft	Primary use of water
1115	110	--	6.5	--	1050	39.33	03-01-84	3	--	H
1116	30	--	6	--	955	11.33	03-01-84	10	--	H
1117	--	--	--	--	1100	6.54	03-01-84	--	--	H
1118	--	--	--	--	1080	--	--	--	--	H
1119	--	--	--	--	955	3.62	03-01-84	--	--	U
1120	--	--	--	--	1145	19.97	03-01-84	--	--	H
1121	--	--	6	--	920	48.71	03-01-84	--	--	U
1122	--	--	--	--	1235	15.91	03-01-84	--	--	H
1123	--	--	--	--	720	5.35	03-01-84	--	--	H
1124	700	--	--	--	940	27.50	03-01-84	80	--	U
1125	300	43	--	--	985	16.79	12-01-84	3	0.038	R
1126	300	27	6	--	1000	21.04	12-01-84	7	--	U
1127	--	--	--	--	1120	15.63	11-01-84	--	--	H
1128	--	--	--	--	1100	26.11	11-01-84	--	--	H
1129	175	41	6	--	1025	17.17	11-01-84	15	--	H
1130	220	68	6.5	00	880	12.36	11-01-84	6	--	U

Tsble 12-- Chemical analysis of water from selected wells snd streams

Local iden- tifier	Aquifer code	Date	Calcium dis- solved (mg/L as Ca) (00915)	Magne- sium, dis- solved (mg/L ss Mg) (00925)	Sodium, dis- solved (mg/L as Na) (00930)	Potas- sium, dis- solved (mg/L as K) (00935)	Silica, dis- solved (mg/L as SiO_2) (00955)	Nitro- gen, nitrate dis- solved (mg/L as N) (00618)	Chlo- ride, dis- solved (mg/L as Cl) (00940)	Sulfate dis- solved (mg/L as SO_4) (00945)	Iron, dis- solved (µg/L as Fe) (01046)	Manga- nese, dis- solved (µg/L ss Mn) (01056)	Phos- phorus, ortho, dis- solved (mg/L ss P) (00671)	Alka- linity WH Wat total field (mg/L as $CaCO_3$ (00410)	pH (stand- ard units) (00400)	Solids, residue at 180 Deg. C dis- solved (mg/L) (70300)	Temper- sture (Deg C) (00010)	Hard ness (mg/L as $CACO_3$) (00900)
								Berks County										
BE-475	3640NTN	12-14-71	65	8.7	4.1	0.5	11	0.00	5.3	59	50	30	0.003	135	7.80	237	--	200
755	367EPLR	12-15-71	100	12	5.9	2.5	9.2	13.3	20	33	20	10	0.00	193	7.60	311	--	300
756	367EPLR	12-14-71	100	26	9.5	5.0	9.0	8.59	20	38	480	10	0.00	303	7.40	423	--	360
759	371RCLD	12-14-71	25	11	0.8	2.7	8.7	0.678	1.8	0.4	50	30	0.036	105	8.00	114	--	110
768	364JKBG	12-14-71	100	11	12	2.5	12	4.75	45	82	10	60	0.00	147	7.60	386	--	300
1093	361MRBGL	12-16-71	58	4.0	4.4	0.6	9.2	0.068	8.7	63	20	40	0.003	98	8.00	208	--	160
1395	000GRGS	09-04-84	19	9.1	16	1.5	24	8.29	20	54	720	30	--	12	5.30	--	12.0	85
1396	000GRGS	09-04-84	9.4	2.1	11	2.0	25	--	1.6	13	<10	10	--	14	5.50	--	13.0	32
1410	000HBLD	09-20-82	7.5	4.0	6.5	1.4	--	4.80	5.0	5.0	--	--	0.01	21	5.70	76	12.0	35
Surface-water site #1		10-11-84	11	3.9	5.4	1.4	18	--	5.0	17	40	<10	--	28	7.30	--	14.5	44
								Lebanon County										
Surface-wster site #2		10-11-84	12	4.4	3.7	1.3	--	--	--	--	20	<10	--	26	6.70	--	14.5	48
LB-1115	000GRGS	09-04-84	5.9	1.9	6.5	0.8	22	--	8.4	16	<10	<10	--	10	5.60	--	12.0	23
1116	000GRGS	09-04-84	.2	0.1	37	0.2	25	--	5.8	26	30	<10	--	26	6.00	--	14.0	1
1117	000GRGS	09-04-84	5.6	2.1	5.0	1.1	20	--	3.4	3.7	<10	<10	--	12	5.50	--	17.0	23
1118	000HBLD	09-04-84	7.1	3.0	4.4	0.6	33	--	1.7	1.1	<10	<10	--	36	6.00	--	12.0	30