WATER RESOURCES AND THE HYDROLOGIC EFFECTS OF COAL MINING IN WASHINGTON COUNTY, PENNSYLVANIA

U.S. GEOLOGICAL SURVEY
Open-File Report 89-620

Prepared in cooperation with the

PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES,
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY,

and the

WASHINGTON COUNTY PLANNING COMMISSION,

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WASHINGTON COUNTY CONSERVATION DISTRICT

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Lemoyne, Pennsylvania
1993

U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
	Flow	
foot per day (ft/d)	0.3048	meter per day (m/d)
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]
gallon per minute (gal/min)	0.06308	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]

CONVERSION FACTORS AND ABBREVIATIONS--Continued

Other Abbreviations

microsiemens per centimeter at 25 degrees Celsius (μS/cm) [formerly micromhos per centimeter at 25 degrees Celsius (μmhos/cm)]

milligrams per liter (mg/L)

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 "Sea Level Datum of 1929."

WATER RESOURCES AND THE HYDROLOGIC EFFECTS OF COAL MINING IN WASHINGTON COUNTY, PENNSYLVANIA

by Donald R. Williams, John K. Felbinger, and Paul J. Squillace

ABSTRACT

Washington County occupies an area of 864 square miles in southwestern Pennsylvania and lies within the Pittsburgh Plateaus Section of the Appalachian Plateaus physiographic province. About 69 percent of the county population is served by public water-supply systems, and the Monongahela River is the source for 78 percent of the public-supply systems. The remaining 31 percent of the population depends on wells, springs, and cisterns for its domestic water supply.

The sedimentary rocks of Pennsylvanian and Permian age that underlie the county include sandstone, siltstone, limestone, shale, and coal. The mean reported yield of bedrock wells ranges from 8.8 gallons per minute in the Pittsburgh Formation to 46 gallons per minute in the Casselman Formation. Annual water-level fluctuations usually range from less than 3 ft (feet) beneath a valley to about 16 ft beneath a hilltop. Average hydraulic conductivity ranges from 0.01 to 18 ft per day. Water-level fluctuations and aquifer-test results suggest that most ground water circulates within 150 ft of land surface.

A three-dimensional computer flow-model analysis indicates 96 percent of the total ground-water recharge remains in the upper 80 to 110 ft of bedrock (shallow aquifer system). The regional flow system (more than 250 ft deep in the main valley) receives less than 0.1 percent of the total ground-water recharge from the Brush Run basin. The predominance of the shallow aquifer system is substantiated by driller's reports, which show almost all water bearing zones are less than 150 ft below land surface. The modeling of an unmined basin showed that the hydrologic factors that govern regional ground-water flow can differ widely spatially but have little effect on the shallow aquifers that supply water to most domestic wells. However, the shallow aquifers are sensitive to hydrologic factors within this shallow aquifer system (such as ground-water recharge, hydraulic conductivity of the stream-aquifer interface, and hydraulic conductivity of the aquifer). A vertical fracture zone would probably increase ground-water availability within the zone and would probably result in a lower head in the shallow aquifers in an upland draw area and an increased head in a valley.

Streams in the northern and western parts of the county drain to the Ohio River and streams in the eastern and southern parts of the county drain to the Monongahela River. The computed 7-day, 10-year low-flow frequencies for the surface-water sites ranged from 0.0 to 55 × 10^{-3} cubic feet per second per square mile. The lowest low-flow discharges per square mile were in the south-central and southwestern parts of the county. The highest low-flow discharges per square mile were in the eastern and northern parts of the county. The annual water loss at five gaged streams ranged from 52 to 75 percent of the total precipitation. The loss resulted from evaporation, transpiration, diversion, mines, ground-water outflow from the system, and plant and animal consumption.

The major ground-water-quality problems are elevated concentrations of iron, manganese, and dissolved solids, and very hard water. Minor ground-water-quality problems include elevated concentrations of fluoride, chloride, and sulfate. Downgradient along the ground-water flow path, principal ions change from mostly calcium, magnesium, sulfate, and bicarbonate to sodium and chloride. Dissolved-solids concentrations generally increase with residence time. Elevated concentrations of sulfate and total dissolved solids were common at the surface-water sites in the northern and eastern parts of the county where most of the active and abandoned coal mines are located and where acid mine drainage is most prevalent. However, measured alkalinity at most of the surface-water sites ranged from 86 to 345 milligrams per liter, indicating that these streams would have a neutralizing effect on most inflows of acid mine drainage.

The model of the hypothetically mined Brush Run basin shows that the vertical hydraulic conductivity (either existing or induced by mine subsidence) between the shallow ground-water system and the mine, and the depth to the mine are critical controls on the amount of ground water entering the mine. When the vertical hydraulic conductivity was increased by a factor of four for a mine about 250 ft deep in the main valley, inflow to the mine increased almost by the same factor. The model also shows that increasing the depth to a mine by 200 ft (mine about 450 ft deep in main valley) would cause mine inflow to decrease one order of magnitude.

Comparisons between stream discharges during low base-flow conditions in a mined basin (Daniels Run) and an unmined basin (Brush Run) indicated that the deep mining did not substantially lower streamflow. Although streamflow decreased and, at times, completely disappeared in the middle and lower parts of Daniels Run basin, it reappeared again downstream as ground-water discharge and was part of the flow at the mouth of Daniels Run. Comparison of the water-quality characteristics of the two basins showed that concentrations of dissolved solids, sulfate, sodium, chloride, fluoride, and manganese were greater in the mined basin than in the unmined basin. The pH and iron concentrations were similar in both basins.

INTRODUCTION

Water managers and residents of Washington County are concerned about the actual and potential effects of large-scale mining on their water resources, particularly in the southwestern part of the county, which contains a significant percentage of the nation's high-grade bituminous-coal reserves. People are concerned particularly about the reduction of ground-water storage in shallow aquifers above potential underground coal mines. These aquifers are the source of waters to numerous municipal and individual water-supply systems. Overlying aquifers have been fractured and dewatered in parts of eastern Washington County because of the collapse of unsupported roofs in some of the deep coal mines. Of equal concern is the effect of underground coal mining on the water supply in municipal surface-water reservoirs, which supply water to many county residents.

The principal sources of water contamination in Washington County are domestic sewage, industrial discharges, and acid mine drainage (AMD). AMD, the chief source of water contamination, is the result of more than 100 years of surface and underground coal mining, primarily in the eastern and northern parts of the county. AMD has affected the quality of surface and ground waters, the public water-supply systems, and water-oriented recreation throughout the mined parts of the county.

If coal continues to be a significant energy resource for the rest of this century, major initiatives will be taken to recover the coal reserves remaining in southwestern Washington County. This could expand the water-supply and AMD problems to presently unmined areas of the county. In response to these concerns, this study was undertaken by the U.S. Geological Survey in cooperation with the Pennsylvania Topographic and Geologic Survey, the Washington County Planning Commission, and the Washington County Conservation District.

Purpose and Scope

This report describes the hydrogeology, water resources, and the effects of coal mining on the water resources. Ground-water data, which include water levels, well and spring yields, and water quality are used to describe the hydrologic conditions of the geologic formations underlying Washington County. Surface-water-quantity and quality data are used to describe the surface-water characteristics and the severity of AMD throughout the county. The hydrologic effects of coal mining are shown by comparing the hydrologic conditions throughout the county, and in particular, the conditions in the unmined Brush Run basin are compared with those in the mined Daniels Run basin. A three-dimensional ground-water-flow model defines the ground-water-flow systems in the unmined basin and simulates conditions under several possible underground mine situations.

Previous Investigations

The coal, oil, and gas resources of southwestern Pennsylvania have provided the impetus for many geologic publications dating back to the early 19th century. A few of these studies are listed by Berryhill and others (1971, p. 3), Socolow and others (1980, p. 47-48), and Piper (1933, p. 2-4).

There are 14 published 7-1/2-minute geologic maps (table 1) and a few recent publications that describe the geology of various parts of the county. Kent and others (1969) discussed the geology and land use in the eastern part of the county. Berryhill and others (1971) further defined the stratigraphy, sedimentation, and economic and engineering geology of the coal-bearing rocks of Late Pennsylvanian and Early Permian age near the city of Washington.

Piper (1933) published the first comprehensive ground-water investigation in southwestern Pennsylvania. Piper's investigation involved the collection of well data and interpretation of the occurrence of ground-water quantity and quality with respect to the rock formations and structure. He also discussed the best methods of well construction and recovery of water. Poth (1962) summarized the occurrence and chemical quality of brine in western Pennsylvania. Newport (1973) published a summary of ground-water resources of Washington County in which he discussed the hydrologic cycle, water-bearing characteristics of the geologic units, and problems threatening the ground water. Chester Engineers (1971) conducted a water-resources study of the Tenmile Creek basin which provided information on streamflow, flood flows and frequencies, water quality, and water supply. Beall (1975) did a stream reconnaissance of nutrients and other water-quality constituents in the greater Pittsburgh region, which included Washington County. Page and Shaw (1977) examined selected sites in Washington County as part of their work on the low-flow characteristics of Pennsylvania streams. During 1979-81, the U.S. Geological Survey measured streamflow and sampled water chemistry and aquatic invertebrates at selected stream sites in the coal region that included Washington County (Herb and others, 1981; Roth and others, 1981).

Table 1.--Names and authors of the 7-1/2-minute geologic-map quadrangles in Washington County

Geologic quadrangle name	Authors
Amity	Berryhill (1964)
Avella and part of the Steubenville East	Schweinfurth (1976)
California	Schweinfurth (1967)
Carmichaels	Kent (1969a)
Ellsworth	Berryhill and Schweinfurth (1964)
Hackett	Kent (1967)
Mather	Kent (1969b)
Midway	Roen (1973)
Monongahela	Roen, Kent, and Schweinfurth (1968)
Prosperity	Kent (1972)
Washington East	Swanson and Berryhill (1964)
Washington West	Berryhill and Swanson (1964)
Waynesburg	Roen (1970)
West Middletown and part of Bethany	Schweinfurth (1975)

Geography

Washington County is near the southwestern corner of Pennsylvania and includes an area of 864 mi^2 (square miles) (fig. 1). The county is bordered on the north by Beaver and Allegheny Counties, on the east by Westmoreland and Fayette Counties, on the south by Greene County, and on the west by West Virginia.

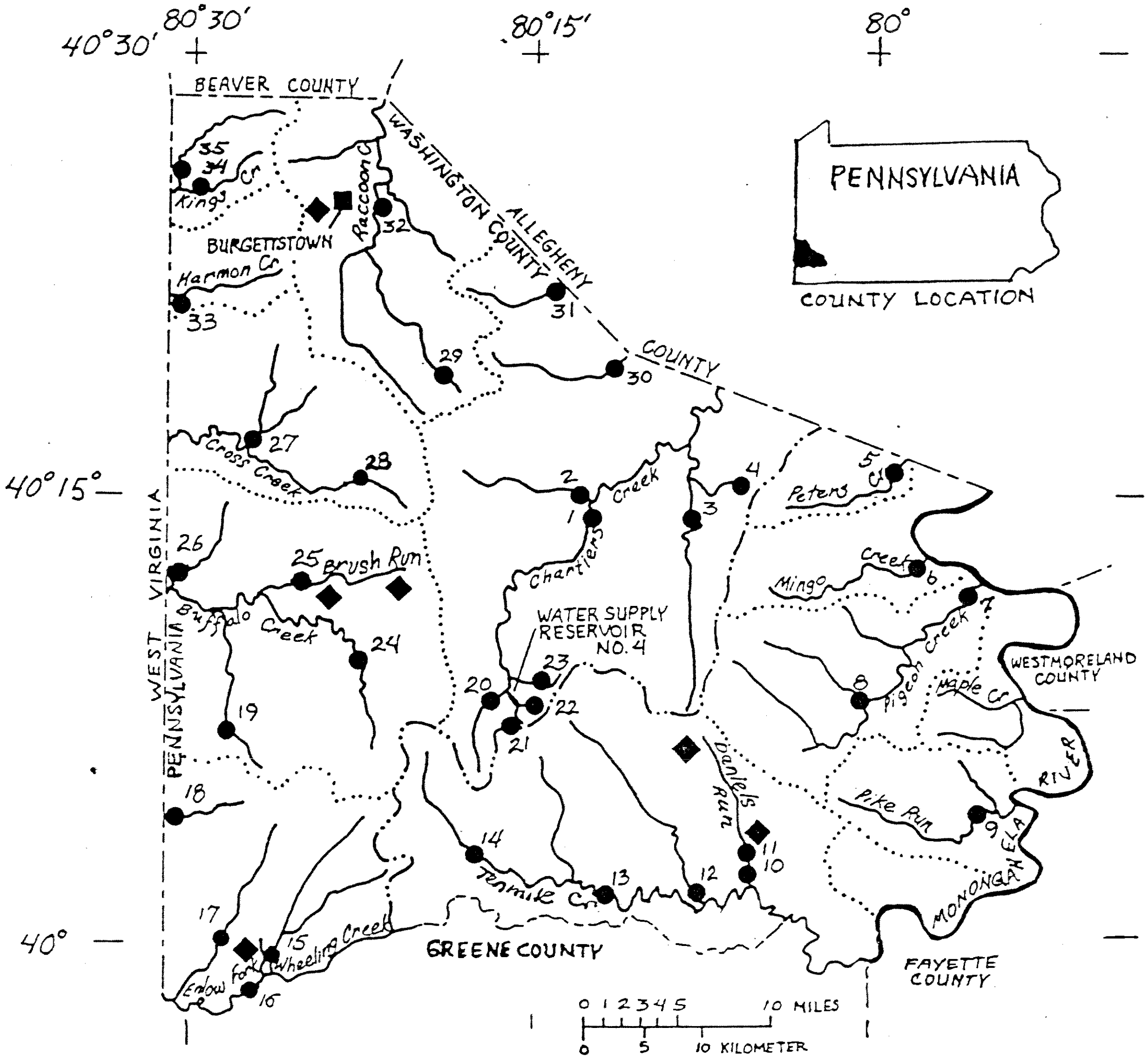
Washington County is in the Pittsburgh Plateaus Section of the Appalachian Plateaus physiographic province. The present land surface was formed through the erosion by streams of a former plain. Remnants of this ancient plain slope from altitudes of about 1,500 ft above sea level in the southern part of the county to about 1,200 ft in the northern part. Stream erosion has created a complexly dissected area, having as much as 750 ft of relief between hilltops and valley bottoms. Tributary streams generally lie in V-shaped valleys, and their gradients are much steeper than those of the major streams.

Washington County is drained by several streams, all of which eventually flow into either the Ohio River on the west and north or into the Monongahela River on the east. The major streams that drain westward into the Ohio River include Kings Creek, Harmon Creek, Cross Creek, Buffalo Creek, and Enlow Fork of Wheeling Creek. Draining to the north and northeast into the Ohio River are Raccoon Creek and Chartiers Creek. Draining to the east into the Monongahela River are Peters Creek, Mingo Creek, Pigeon Creek, Maple Creek, Pike Run, and Tenmile Creek.

The 1980 population of Washington County was 217,000. Most of the large municipalities are in the extreme eastern part of the county along the Monongahela River and in the central part of the county. The populations of these municipalities have decreased within the last 10 years, while the small, rural municipalities have increased.

Agricultural land accounts for about 47 percent of the total land use. Because of the soils and slopes throughout the county, hayland and pastureland rank largest in agricultural land use. Forest land covers about 35 percent of the county's total area and a large percentage is not readily adaptable to most uses because of the steepness of the terrain. County and community parks, surface mines, state gamelands, and areas of commercial, industrial, and residential development make up the remaining land use.

The climate of Washington County is humid continental. Annual precipitation for 1949-85 averaged 36.4 in. (inches) at Donora on the eastern border of the county and 40.2 in. at Burgettstown in the northern part of the county (U.S. Department of Commerce). Summers generally are mild to warm and humid; the mean temperature is about 70 °F (degrees Fahrenheit). Winters generally are cold; the mean temperature is about 30 °F. The average annual snowfall is about 30 in. The prevailing wind is generally from the west-southwest.



EXPLANATION

— · · — BOUNDARY BETWEEN OHIO AND MONONGAHELA RIVER BASINS

· · · · · · · DRAINAGE DIVIDE

● 12 SURFACE-WATER DATA SITE AND NUMBER

■ TOWN

◆ PRECIPITATION GAGE

Figure 1.--Surface-water sites and drainage basins.
(See table 3 for names of stations.)

Water Use

In 1984, withdrawals for public water-supply systems in Washington County averaged about 24.2 Mgal/d (million gallons per day). About 69 percent of the total population was served by public water supplies, and the remaining 31 percent depended on wells, springs, and cisterns for their domestic supply. The large municipalities, such as Washington and Canonsburg, and the towns along the Monongahela River and other sparsely-populated areas scattered throughout the county depend largely on public water-supply systems. The main water-supply companies serving the majority of the residents of Washington County are listed in table 2. The data in table 2 are based on information from the State Water Plan of the Pennsylvania Department of Environmental Resources (1984). Rivers, streams, and reservoirs are the sources of 98.8 percent of the water for the public supply systems; wells provided 1.0 percent of the water and springs provided 0.2 percent. The Monongahela River supplies more than 78 percent of the water used by the public-supply systems. Figure 2 shows the approximate areas served by the major water-supply systems. Areas in figure 2 not serviced by public supplies depend mainly on wells, springs, and cisterns for water supply.

Acknowledgments

We gratefully acknowledge the interest and cooperation of the many individual land owners and companies throughout the county who provided access to private property for the collection of the field data for this study. A special thanks goes to the following persons, companies, organizations, and government agencies who permitted us to install hydrologic monitoring equipment on their property: Mr. Ralph Barnhart; Mrs. Margaret Brown; Mr. William Calvert; Mr. Charles Chase; Mr. Kenneth Craft; Mr. Arthur Foertsch; Mr. Mike Guza; Mr. Jason Meloy; Mr. Jack Pritts; Mr. Angelo Quarture; Mr. Edward Schultz; Mr. Reed Shaw; Mr. David Smith; Consol, Pennsylvania Coal Company; Mount Pleasant Township; Pennsylvania Department of Transportation; Pennsylvania Game Commission; and Western Pennsylvania Water Company, Washington District. We also thank the Vesta Mining Company for providing us with mine pumping rates and mine maps, which were extremely useful for the study.

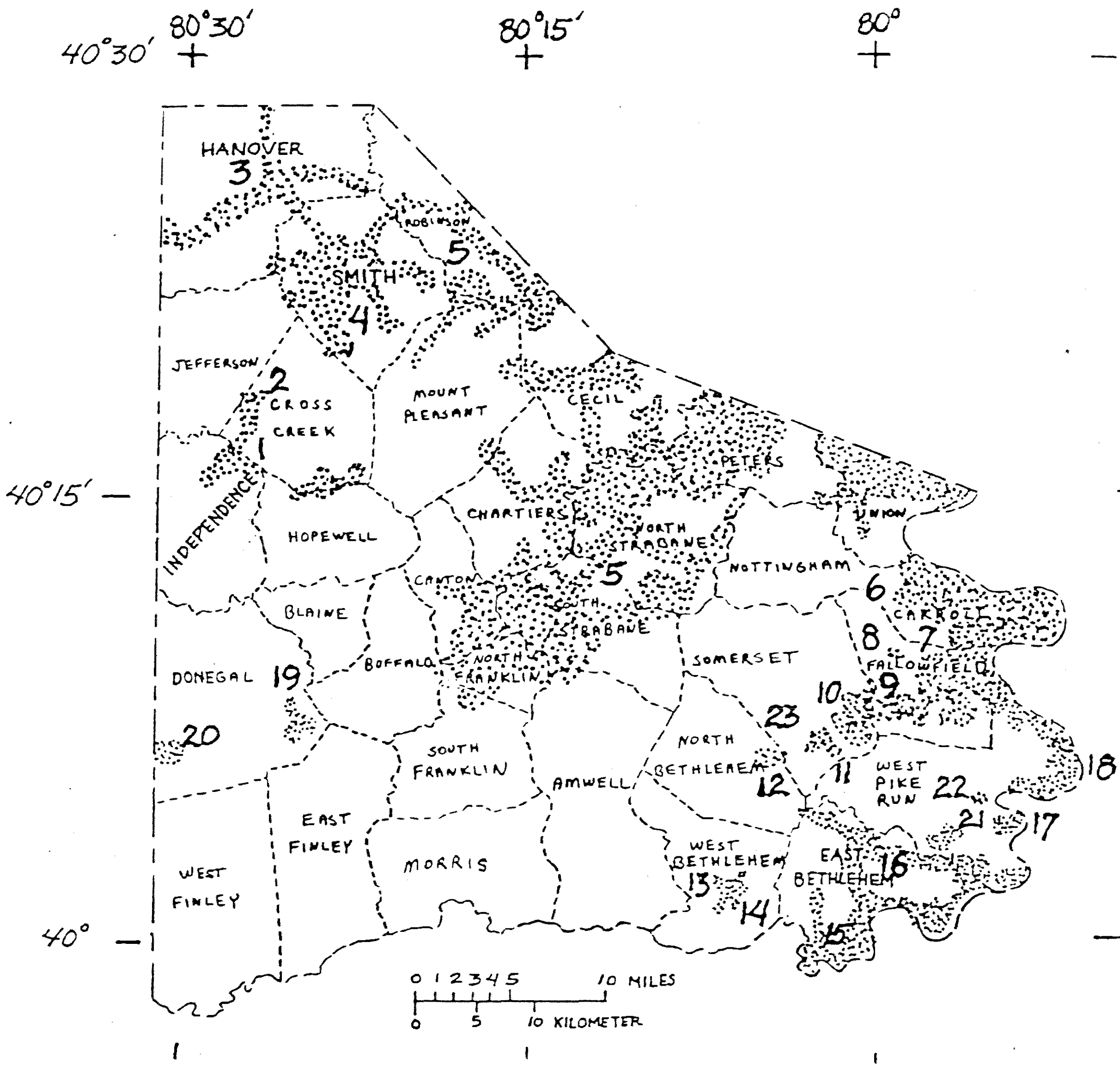
The Pennsylvania Department of Environmental Resources, Division of Mine Subsidence Office in McMurray, Pa., provided us with valuable information on the extent and depth of underground mining throughout the county.

Table 2.--Water use for public-supply systems in Washington County, Pennsylvania for 1984

[--, no data available. Data from Pennsylvania Department of Environmental Resources, Annual Water Supply Report, 1984]

	Water company[1]	Water source	Average daily consumption, in gallons per day: Domestic	Commercial and industrial	Other	Total
1.	Independence Municipal Authority	Donahue Dam	48,300	2,000	30,700	81,000
2.	Cedar Grove Water Association	Donahue Dam	17,600	1,200	--	18,800
3.	P-F Area Water Association	Ground-water wells from Weirton, W.Va.	111,000	11,000	31,000	153,000
4.	Smith Township Municipal Authority	Dinsmore Dam and one well	237,000	73,800	34,500	345,300
5.	Western Pennsylvania Water Company, McDonald and Washington District	Chartiers Creek Reservoirs 1, 3, 4; Little Chartiers Creek Reservoirs 1 and 2; Monongahela River	6,132,000	5,575,000	681,000	12,388,000
6.	Western Pennsylvania Water Company, Monongahela District	Monongahela River	1,309,000	280,500	280,500	1,870,000
7.	Charleroi Municipal Authority	Monongahela River	1,680,000	3,760,000	1,050,000	6,490,000
8.	Van Voorhis Water Company	Spring	7,240	--	--	7,240
9.	McCormick Water Company	Monongahela River	3,420	--	3,530	6,950
10.	Bentleyville Water Company	Monongahela River	107,800	43,900	45,300	197,000
11.	Ellsworth Water Company	Pigeon Creek	63,500	177,000	65,900	306,400
12.	Cokeburg Water Company	South Branch Pigeon Creek	39,900	--	--	39,900
13.	Marianna Water Company	Tenmile Creek	37,400	175,000	119,000	331,400
14.	West Bethlehem Township Water Company	Tenmile Creek	20,100	--	9,800	29,900
15.	Southwestern Pennsylvania Water Authority	Monongahela River, South Fork Tenmile Creek	33,600	2,700	1,200	37,500
16.	Tri-County Joint Municipal Authority	Monongahela River	280,000	114,000	15,000	409,000
17.	California Water Company	Monongahela River	309,000	37,600	51,400	398,000
18.	Washington Township Municipal Authority	Monongahela River	146,000	650,000	--	796,000
19.	Claysville-Donegal Joint Municipal Authority	Tributary of Buffalo Creek	50,000	13,000	20,000	83,000
20.	West Alexander Borough Municipal Authority	Ohio River	27,400	700	1,400	29,500
21.	Redstone Water Company	Spring	34,700	--	--	34,700
22.	Somerset Water Company	Pigeon Creek	5,500	--	3,000	8,500
23.	Bethenergy Mines, Inc.	Central Branch Pigeon Creek	1,600	176,000	2,300	179,900
	TOTALS		10,702,060	11,093,400	2,445,530	24,240,990

[1]Locations shown on figure 2.



EXPLANATION

SHADED AREAS SERVED BY PUBLIC WATER SUPPLIES

20 WATER-SUPPLY COMPANY SERVICING SHADED AREA (listed in table 2)

MORRIS NAMES WITHIN DASHED AREAS ARE TOWNSHIPS

Figure 2.--Areas served by public water-supply companies.

METHODS OF INVESTIGATION

A description of the geology of Washington County was compiled from several geologic maps onto a single county map (plate 1). The geology was used to establish the framework for ground-water occurrence, movement, and quality. More than 500 domestic wells and 50 springs were inventoried to define the availability of ground water with respect to geologic formation and topographic position. To help quantify ground-water occurrence and flow, aquifer tests and slug tests were made and geophysical logs were run on nine wells. Water-level recorders were installed on these nine observation wells to determine characteristics of ground-water recharge and premining water-level fluctuations. Water-level data were collected at 12 additional observation wells in Greene County that were drilled for the Greene County Water Resources Study (Stoner and others, 1987). Similarities in the geology and mining conditions in Greene County make such data comparable with Washington County water-level data. Water levels in about 150 of the inventoried domestic wells in 14 populated areas in the unmined section of the county (fig. 3) were measured 4 to 5 times between 1983 and 1985. This information was used as a generalized, premining water-level data base.

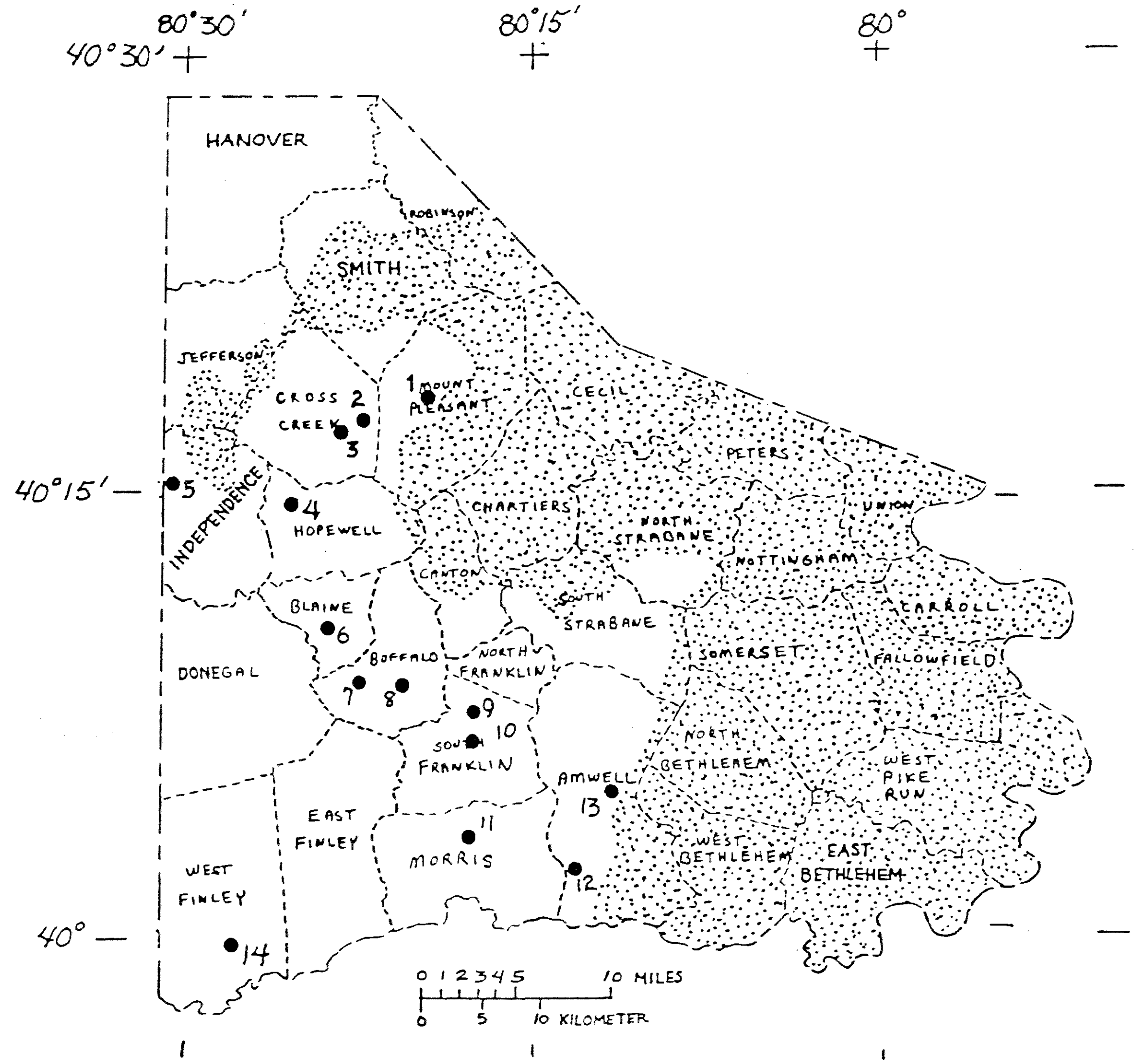
Water samples from the nine observation wells were collected for water-quality analyses after pumping the wells until the specific conductance had stabilized. Water samples were collected from house taps of 90 domestic well systems that did not have filters or water conditioners.

Thirty-five sites for measuring surface-water quantity and quality were established throughout the county (fig. 1 and table 3). Sites 11, 16, 20, 21, 22, and 25 were streamflow-gaging stations where continuous streamflow data were recorded. Instantaneous streamflow data were recorded at the other 29 sites. Sites 15 and 16 were part of the surface-water network of the Greene County Water Resources Study from September 1979 through September 1982 (Stoner and others, 1987). Sites 1, 2, 3, 6, 8, 10, 13, 27, 28, 32, 33, and 34 were part of the U.S. Geological Survey Coal Hydrology Network that was sampled from 1979-81. Streamflow data were collected at site 25 from 1960-78 as part of the U.S. Geological Survey's streamflow-gaging network.

Water samples were collected four times from 1983-85 at all surface-water sites during low and high base flows. Samples were collected more frequently at the six streamflow-gaging stations. Water-quality data collected from previous studies are also reported. Water-quality field measurements of ground water and surface water included acidity, alkalinity, specific conductance, pH, and temperature. Laboratory analyses included dissolved calcium, magnesium, sodium, potassium, sulfate, chloride, fluoride, silica, boron, total and dissolved iron, total and dissolved manganese, and total dissolved solids. Total sulfide was determined for ground-water samples only. Trace elements analyzed for the nine observation wells included dissolved aluminum, arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, strontium, and zinc. The samples were analyzed at the U.S. Geological Survey laboratory in Doraville, Georgia.

The effects of coal mining on the water resources were determined by comparing the hydrologic conditions in a mined basin (Daniels Run) and an unmined basin (Brush Run). Two recording rain gages were installed in each basin. Surface-water discharge from each basin was recorded at a stream-gaging station. Ground-water discharge in each basin was measured by five seepage runs made during base-flow periods in the spring and fall during 1983-85. Continuous water-level data were recorded at one observation well in the Daniels Run basin and at two observation wells in the Brush Run basin. Additional water-level data were collected at 20 domestic wells in the Daniels Run basin and at 25 domestic wells in the Brush Run basin.

A three-dimensional ground-water model was constructed to improve the understanding of ground-water-flow concepts in the Brush Run basin. The steady-state calibration of the model was based on hydrologic data collected in the basin, from data transferred from areas outside the basin in Washington County, and from the results derived from the Greene County Water Resources Study (Stoner and others, 1987). Finally, simulations of several underground mine scenarios were conducted to determine potential effects mining would have on the hydrologic system.



EXPLANATION

● POPULATION CENTERS

1. Hickory
2. Woodrow
3. Rea
4. West Middletown
5. Independence
6. Taylorstown
7. McGuffy Educational Complex
8. Taylorstown Exit
9. Lagonda
10. South Franklin Manor
11. Posperity
12. Lone Pine
13. Amity
14. West Finley

DEEP-MINED AREAS

UNION NAMES WITHIN DASHED AREAS ARE TOWNSHIPS

Figure 3.--Locations of areas where water levels in domestic wells were measured four to five times.

Table 3.--Site numbers, station numbers, station names, and drainage areas for surface-water sites

Site number	Station number	Station name	Drainage area in square miles
1	03085237	Chartiers Creek at Houston, Pa.	54.5
2	03085240	Chartiers Run at Houston, Pa.	22.3
3	03085300	Little Chartiers Creek at Linden, Pa.	37.0
4	03085310	Res #2 Little Chartiers Creek near McMurray, Pa.	.75
5	03075081	Peters Creek at Gastonville, Pa.	13.6
6	03075058	Mingo Creek at River View, Pa.	22.2
7	03075037	Pigeon Creek at Hazel Kirk, Pa.	52.6
8	03075035	North Branch Pigeon Creek at Bentleyville, Pa.	11.1
9	03074800	Pike Run at Daisytown, Pa.	20.9
10	03072820	Daniels Run at West Zollarsville, Pa.	12.2
11	03072818	Daniels Run near West Zollarsville, Pa.	8.47
12	03072817	Little Tenmile Creek near Tenmile, Pa.	27.2
13	03072815	Tenmile Creek near Amity, Pa.	51.6
14	03072813	Tenmile Creek at Prosperity, Pa.	13.5
15	03111580	Templeton Fork near West Finley, Pa.	20.8
16	03111585	Enlow Fork near West Finley, Pa.	38.1
17	03111603	Robinson Fork at West Finley, Pa.	14.8
18	03111900	Middle Wheeling Creek near West Alexander, Pa.	10.4
19	03111220	Dutch Fork Creek near Claysville, Pa.	13.8
20	03085217	Chartiers Creek at Lagonda, Pa.	3.97
21	03085220	Unnamed Tributary 2B to Chartiers Creek at Lagonda, Pa.	.38
22	03085221	Unnamed Tributary 1 to Chartiers Creek at Lagonda, Pa.	.90
23	03085224	Res #3, Chartiers Creek near Washington, Pa.	.98
24	03111140	Buffalo Creek at Taylorstown, Pa.	30.9
25	03111150	Brush Run near Buffalo, Pa.	10.3
26	03111250	Sugarcamp Run at Frogtown, Pa.	9.17
27	03111005	North Fork Cross Creek at Avella, Pa.	16.3
28	03111001	Cross Creek near Hickory, Pa.	4.17
29	03107690	Raccoon Creek near Hickory, Pa.	3.73
30	03085400	Millers Run at Cecil, Pa.	13.9
31	03085450	Robinson Run at McDonald, Pa.	7.84
32	03107600	Raccoon Creek at Raccoon, Pa.	18.9
33	03110920	Harmon Creek near Hanlin Station, Pa.	19.9
34	03110812	Kings Creek near Florence, Pa.	7.10
35	03110820	Aunt Clara Fork near Paris, Pa.	14.2
[1]36	03073000	South Fork Tenmile Creek at Jefferson, Pa.	180
[2]37	03112000	Wheeling Creek at Elm Grove, W. Va.	282

[1]Site 36 is in Greene County, Pennsylvania

[2]Site 37 is in Ohio County, West Virginia

HYDROGEOLOGIC FRAMEWORK

Geologic Setting

The geology of Washington County includes sedimentary rocks of Pennsylvanian and Permian age (plate 1) and alluvial deposits of Quaternary age that occupy the valley bottoms. The oldest exposed bedrock unit, the Glenshaw Formation, crops out in the valley bottoms in the extreme northwest corner of the county. The youngest bedrock unit, the Greene Formation, underlies most of southwest and south central Washington County. A geologic cross section of the county is shown on plate 1. Washington County stradles two structural motifs. The structure in the area is a transition between almost parallel anticlines and synclines, the axis of which trend northeastward, and an area on the outer limits of Allegheny deformation in which only the incipient stages of deformation are apparent. This outer area is characterized by short, randomly oriented axial-plane traces and domes.

The altitude of the base of the Pittsburgh coal bed, at the base of the Pittsburgh Formation, was contoured from records of oil, gas, and coal exploratory drilling; these contours show the orientation of the folding (plate 2a,b). The dips of folded limbs range from less than 20 to 180 ft/mi (feet per mile) in the central and eastern parts of the county. The base of the Pittsburgh coal bed is lowest along the axis of the Nineveh Syncline near the Greene and Washington County boundary and is highest at the Aunt Clara Dome in the northwest corner of the county (plate 2a). The Pittsburgh coal bed is easily identifiable in test borings and generally is continuous across the county except in the northernmost part where it has eroded away.

Structural features in the northern and southern parts of the county are noticeably different. Southern Washington County is characterized by a regular series of northeast trending anticlines and synclines. However, this symmetry is broken in the northern part of the county where many of these features terminate or abruptly change direction. For example, the Claysville and Washington Anticlines and the Finney Syncline are truncated near the Westland Dome. The northwestern part of the county has four domes (structural highs) and fewer folded structures. The domes and the fold interference patterns in the area may be the result of forces that created the west-to-east trending Cross Creek Syncline.

Fractures are breaks that occur in rocks when stress induces mechanical failure within a rock unit. Because movement of water through bedrock occurs primarily through fractures, it is important to understand fracture distribution and character. There are two basic types of fractures; joints are near-planar surfaces along which there has been little or no movement, while faults are breaks across rock units that have had noticeable differential movement. Jointing is a characteristic common to bedrock in all areas; faults are less common. Fracture orientation is usually controlled by bedding, being either parallel or perpendicular to the layers forming a bedrock unit.

Kohl (1980) measured the density and orientation of joints in outcrops in parts of Washington County and several other adjacent counties and reported that sandstones have the largest joint spacing; the average joint spacing for sandstone is about 8 ft. The average joint spacing of shale and limestone is about 5.5 and 2.5 ft, respectively. Coal beds have the smallest joint spacing of rock types exposed in the area; their average spacing is less than 0.2 ft. Joints commonly occur in sets, which have a definite trend or orientation. The most common and best developed joint sets in bedrock in Washington County trend N. 25 °E. and N. 65 °W. from rose diagrams by Kohl (1980).

Local stress relief of natural rock pressure in valleys causes another fracture pattern. Wyrick and Borchers (1981) concluded that stress-relief fractures in the Appalachian Plateau exhibit a horizontal orientation beneath valley floors and are vertical along valley walls.

A 1.5-mi-long fault is located south of West Middletown and east of the axis of the West Middletown Syncline (plate 2a). This fault is a possible extention of a larger fault that extends from western Fayette County across the Monongahela River into eastern Greene County.

Additional geologic information may be obtained from Berryhill, Schweinfurth, and Kent (1971), Piper (1933), and Geologic Quadrangle Maps of Washington County (authors listed in table 2).

Bedrock Formations

The stratigraphy and water-bearing properties of geologic formations are discussed in this section. The stratigraphy includes a description of the color, texture, thickness, and lithology of the formations.

The bedrock geologic map, generalized geologic column, and geologic cross section shown on plate 1 complement the discussion of this section. The thickness, relative position, and generalized lithology of the formations are shown on the geologic column. The cross section, in plate 1, shows the changes in extent and thickness of the formations along the trace of the section. A brief summary of the lithology and hydrologic characteristics of the rocks is also included on plate 1. Figure 4 presents a generalized stratigraphic column that emphasizes the dominant lithologies and the relative positioning of the geologic units and their nomenclature.

Pennsylvanian System

The Upper Pennsylvanian bedrock consists of the Conemaugh and Monongahela Groups. The combined exposed thickness is 570 to 820 ft.

Conemaugh Group

The Glenshaw and Casselman Formations comprise the Conemaugh Group in Washington County. The maximum exposed thickness of the group is 400 ft.

Glenshaw Formation.--About 150 ft of the uppermost section of the Glenshaw Formation are exposed along stream valleys in the northwestern corner of the county. The formation consists of sandstone, siltstone, shale, limestone, and coal. Sandstone is bedded to massive, fine to coarse grained. Shales commonly are variegated red and green and are argillaceous. The Ames Limestone Member, which is the uppermost unit of the Glenshaw Formation, consists of limestone and calcareous shale. The Ames Limestone Member is light greenish-gray in color, is thin to medium bedded, and is typically 3 ft thick. It contains an abundance of marine fossils including brachiopods and crinoid stem fragments. The Harlem coal bed is found anywhere from an inch to 20 ft below the Ames Limestone Member and is as much as 24 in. thick.

Few hydrologic data are available for the Glenshaw Formation because of its small areal extent. Reported well yields from 4 wells ranged from 1 to 110 gal/min (gallons per minute). A specific capacity of 0.52 (gal/min)/ft (gallons per minute per foot) was reported for one well.

Casselman Formation.--The Casselman Formation ranges in thickness from 220 to 335 ft. The formation crops out in the northwest corner of the county, along reaches of Chartiers and Peters Creeks, near the mouths of stream valleys in eastern Washington County and along the Monongahela River. The formation consists chiefly of sandstone and mudstone containing some limestone, siltstone, and thin coal beds. The sandstone is light to dark gray, micaceous, feldspathic, fine to coarse grained, thin and evenbedded to massive and crossbedded. A prominent sandstone unit is the Morgantown Sandstone Member described by Piper (1933). The siltstone in this formation is greenish gray and thin bedded to nonbedded. The mudstone is dark gray, gray green, and maroon, and contains siderite nodules and calcareous concretions. The limestone is light to dark gray, argillaceous, in beds 3 in. to 3 ft thick, and may contain fossils including fresh water ostracodes, *Spirorbis*, fish remains, and small pelecypods and gastropods. The Skelley marine zone, near the base of the formation, is the youngest marine unit in the county. All younger units were deposited in fresh water or under subaerial conditions on a deltaic plain.

Four coal beds of minor importance in the Casselman Formation are, in ascending order, the Duquesne, Elk Lick, Little Clarksburg, and Little Pittsburgh coal beds. These coals are typically of such inconsistent thickness, areal extent, and quality that they generally have not been mined.

Well-yield data from 15 wells indicate that the Casselman Formation had the highest mean well yield of all the bedrock units. The mean well yield was 46 gal/min and yields were as much as 160 gal/min. Specific capacities of two wells were 9.7 and 22 (gal/min)/ft. Three spring discharges ranged from 0.07 to 2.86 gal/min.

Monongahela Group

The Monongahela Group consists of the Pittsburgh and Uniontown Formations and ranges in thickness from 250 to 385 ft. The Monongahela Group overlies the Conemaugh Group and is exposed in the northern and eastern parts of the county.

Pittsburgh Formation.--The Pittsburgh Formation is divided into five members which in ascending order are: lower, Redstone, Fishpot, Sewickley, and upper. The Pittsburgh Formation ranges in thickness from 205 to 290 ft and consists chiefly of limestone, sandstone, siltstone, mudstone, and coal.

The lower member of the Pittsburgh Formation consisting of sandstone, siltstone, limestone, mudstone, carbonaceous shale, and coal has been reported to range in thickness from 40 to 100 ft. The basal unit of the lower member is the Pittsburgh coal bed, which is the most prominent coal bed in southwestern Pennsylvania. The Pittsburgh coal bed consists of two or more benches with clay or shale partings. The lower bench or main bench, which is the most persistent and thickest of the Pittsburgh benches, ranges in thickness from 31 to 124 in. and has an average thickness of 66 in. A sandstone unit, which overlies the Pittsburgh coal bed in places, generally represents an ancient river channel deposit truncated with widespread festoon crossbedding. Locally, the Pittsburgh coal bed is cut out by these sand-filled channels. Mudstone and limestone overlie the Pittsburgh coal bed in areas where sandstone is absent.

The Pittsburgh Rider coal bed of Hickok and Moyer (1940) is as much as 34 in. thick and is between 20 to 40 ft above the base of the Pittsburgh coal bed. The sandstone unit above the Pittsburgh Rider coal bed occurs both as sheet-like and channel-fill deposits and is related to the sandstone overlying the Pittsburgh coal bed. The sandstone is micaceous, light gray, and fine to medium grained. The mudstone in the lower member is dark gray and contains thin beds of siltstone and sandstone. The limestone is light to dark gray in color. The carbonaceous shale is black, micaceous, and grades laterally into mudstone.

The Redstone Member consists chiefly of limestone, with some mudstone, carbonaceous shale, siltstone, sandstone, and coal, and ranges in thickness from 20 to 70 ft. The basal unit, the Redstone coal bed, is composed mostly of carbonaceous shale and thin coal stringers. The coal bed, which may be as much as 60 in. thick, commonly is less than 12 in. thick. The Redstone coal bed is present only in the northeast corner of the county and has a very definite boundary (Skema, 1987). The "Redstone Member is separable from underlying member only where Redstone coal bed (or horizon) is present"

(Schweinfurth, 1967). Because the Redstone coal horizon is missing in parts of the county, the Pittsburgh Rider coal has been sometimes misidentified as the Redstone coal bed. As a result, the lower member has been erroneously reported to be as thin as 40 ft (V.W. Skema, Pennsylvania Topographic and Geologic Survey, written commun., 1988). The mudstone is dark gray and may be calcareous. Siltstone may contain siderite and limestone nodules. The limestone is olive-gray, microcrystalline, and argillaceous.

The Fishpot Member is the thinnest member of the Pittsburgh Formation. The member is as much as 40 ft thick and contains siltstone, sandstone, mudstone, carbonaceous shale, and coal. The basal unit, where present, is a carbonaceous shale equivalent to the Fishpot coal bed of Greene County and is as much as 36 in. thick. The siltstone is usually light to dark gray and occasionally black. It is characteristically very thinly bedded and locally has abundant macerated plant debris on bedding planes (Schweinfurth, 1967). The sandstone in this unit is light gray, very fine to medium grained, micaceous, and thin to thick bedded. The mudstone in this unit is light to dark gray, laminated, and may contain siderite nodules.

The Sewickley Member ranges in thickness from 40 to 65 ft and consists chiefly of limestone, with minor amounts of sandstone, claystone, carbonaceous shale, and coal. The limestone sequence that comprises most of the Sewickley Member is called the Benwood Limestone Bed by Campbell (1903). The limestone is light to dark gray, microcrystalline to finely crystalline, and very argillaceous. That part of the limestone that is a sedimentary breccia weathers to a characteristic hackly cleavage. Limestone beds are as much as 3 ft thick and are interbedded with thin claystone beds. Fossils in the limestone include fresh water ostracodes, *Spirorbis*, fish remains, small gastropods, and fresh water pelecypods. The claystone interbeds are greenish gray, partly calcareous, and bedded to nonbedded. Locally, the middle of the member contains a calcareous claystone and mudstone facies of the limestone that attains a maximum thickness of 20 ft. The basal part of the Sewickley Member generally is composed of several feet of calcareous claystone and carbonaceous shale. The Sewickley coal bed is either absent or thin with many impurities throughout Washington County. The maximum thickness of the coal is approximately 2 ft.

The upper member of the Pittsburgh Formation consists chiefly of limestone, siltstone, sandstone, and mudstone, and ranges in thickness from 50 to 90 ft. The upper member generally is divided into four more less persistent units of argillaceous limestone. These units are light to dark gray, microcrystalline to finely crystalline, and range in thickness from 2 to 15 ft. Individual limestone beds in these units are several in. to 3 ft thick and separated by thin greenish-gray claystone interbeds. A few beds are laminated, suggesting algal structure. Fossils include fresh water ostracodes, *Spirorbis*, fish remains, and small pelecypods and gastropods. Beds of greenish-gray shales, siltstone, and mudstone, 1 to 15 ft thick, commonly separate the limestone units. A dark greenish-gray, fine-grained, micaceous sandstone, which locally is massive and crossbedded, sometimes separates or replaces the limestone sequences.

The Pittsburgh Formation has the lowest mean well yield of all the bedrock formations. The mean reported yield from 49 wells is 8.8 gal/min and yields range from 0.33 to 50 gal/min. The specific capacity of one well was 0.04 (gal/min)/ft. Yields from nine springs ranged from 0.25 to 40 gal/min.

Uniontown Formation.--The Uniontown Formation consists of a lower and upper member and ranges in thickness from 45 to 95 ft. The formation consists chiefly of sandstone, siltstone, mudstone, limestone, and coal.

Sandstone, siltstone, limestone, mudstone, carbonaceous shale, and coal form the lower member, which ranges in thickness from 15 to 75 ft. The basal unit is the Uniontown coal bed where present. The coal bed commonly is less than 12 in. thick. The Uniontown coal bed is impure and may be represented by black carbonaceous shale. A light-gray, fine-grained sandstone unit sometimes overlies the Uniontown coal bed. The upper part of the member generally consists of very finely crystalline, olive-gray to medium-dark gray argillaceous limestone containing small chert nodules locally.

The upper member ranges in thickness from 5 to 40 ft and consists chiefly of sandstone, siltstone, limestone, mudstone, and coal. The basal unit is the Little Waynesburg coal bed, a thin impure coal bed that commonly is represented by a grayish-black carbonaceous shale. The sandstone is light to medium gray and very fine grained; it grades laterally into siltstone and mudstone.

The mean reported well yield from 26 wells in the Uniontown Formation is 15 gal/min but reported well yields are as much as 75 gal/min. Specific capacities of two wells were reported as 0.08 and 0.24 (gal/min)/ft. Yields of four springs ranged from 0.58 to 5.0 gal/min.

Pennsylvanian and Permian Systems

Dunkard Group

The Dunkard Group includes the Waynesburg Formation of Late Pennsylvanian and Early Permian age and the Washington and Greene Formations of Early Permian age. In Washington County, the Dunkard Group has a maximum thickness of appproximately 900 ft. These rocks subtly change upward from more persistent coal-bearing rocks that resemble the strata of the Monongahela Group to the finer grained highly lenticular strata of the Greene Formation, which contains only thin lenses of impure coal (Berryhill, Schweinfurth, and Kent, 1971).

Waynesburg Formation.--The Waynesburg Formation is divided into three members: lower, middle, and upper. The thickness of the formation ranges from 80 to 180 ft.

The lower member of the Waynesburg Formation consists chiefly of sandstone, limestone, siltstone, mudstone, and coal, and ranges in thickness from 40 to 90 ft. The Waynesburg coal bed, present in most of the county, is the basal unit of the lower member and is as much as 100 in. thick. Throughout most of the eastern half of the county, the coal bed is of minable thickness and commonly has two benches with a distinctive clay parting, which is generally 12 in. thick. In the western half of the county, the coal generally is thinner, less persistent, and confined to one bench. A light-gray, fine- to coarse-grained, sometimes massive sandstone unit above the Waynesburg coal bed is the Waynesburg Sandstone (member). The sandstone is sheetlike, has tabular (foreset) and festoon crossbedding, and locally grades laterally and vertically to siltstone and shale. The sandstone is developed best in the eastern half of the county and may be as much as 65 ft thick. The limestone in the lower member is medium gray, fine grained, argillaceous, and as much as 8 ft thick. Two limestone units commonly are found in the lower member; one is at the top of the member, and the other is in the middle. The mudstone is light to dark gray, and micaceous and locally is calcareous.

The middle member consists mostly of mudstone, with some interbedded limestone, sandstone, siltstone, carbonaceous shale, and coal, and is as much as 90 ft thick. Two poorly developed coal horizons are present. These are found at the base and near the top of the member. The Waynesburg 'A' coal bed is the basal unit of the middle member. The coal bed, when not represented by calcareous shale, typically is less than 24 in. thick and may have numerous clay partings. The coal bed is impure and may be represented by carbonaceous shale. The mudstone is light to dark gray and locally calcareous. The sandstone is light gray, very fine to fine grained, micaceous, crossbedded, and generally grades laterally and vertically to siltstone and mudstone. The siltstone is light to medium gray, micaceous, and locally is ripple bedded. The limestone is olive to dark gray, microcrystalline to finely crystalline, argillaceous, and thin to thick bedded. A thin, nonpersistent coal bed near the top of the member tentatively identified as the Waynesburg 'B' coal bed has been reported in many parts of the county. The coal bed is impure and less than 12 in. thick and may be represented by carbonaceous shale. It appears to always be overlain by clastic rocks and probably is a lower split of the overlying Little Washington and Washington coal complex (V.W. Skema, Pennsylvania Topographic and Geologic Survey, written commun., 1988).

The upper member of the Waynesburg Formation is separated from the middle member by the Little Washington coal bed. The upper member is as much as 25 ft thick and consists of sandstone, siltstone, mudstone, and carbonaceous shale. The basal Little Washington coal bed, where present, is typically thin and may be represented by grayish-black, carbonaceous shale.

The mean reported yield of wells tapping the Waynesburg Formation is 10 gal/min. The reported yields of 30 wells range from 0.5 to 60 gal/min. The specific capacities ranged from 0.18 to 2.8 (gal/min)/ft. Yields from 16 springs ranged from 1.0 to 18.4 gal/min.

Permian System

Dunkard Group

Washington Formation.--Cyclic sequences of sandstone, shale, limestone, and coal comprise the Washington Formation. The base is at the bottom of the Washington coal bed and the Formation thickness ranges from 140 to 235 ft. The Formation is subdivided into a lower limestone member, a middle member, and an upper limestone member. The distinguishing feature of this Formation is the abundance of limestone, especially in the western part of the county where it is the predominant lithology.

The lower limestone member consists of limestone, claystone, siltstone, sandstone, carbonaceous shale, and coal, and ranges in thickness from 15 to 40 ft. The Washington coal bed, the basal unit, is as much as 144 in. thick but is generally 24 to 48 in. thick. The coal bed is impure and often split into a sequence of thin coals. Locally, it is absent and is represented by carbonaceous shales. The limestone is light to dark gray and argillaceous and commonly is found in beds as much as 3 ft thick separated by clay, claystone, or carbonaceous shale beds. Fossils include fresh water ostracodes, *Spirorbis*, fish remains, and small gastropods. Tongues of sandstone and siltstone locally may represent the entire member.

The middle member may be as much as 155 ft thick and consists chiefly of limestone, sandstone, siltstone, mudstone, and coal. The limestone is light to dark gray and argillaceous; it has bedding thickness from a few inches to as much as 3 ft. Sandstone in this member is light gray, fine to medium grained, micaceous, and locally is crossbedded. Mudstone in this member is dark gray, poorly bedded, and locally contains small siderite nodules. The middle member has several impure, thin coal beds, the most persistent coal bed being the Jollytown coal bed of Stevenson (1876). The Jollytown coal bed is an impure coal, usually less than 12 in. thick and may be represented as carbonaceous shale. The coal bed lies about 25 ft below the top of the middle member.

The upper limestone member commonly has two beds of limestone separated by beds of sandstone, siltstone, or mudstone. The limestone is light to dark gray, fine grained, and contains fossils. The upper limestone member has a relatively high calcium carbonate content and may be as much as 50 ft thick.

The mean reported yield of 39 wells is 9.6 gal/min; the yields range from 0.5 to 50 gal/min. Specific capacities for six wells ranged from 0.03 to 3.3 (gal/min)/ft. Measured discharges from six springs ranged from 0.18 to 7.0 gal/min.

Greene Formation.--The Greene Formation overlies most of the southwestern part of the county except for valley bottoms where the Washington Formation crops out. The Greene Formation has a maximum thickness of more than 500 ft and consists chiefly of sandstone, siltstone, mudstone, and thin units of limestone, clay, carbonaceous shale, and coal. The rock types generally repeat vertically into a crude cyclic sequence. The cyclic sequence in ascending order is coal, carbonaceous shale, sandstone, siltstone, mudstone, limestone, and clay. Coal beds are thin, impure, and lenticular. Carbonaceous shale contains abundant coalified plant stems and logs, fish remains, and fresh water ostracodes. The sandstone is light gray, micaceous, friable, and fine to medium grained. Bedding is thin to massive and locally crossbedded. The siltstone is micaceous and generally planar with local small scale cross-laminations and current ripples. The siltstone locally contains ironstone and limestone nodules and may occur both above and below sandstone units. Siltstone is the most abundant rock in the Greene Formation. The mudstone in this formation is medium to dark gray and poorly bedded; it commonly underlies limestone units and overlies carbonaceous units. The limestone in this formation is light to dark gray, argillaceous, fine grained, and thin bedded. Fossils include fresh water ostracodes, fish remains, and small pelecypods and gastropods. The clay in this formation is light to medium gray and generally shaly; it may be as much as 1 ft thick beneath carbonaceous units and between limestone beds. The Tenmile coal bed of Clapp (1907) is a thin, impure coal, usually found 20 to 25 ft above the base of the formation. The Sparta coal bed of Griswald and Munn (1907) and the Nineveh coal bed are thin, impure, and lenticular and are about 80 and 310 ft above the base of the formation, respectively. The Prosperity Limestone Member of Griswald and Munn (1907) is a persistent unit, found about 100 to 115 ft above the base of the formation, and generally is a sequence of argillaceous limestone beds and mudstone as much as 9 ft thick.

The mean reported yield of 13 wells tapping the Greene Formation is 11 gal/min and the yields ranged from 2 to 35 gal/min. Yields from nine springs ranged from 0.2 to 39.9 gal/min.

Unconsolidated Deposits

Quaternary System

The Quaternary System contains both Pleistocene and Holocene deposits. These deposits rest unconformably above the previously described bedrock units. Pleistocene deposits are typically 0 to 90 ft thick. Holocene alluvium deposits are about 10 to 15 ft thick.

Pleistocene Series

Carmichaels Formation.--The Carmichaels Formation generally is unconsolidated and poorly sorted alluvium, which consists of mixed clay, silt, and sand containing rounded pebbles, cobbles, and boulders. Boulders may be as much as 4 ft in diameter and generally are concentrated at the base of the unit. Pure clay and sand lenses are scattered throughout the unit and locally small limonite nodules are abundant. The Carmichaels Formation generally is found in the eastern part of the county along the lower parts of the tributaries to the Monongahela River and along the Monongahela River. In this area, the base of the deposit is about 170 ft above the present Monongahela River level or at an altitude of about 910 ft. The deposits also are found along reaches of Raccoon and Chartiers Creek in northern Washington County. The Carmichaels Formation may be as much as 150 ft thick (Schweinfurth, 1967).

Because of limited areal extent and the small number of wells completed in the Carmichaels Formation, well yield, specific capacity, and water quality data were not available. Low well yields, probably less than 5 gal/min, would be expected from this formation because of the heterogeneous composition.

Holocene Series

The Holocene Series consists of alluvial deposits and are typically 10 to 15 ft thick.

Alluvium.--The alluvium consists of clay, silt, sand, gravel, and cobbles in and adjacent to streams. The material is derived mostly from local bedrock and may be as much as 63 ft thick (Newport, 1973).

The reported well yields for the alluvial aquifer are the highest of all the aquifers. The mean reported well yield from four wells is 194 gal/min and the yields ranged from 100 to 350 gal/min. The high yield wells are adjacent to the Monongahela River. The specific capacities of two wells were 1.6 and 5.1 (gal/min)/ft.

HYDROLOGIC SETTING

Water enters Washington County as precipitation. A small percentage of the water is held as soil moisture and stored in ponds and reservoirs, and the rest leaves as water vapor to the atmosphere, or as streamflow, which includes ground-water discharge. The ground water discharges to perennial streams within the county and adjacent counties. The hydrologic system is thus composed of dynamically related parts, and the quantities of water that are present in and move through each part of the hydrologic system place natural limits on the development and management of the water resources. Neither the ground-water nor surface-water part of the system can be developed without affecting the other.

Precipitation

The average annual precipitation for 37 years of record (1949-85) at Burgettstown (fig. 1) in northern Washington County was 40.18 in. (U.S. Department of Commerce). The cumulative departure of annual precipitation from the average at this site illustrates recent variations in the availability of water in the study area (fig. 5). The graph shows a steady decline in the cumulative precipitation from 1962-71. Figure 6 is a bar graph of annual precipitation at Burgettstown that also shows precipitation was considerably below normal during that period (1962-71), indicating a period of drought. Deficiencies for that period ranged from 1.5 to 36.0 percent of the 37-year average annual precipitation. In the 3-year study period, precipitation at this site was above average in 1983 and below average in 1984 and 1985 (fig. 6). Precipitation differed considerably between the U.S. Weather Service rain gage at Burgettstown in northern Washington County and the project rain gages in the Brush Run, Daniels Run, and Enlow Fork basins (fig. 1), located in the west-central, the southeastern, and the southwestern parts of the county, respectively. Table 4 shows measured annual precipitation for the four sites. Precipitation was consistently greater at Burgettstown than at the other three sites.

Precipitation varies somewhat with the seasons; the highest rainfall is in spring and summer (fig. 7). July has the highest average monthly precipitation, which is caused by intense thunderstorms of short duration.

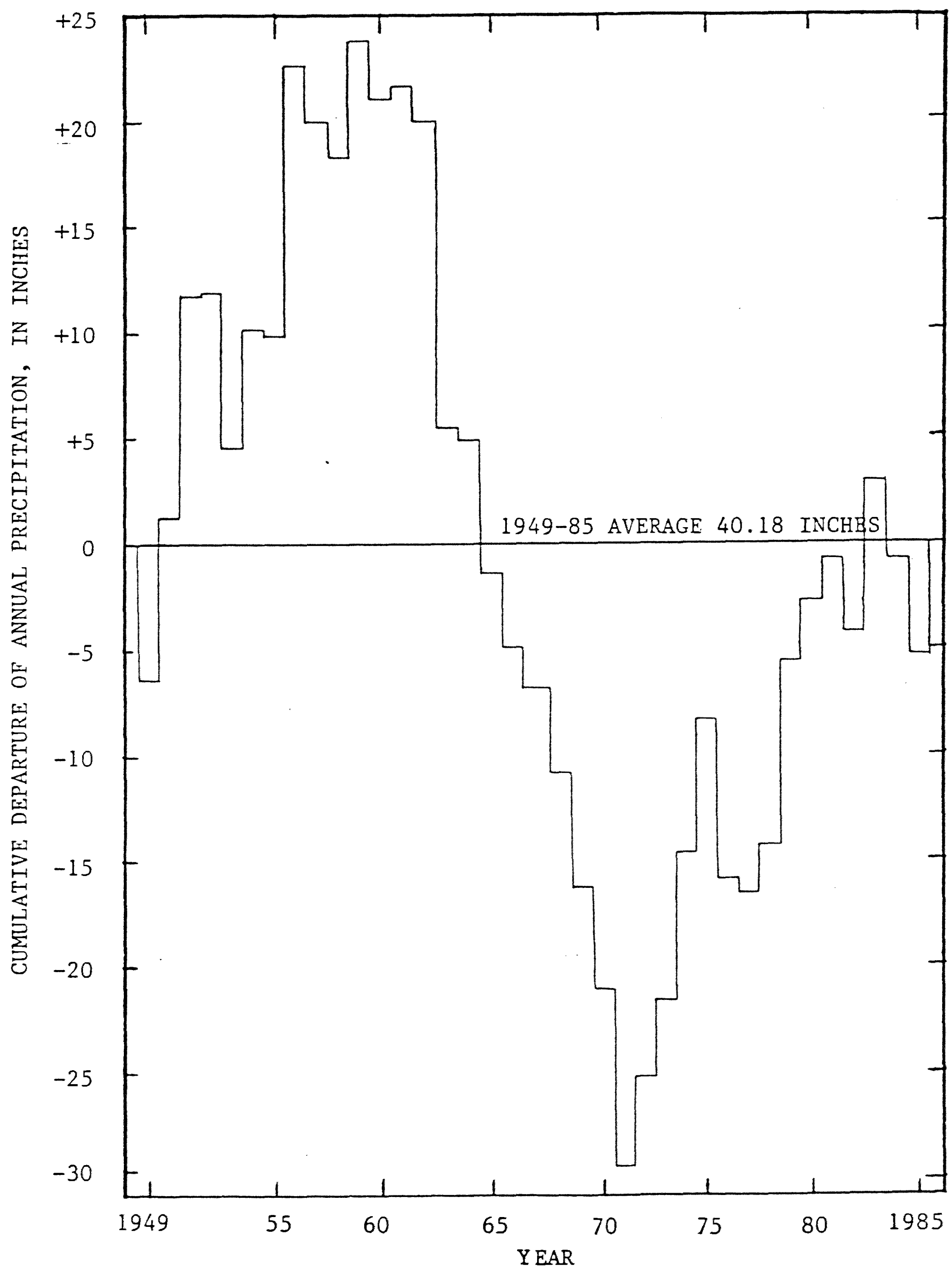


Figure 5.--Cumulative departure of annual precipitation from 37-year (1949-85) average at Burgettstown.

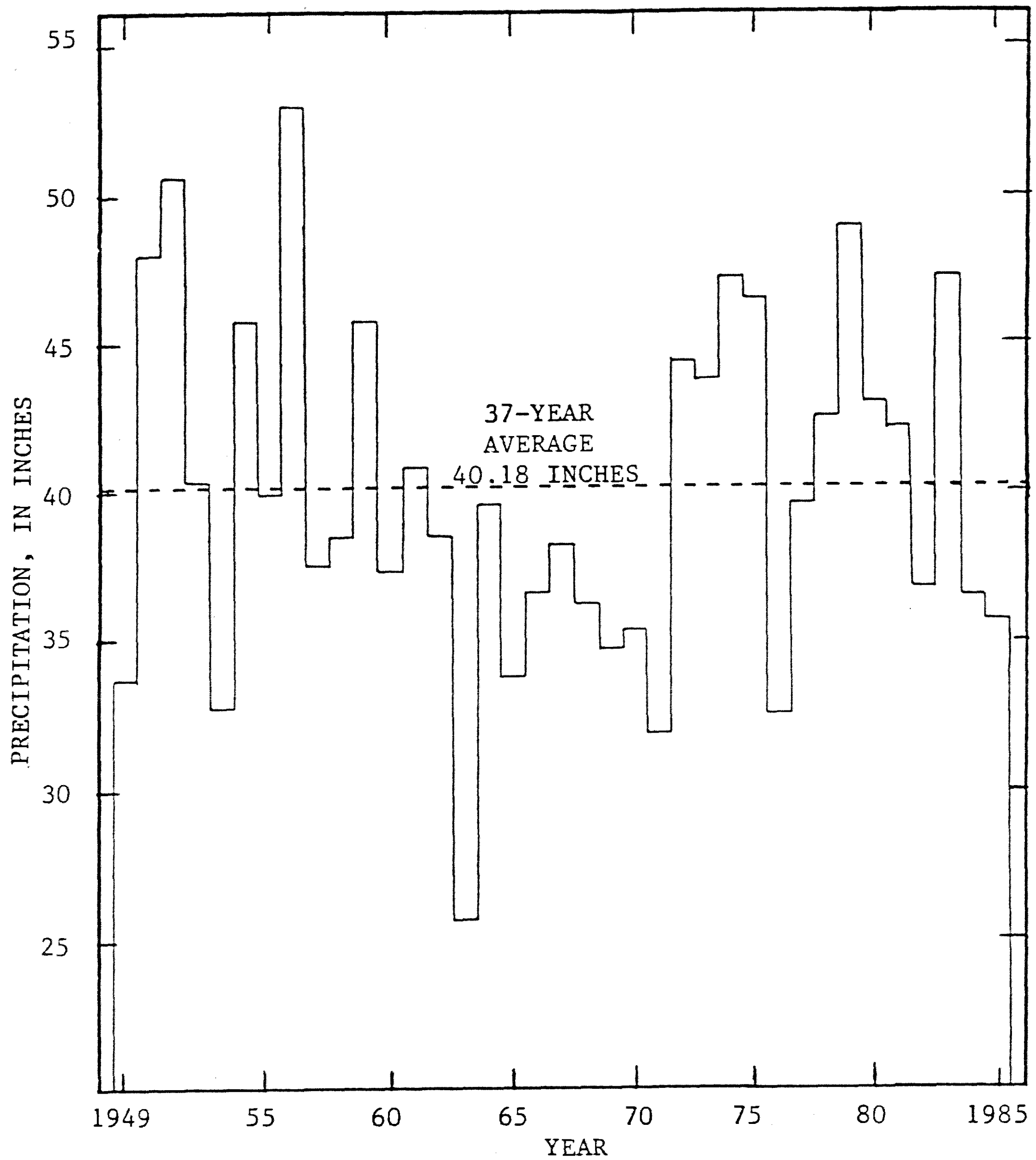


Figure 6.--Annual precipitation at Burgettstown, 1949-85.

Table 4.--Annual precipitation at four raingages, 1983-85

[Values in inches]

Site	Water year		
	1983	1984	1985
Brush Run	37.34	37.23	31.73
Daniels Run	35.27	36.86	31.74
Enlow Fork	32.19	34.72	35.78
Burgettstown	40.75	40.04	37.50

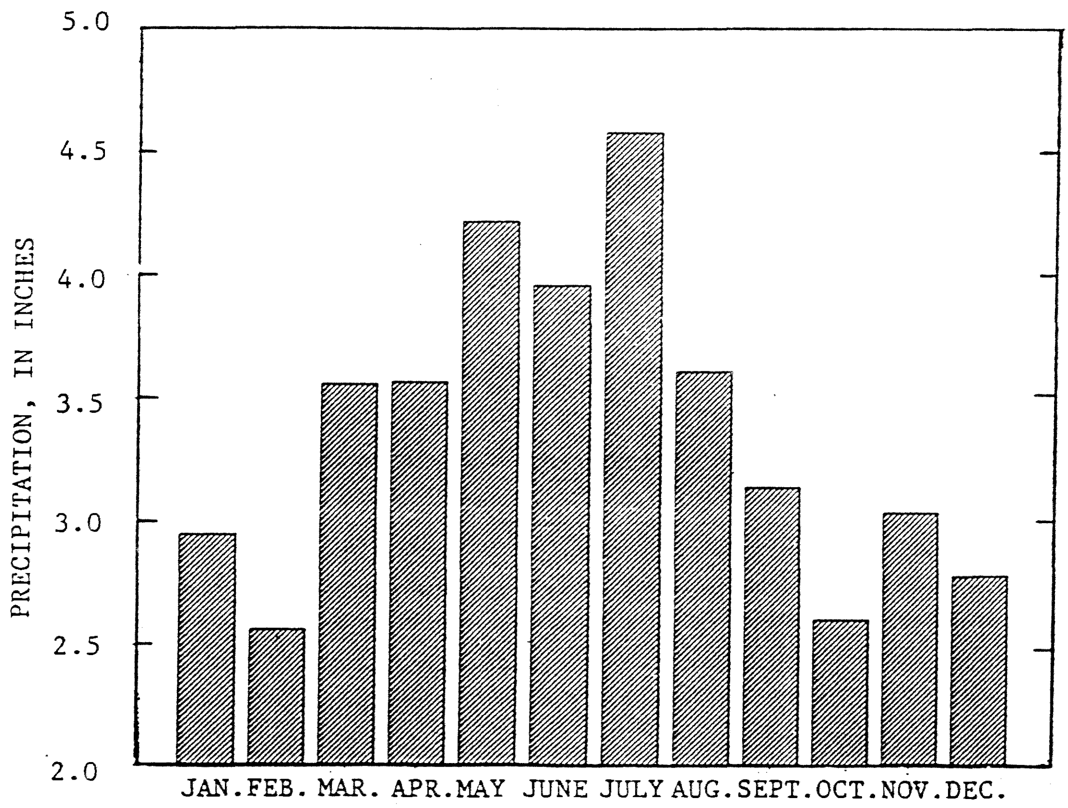


Figure 7.--Average monthly precipitation for 37 years of record (1949-85) at Burgettstown.

GROUND-WATER SYSTEM

Occurrence

Ground water is the subsurface water in the zone of saturation--the zone in which all voids in the subsurface material are filled with water. The surface of this zone is the water table. An aquifer is a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield useable quantities of water to wells and springs. Aquifer is used in this report in strictly the general sense. A formation name associated with the term aquifer is not meant to imply the formation is part of a formal aquifer name. A bedrock aquifer normally has several discrete water-bearing zones that supply much of the ground water to the well. Normally, a single water-bearing zone is not capable of providing enough water to a well for both domestic and livestock uses combined in this region.

The permeability of an aquifer is a measure of the relative ease with which the aquifer can transmit water. Connective openings within an aquifer can be formed at the time of material deposition (primary permeability--water between grains of sand) or after solidification of the aquifer material (secondary permeability--fracturing of rock). The size and the degree of interconnection of these openings control the permeability of the aquifer. Unconsolidated sand and gravel deposits normally have relatively large and well connected pore spaces, and therefore have a high primary permeability. In contrast, water movement in bedrock is largely controlled by secondary permeability created by fracture openings both parallel and perpendicular to bedding planes.

The primary permeability in most sandstone and siltstone aquifers is largely reduced by calcareous and siliceous cement in the pore spaces. However, because of the presence of fractures, the sandstone units are known to be major ground-water producers and have supplied sufficient water for domestic and stock uses (Kent, Schweinfurth, and Roen, 1969, p. 12). Limestone, coal, and shale have less primary permeability than siltstone, but limestones may be exceptionally permeable near the land surface where slightly acidic recharge water forms cavities by dissolving the limestone. According to Stoner and others (1987), sandstone and coal beds in Greene County have the greatest secondary permeability because fractures in the other types of rocks may be filled with clay, which would reduce the water-transmitting characteristics. Water-bearing zones commonly are found at the contact between different lithologic units because of horizontal fracture openings along the contact and the lower permeability of the underlying confining unit.

Stress-relief fracturing (Wyrick and Borchers, 1981) is thought to be the dominant cause of secondary permeability in aquifers. Stress-relief fractures (horizontal and vertical) result from the removal of compressional stress on underlying rocks by the erosion of overlying rocks. Valleys are formed by extensive erosion of the bedrock, which results in a high number of horizontal stress-relief fractures in valley aquifers, whereas hilltop and hillside topographic settings generally contain vertical stress-relief fractures. The number of fractures is thought to decrease in two directions: from valley to hilltops and with increasing depth. Furthermore, in the deep aquifer systems, the reduction in number and size of vertical fractures causes ground water to flow dominantly along bedding-plane fractures from recharge areas to discharge areas.

Water-bearing zones reported by drillers in the study area are generally no deeper than 150 ft from land surface. Furthermore, the computer flow model (Appendix A) shows that more than 90 percent of the total ground-water recharge remains within 150 ft of the land surface. Ground-water flow in this shallow aquifer system generally follows topography, moving from the recharge areas near hilltops to discharge areas in valleys.

Water commonly enters wells through fracture openings oriented along bedding planes. Figure 8 shows examples of graphic and geophysical logs from a well with three distinct water-bearing zones within the Waynesburg Formation. The water-bearing zones in figure 8 are located at bedding plane openings between different rock types; limestone and sandstone, shale and sandstone, and coal and shale. The discrete water-bearing units tapped by the well include two sandstone layers and a coal bed. During drilling, observations of water were noted at depths of 31.5, 53, and 96 ft. The caliper log confirmed fractures in the rock at these depths.

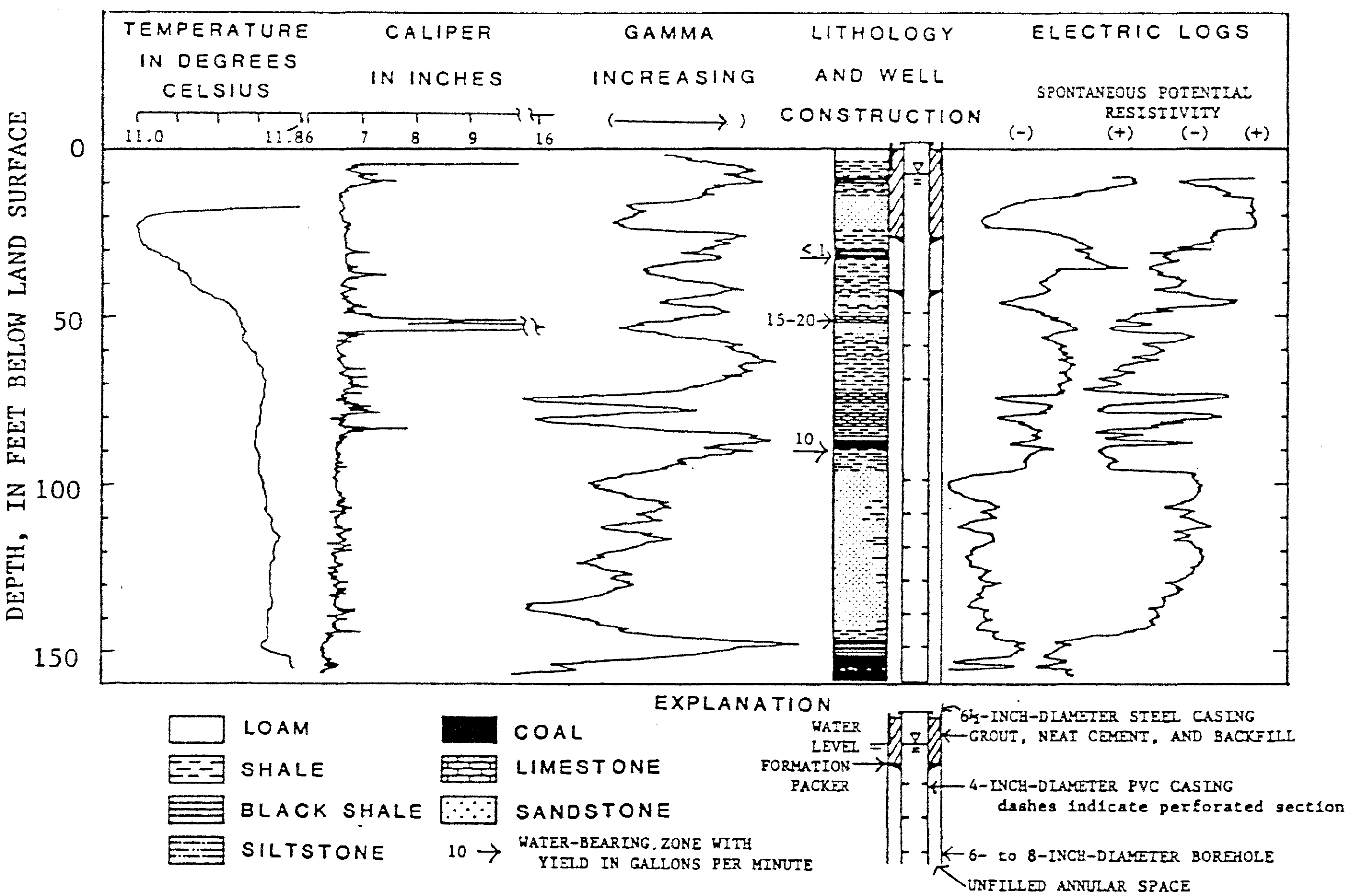


Figure 8.--Geophysical logs and water-bearing zones in a well tapping the Waynesburg Formation. (Modified from Stoner and others, 1987.)

Availability

Information on the availability of ground water is given in the hydrologic properties column on plate 1 and in the well and spring tables (Appendixes C and D). The data in Appendixes C and D were obtained from several sources including water-well completion reports from drillers, field measurements, and previous studies. Location of the wells and springs in Appendixes C and D are found on plates 3A and 3B.

Well depth, reported yield, water level, and specific-capacity data from the well inventory and previous reports are summarized statistically in table 5. Well yields and specific capacities generally are based on drillers' records. Specific capacity (SC) decreases with increased pumping rates and time in low permeability aquifers. Therefore, a well pumped at 5 gal/min, with 10 ft of drawdown, [SC=0.5 (gal/min)/ft] will not necessarily discharge 10 gal/min with a 20-ft drawdown.

The five principal water-bearing units tapped for ground-water supplies in Washington County are in the Greene, Washington, Waynesburg, Uniontown, and Pittsburgh Formations. The mean values of reported yields for the five formations range from 8.8 to 15 gal/min. The 11-gal/min mean of reported yields for the Greene Formation may be high because of the small sampling size and several wells with high reported yields.

The alluvial aquifers and the aquifers in the Casselman and Glenshaw Formation have the largest mean reported yields, however, they also have the smallest areal extent. The highest mean reported yield was 194 gal/min for the alluvial aquifer. The Casselman Formation had the highest mean reported yield of the bedrock aquifers (46 gal/min).

Water levels in wells of the same depth and construction will vary because of topographic setting and head in the water-bearing zones. Water levels in wells generally are shallow in valleys and become deeper with increasing elevation to hilltops. The mean of measured water levels and mean depth of wells located in upland draws, valleys, hillsides, and hilltops are as follows:

	Mean depth to water level (feet below land surface)	Number of wells	Mean well depth (feet below land surface)	Number of wells
Upland draw	21	11	104	13
Valley	22	58	88	97
Hillside	42	201	102	345
Hilltop	62	94	114	185

Table 5.--Summary of well depths, reported yields, water levels, and specific capacities by aquifer

[F, flowing; --, no data available; gal/min, gallon per minute; (gal/min)/ft, gallons per minute per foot]

Aquifer	Well depth (feet)			Reported yield (gal/min)			Water level (feet below land surface)			Specific capacity (gal/min)/ft		
	Number of wells	Mean	Range	Number of wells	Mean	Range	Number of wells	Mean	Range	Number of wells	Mean	Range
Alluvium	4	40	7- 63	4	194	100-350	4	8	3- 14	2	--	1.6-5.1
Greene Formation	66	81	15-204	13	11	2- 35	38	33	5- 90	--	--	--
Washington Formation	114	107	19-310	39	9.6	.5- 50	62	52	8- 38	6	1.2	.03-3.3
Waynesburg Formation	148	99	15-310	30	10	.5- 60	93	43	3-170	4	1.6	.18-2.8
Uniontown Formation	137	101	15-285	26	15	1- 75	73	38	F-170	2	--	.08-.24
Pittsburgh Formation	140	114	18-250	49	8.8	.33- 50	79	47	F-170	1	--	.04
Casselman Formation	25	139	44-438	15	46	2-160	13	57	F-150	2	--	9.7-22
Glenshaw Formation	6	112	60-165	4	33	1-110	2	--	33- 55	1	--	.52

Water-Level Fluctuations

Water levels were recorded continuously at selected wells located on plates 4A and 4B to improve the understanding of aquifer response to recharge and discharge. Private wells and several drilled observation wells in adjacent Greene County also were used to aid in understanding. Each well was tested to ensure that the well had a good hydraulic connection with the aquifer. Water-level data for observation wells are published in the annual report "Water Resources Data, Pennsylvania, Volume 3," for 1984 and 1985 (U.S. Geological Survey, 1984, 1985).

Short Term

Water levels in wells respond not only to changes in the recharge and discharge rates of the aquifer, but also to some external forces such as barometric pressure.

Daily water levels and precipitation from December 1984 to May 1985 are compared for various topographic settings in figure 9. Well depths ranged from 74 ft for well WS-182 to 218 ft for well GR-803. Plate 4B shows the locations of these wells. Water-level fluctuations differ significantly from hilltop to valley topographic settings. Hilltop wells WS-271 (depth 176 ft) and WS-277 (depth 126 ft) and upland draw well WS-265 (depth 99 ft) had the largest water-level fluctuations. The water levels in hilltop well WS-277 fluctuated more than 40 ft. In contrast, the water levels in valley well GR-803, tapping a confined aquifer, fluctuated less than 1-1/2 ft (fig. 9). Intermediate water-level fluctuations are represented by well WS-182, which is on a hillside.

The water-level fluctuations in hilltop well WS-271 are different than fluctuations in hilltop well WS-277 even though they are within 2 mi of each other (plate 4A). The responses (rounded peaks) of well WS-271 to recharge are slower and smaller than the responses (pointed peaks) of well WS-277 (fig. 9). Well WS-271 taps a confined aquifer that has a hydraulic conductivity one order of magnitude larger than the aquifer tapped by well WS-277. Well WS-277 taps an unconfined aquifer, has a smaller hydraulic conductivity than well WS-271, and responds more readily to recharge. Well WS-277 receives recharge directly from percolation of rain water. In addition, because the aquifer tapped by well WS-277 has a smaller hydraulic conductivity and probably a lower storage coefficient than the aquifer tapped by well WS-271, its water levels rise faster and higher for a small amount of recharge.

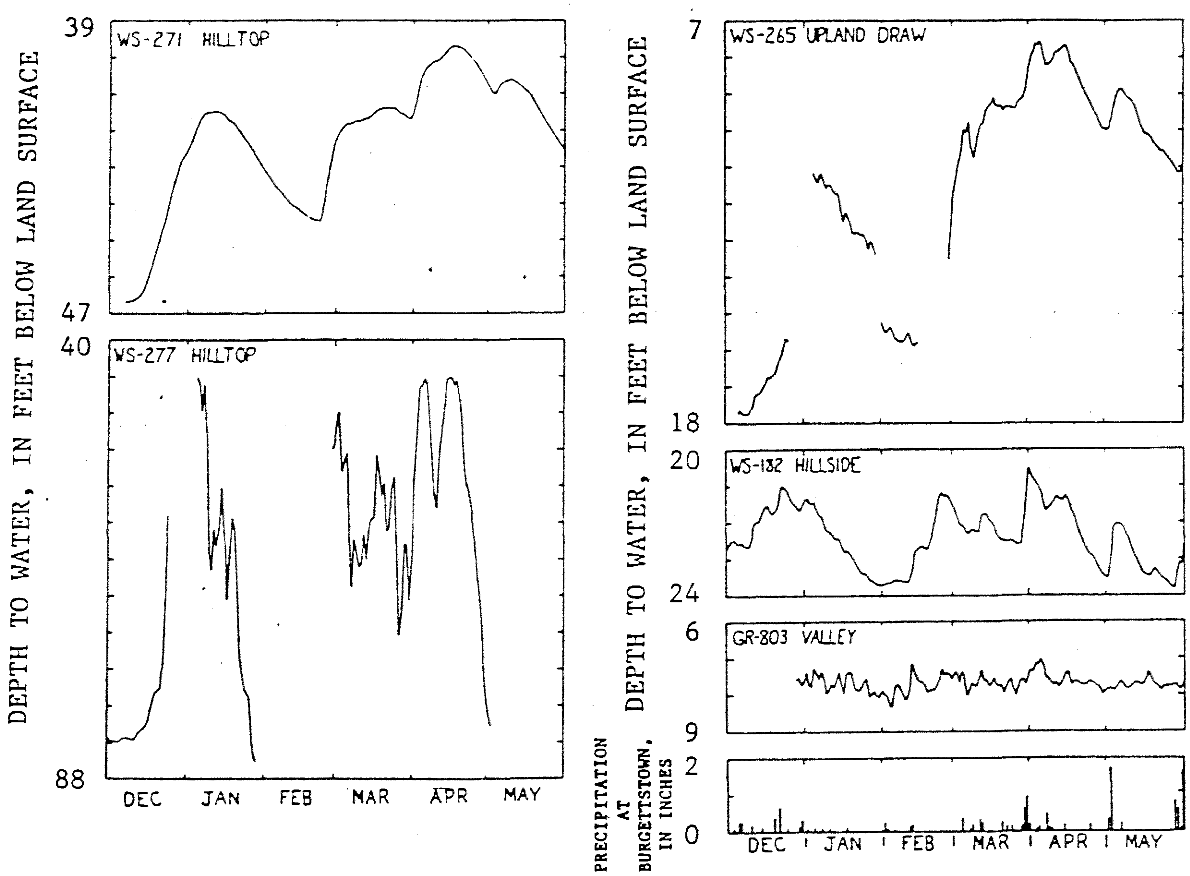


Figure 9.--Relation of water levels in wells to daily precipitation and topographic position for December 1984 through May 1985.

Seasonal and Long Term

The factors causing seasonal water-level fluctuations include precipitation, evaporation, and transpiration. Water levels are generally the lowest in September and October, and highest in December, March, and April. Annual water-level fluctuations usually range from less than 3 ft beneath a valley to about 13 ft beneath an upland draw.

Water-level data show the effects of evapotranspiration. During late summer and early fall, water levels generally are the lowest. The evaporation of surface water and the transpiration by plants usually are highest during this period, and potential recharge to the aquifers by precipitation is reduced. During the winter and spring, the water levels tend to recover because of recharge from snowmelt and rainfall, when evaporation and transpiration are at a minimum.

Water levels were measured continuously from 1971-85 in well WS-155 (plate 4B). Mean monthly water levels based on daily low levels are shown in figure 10. Daily low levels averaged for each month closely approximate the actual monthly mean because daily water-level fluctuations commonly are less than 0.3 ft in well WS-155. Water levels rose from 1971 to the early part of 1975, had relatively little change from 1975 to the middle of 1981, and then gradually declined from 1981 to September 1985. The general water-level trend in well WS-155 only partially correlates with the precipitation trend at the Burgettstown precipitation station (fig. 10) because the well is artesian and because of differences in precipitation patterns and the distance (about 22 mi) between the station and the well.

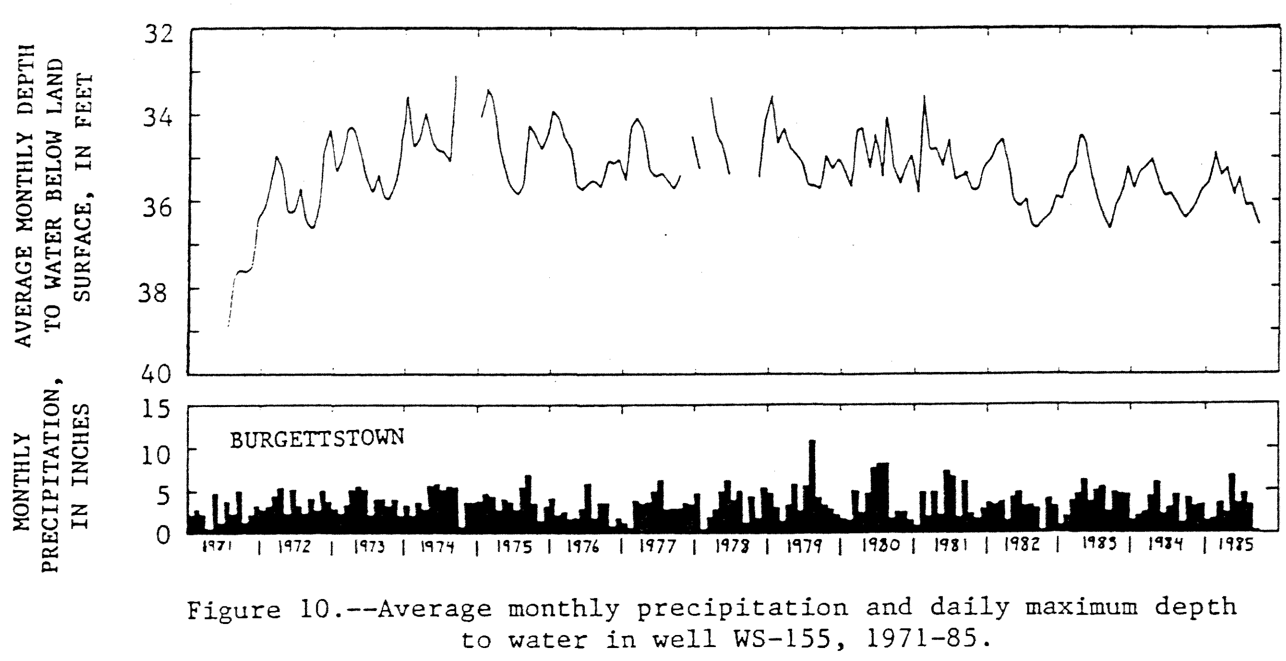


Figure 10.--Average monthly precipitation and daily maximum depth to water in well WS-155, 1971-85.

Aquifer Characteristics

Determination of the hydraulic characteristics of the aquifer systems is necessary for the design of water supplies for municipalities and for the design and construction of a computer ground-water flow model. These characteristics, or properties, include transmissivity, hydraulic conductivity (or permeability), and storage coefficient for confined aquifers, which are determined by well-testing methods. With these characteristics, the effects of human-induced stresses on aquifer systems can be estimated. For example, estimates can be made of water-level declines in aquifers caused by pumping at wells and pumping of mine inflow (surface and underground).

Ideally, aquifer testing requires a pumped well and one or more observation wells that are within the zone affected by the pumping stress on the aquifer. However, with bedrock wells, single well testing is common. The analysis of the drawdown versus time data utilized in this report include the techniques of Theis (1935), Cooper and Jacob (1946), and Papadopulos and Cooper (1967). The results of the single-well tests are greatly influenced by aquifer conditions adjacent to the well. Therefore, the results from the single-well tests are not as reliable, nor as representative, as those from aquifer tests employing observation wells at some distance from the pumping well.

In Greene and Washington Counties, secondary permeability is the dominant component of aquifer permeability and is related to the number, size, and extent of interconnected fractures within the aquifers. Primary permeability is related to the formation of the basic rock type (lithology) prior to any bending and breaking of the rock mass. The ranking of hydraulic conductivity from highest to lowest among bedrock water-bearing units is: (1) coal bed, (2) sandstone, (3) siltstone and shale, and (4) limestone. Coal beds commonly have the greatest density of fractures, while sandstone has the highest primary permeability. Most of the permeability of siltstone and shale is attributed to fractures, which commonly are filled with clay. Limestone has the lowest relative permeability because of high density and clay content. The depth of the aquifer and the topographic position of the well also affect the average conductivity. Stoner and others (1987) reported that the hydraulic conductivity decreases one order of magnitude for every 100 ft of depth and that well sites in valleys have the largest hydraulic conductivities, while well sites on hilltops have the smallest. Wyrick and Borchers (1981) speculate that stress-relief fracturing is responsible for the changes in hydraulic conductivity for wells in different topographic positions.

The hydrogeology of Washington County is similar to that of adjacent Greene County, which was investigated by Stoner (1983) and by Stoner and others (1987). In the fractured sedimentary rock aquifers in Greene County, aquifer-testing methods determined that average hydraulic conductivities range from 2.4×10^{-6} to 50 ft/d (feet per day). Storage coefficients from aquifer tests range from 0.6×10^{-6} to 8×10^{-4}.

For Washington County, the drawdown plots for aquifer tests are presented in Appendix H and the resulting aquifer characteristics are presented in table 6. The average hydraulic conductivity of the bedrock determined by aquifer tests ranges from 0.003 to 1.2 ft/d. Hydraulic conductivity was determined by dividing the calculated transmissivity by the thickness of the aquifer tested at the well. The median specific capacity of the bedrock wells tested is 0.10 (gal/min)/ft of drawdown, and individual specific capacity values lie within the range of values for the formations listed in table 5. These test results fall within the range of aquifer characteristics reported for Greene County.

The results of an aquifer test with an observation well are shown in table 6. The wells tested penetrate the lower 105 ft of the Waynesburg Formation and the upper 14 ft of the Uniontown Formation. The wells are in the Enlow Fork Valley of northern Greene County, immediately adjacent to the southern border of Washington County (plate 4B). The storage coefficient of the aquifer test is reported by Stoner and others (1987) in the section titled Burdette Test Site.

Aquifer-test data indicate that the alluvial aquifer tapped by well GR-804 (plate 4B) had the highest hydraulic conductivity (table 6). The alluvial aquifer is composed mostly of silt and clay. However, a gravel layer of high permeability with a thickness of less than 1 ft is the probable cause for the high hydraulic conductivity value for the well.

Table 6.--Summary of aquifer-test data and results

[gal/min, gallons per minute; ft^2/d, square feet per day; ft/d, feet per day; --, no data]

Well number	Geologic formation	Date	Depth of interval tested (feet)[1]	Pumping rate (gal/min)	Duration of pumping (hours)	Transmissivity (ft^2/d)	Average hydraulic conductivity (ft/d)	Total drawdown (feet)	Method of analysis[2]
				Aquifer test with pumped well only					
WS-155	Washington	07-01-71	39-140	2.0	1.5	1.0	0.01	17.0	C&J,'46
					(2.6)	15	.15	--	T Recovery
WS-155	Washington	08-23-83	39-140	4.6	2.0	18	.18	60.8	C&J,'46
WS-181	Waynesburg	08-19-83	40- 92	2.0	1.3	65	1.2	1.4	C&J,'46
WS-182	Waynesburg	08-26-83	25- 75	3.2	2.8	35	.7	10.1	P&C,'67
						31	.6	--	C&J,'46
WS-205	Waynesburg	08-24-83	15- 91	2.0	1.5	19	.25	11.6	C&J,'46
						24	.32	--	P&C,'67
WS-265	Uniontown	07-12-83	22- 99	4.4	1.0	3	.04	51.2	P&C,'67
						4	.05	--	C&J,'46
WS-271	Washington	12-05-84	46-176	17.5	.43	18	.14	23	T Recovery
WS-277	Pittsburgh	07-13-83	83-125	1.4	.48	1	.02	36.2	C&J,'46
		08-19-83	77-125	2.4	.71	2	.04	35.0	C&J,'46
WS-322	Washington	05-03-84	22-125	2.3	1.7	.7	.007	74.7	C&J,'46
					(3.7)	.4	.003	--	T Recovery
GR-804[3]	Alluvium	09-29-80	5- 14	4.4	6.5	160	18	3.5	C&J,'46
						159	18	--	T Recovery

Well number	Geologic formation	Date	Pumping rate (gal/min)	Duration of pumping (hours)	Transmissivity (ft^2/d)	Average hydraulic conductivity (ft/d)	Storage coefficient	Total drawdown (feet)	Method of analysis[2]
				Aquifer test with observation well					
GR-802[3]	Waynesburg	09-30-80	12	5.2	84	0.6	--	6.6	C&J,'46
		07-29-81	23.7	15.9	130	1.0	--	26.5	Theis
					57	.4		26.5	C&J,'46
				(25.6)	81	.6		--	T Recovery
GR-803[3]	Waynesburg	09-30-80	--	--	120	1.0	1.7×10^{-4}	5.4	Theis
					81	.6	--	6.6	C&J,'46
		07-29-81	--	--	330	2.6	9.0×10^{-5}	18.6	Theis
					68	1.9	--	--	T Recovery

[1]Depth below land surface.

[2]C&J,'46, Cooper and Jacob, 1946; T Recovery, (Theis Recovery) Theis, 1935; P&C,'67, Papadopulos and Cooper,1967; Theis, Theis, 1935.

[3]Data from Stoner and others, 1987.

Flow

Local

Rainfall and snowmelt percolate through the soil zone and enter the local aquifer system at the water table. Water will flow along paths of least resistance towards areas of lower head. Flow generally parallels topography moving downward from hilltops to valleys. Occasionally, an impermeable layer or bedding separation will divert water laterally to discharge as a hillside spring or seep. In upland draws and valleys where the head is lower, water will flow laterally or upward to streams where the ground water is discharged. In general, the local flow system is confined to a zone within 150 ft of the land surface.

Regional

Local flow systems lose some of their water to the underlying regional flow system by slow downward vertical leakage. Regional flow is predominantly lateral toward major valleys. Velocity in the regional system is very low in comparison to that of the local flow system. Discharge from the regional aquifer system is by upward leakage beneath major valleys such as the Monongahela and Ohio River Valleys.

Briny water [water with greater than 35,000 mg/L (milligrams per liter) dissolved solids] is first encountered at depths of 900 to 1,200 ft below land surface according to oil and gas well drilling records. The top of this saline water marks the base of the fresh water (less than 1,000 mg/L dissolved solids) flow system.

Flow Model and Results of Simulations

A three-dimensional computer flow model of the unmined Brush Run basin was constructed to improve understanding of premining ground-water flow and hydrologic conditions in the county. Depth and quantity of ground-water flow, the sensitivity of variations in certain hydrologic parameters, and hydrologic boundaries were evaluated. Details of the model are available in Appendix A.

The flow model produces a simulated flow system by solving a series of equations containing known hydrologic factors and estimates of poorly known factors. The model is calibrated by comparing the output of the simulated flow system with the known hydrologic data of the real flow system (such as head, mine inflow, or stream discharge). Input parameters to the model (such as vertical and horizontal hydraulic conductivity) are then adjusted until a reasonably close match of model derived values and observed data is achieved. The calibrated model is used to improve understanding of the real flow system.

The calibrated model is known as the "hypothetical unmined-basin model" because of the limited amount of hydrologic data, the variability within the data, and because few data describing the lower aquifers of the model were collected during the study. If more data were available, a better model calibration would have been possible, and a more reliable model would have been produced.

Conclusions from the flow model indicate that approximately 95 percent of the total ground-water recharge is in the upper 80 to 110 ft of bedrock (layer 1 of the model), and that the regional flow system (greater than 250 ft deep, represented by layers 3 and 4 of the model) probably removes less than 0.1 percent of the total ground-water recharge from the basin.

The water-level data collected for the project show that the heads in the aquifers within a basin generally follow the topography, but are subdued. The model shows that the relief of the head decreases with depth. Heads decrease downdip along geologic structure (when ground water moves from areas of recharge to discharge in the regional aquifers).

Data defining the hydrologic properties of the deep aquifer systems are meager. The model shows that the properties of the deep aquifers can vary substantially but have no effect on the shallow aquifers that supply water to almost all domestic wells.

The shallow aquifer system is most sensitive to changes of hydrologic factors within that system. The amount of ground-water recharge, and the impediment of ground water to discharge into streams by alluvium or vertical anisotropy within the aquifer may cause head fluctuations of up to 30 ft or more.

Vertical gradients may provide clues to the hydrologic nature of the deep aquifer system. If the amount of ground-water recharge remains about the same, and if the shallow aquifer is cased off in the well, a gentle downward vertical gradient on deep hilltop and hillside wells may be indicative of deep aquifers with higher vertical hydraulic conductivity. A steep downward vertical gradient under the same conditions may indicate deep aquifers with low vertical hydraulic conductivity. A very small upward gradient in a deep valley well may indicate the presence of a vertical fracture zone.

A vertical fracture zone probably would lower the head in a small tributary valley and increase head in a valley setting. The components of a ground-water flow budget for a basin with a deep vertical fracture probably would differ from those in an unfractured basin by less than 1 percent of the total ground-water recharge.

Guidelines for Developing Supplies

The individual homeowner generally has little choice in the selection of a well site. Usually the well location is restricted to the proximity of the residence and a power supply, and the only consideration given to well siting is the prevention of possible contamination. Siting of a ground-water supply for stock, commercial, or public use may not be as restricted. For both situations, an understanding of the geologic and hydrologic information given in this report, combined with proper well construction, may make the difference between a successful and unsuccessful well or spring. The following facts and procedures, listed in order of importance, may be helpful when considering a ground-water supply.

General Procedures

1. The yields and quality of water of nearby wells and springs often indicate what can be expected at a site. Altitude of reported water-bearing zones and springs mark the location of aquifers. However, there may be large variations in ground-water yield in short distances because of the variation of fractures.

2. The best time for well construction and spring development is during dry periods, when water levels are lowest. Optimum setting of the pump and adequacy of the well are best tested when water levels are low. The relative permanence of a proposed spring is also best established during this period. The water quality commonly is at its worst during dry periods.

3. Most bedrock aquifers in Washington County include fractured rocks located within 150 ft of land surface. Drilling a well deeper than 150 ft generally will not increase aquifer yield. Dissolved solids generally tend to increase with well depth because of the longer residence time of ground water produced from deep water-bearing zones. Drilling deeper than 150 ft also increases the probability of encountering saline water with undesirable concentrations of sodium chloride. Additional problems with deep wells include high initial costs for drilling and high pumping costs because of deep-water levels commonly found in hilltop, hillside, and some upland draw areas.

4. Storage capacity is important where wells yield meager supplies of water. Storage tanks or reservoirs may be used to provide necessary storage. Consideration may also be given to drilling wells with as large a diameter as practical to provide as much storage capacity as possible in the well itself. For example, each foot of water in a 6-in.-diameter well represents about 1-1/2 gal (gallons). Each foot of water in an 8-in.-diameter well represents about 2-1/2 gal. Thus, a 6-in.-diameter well that contains 50 ft of water has 75 gal in storage and an 8-in.-diameter well, 125 gal. The cost of drilling a well with a diameter of more than 8 in. may become prohibitive below a certain depth. The cost of well storage needs to be compared to that of storage above ground level.

Site Selection Restricted

1. Topographic setting.--Procedures pertinent to the general topographic position of a ground-water supply are:

   (a) Hilltop.--Drill only to the depth of sufficient yield. Drilling a well deeper for added yield or storage commonly results in water-level decline and sometimes complete loss of well yield. Also, an uncased deep well may reduce the yield of a nearby shallow well.

   (b) Hillside.--In addition to procedures for the hilltop setting, hillside wells need to be sited at some distance from potential contamination points such as septic tanks, trash dumps, or stock pens located up gradient (usually uphill). At many hillside locations, springs are a suitable alternative to wells as a potable water supply; however, care must be taken to eliminate contamination when using springs for domestic supply. For stock water supply, the spring-box and storage-tank construction used by the U.S. Department of Agriculture, Soil Conservation Service (1969) has been successful. In some places, several springs can be developed and the combined discharge piped to the desired location. Where conservation is critical, multiple storage tanks may be used.

   (c) Valley.--The depth of valley wells used for domestic supply may be limited because slightly saline ground water is shallowest beneath valleys. High yielding shallow wells are possible in the alluvium of major valleys, but ground water is susceptible to contamination by surface activities. Tightly cased deep wells in large valleys may be free flowing.

Site Selection Unrestricted

1. On any given hillslope, springs developed farthest downhill are most likely to produce the highest sustained yields during droughts.

2. Of all the topographic positions, wells in valleys will probably have the highest yields. These high yields commonly are because of fractures beneath the valley bottom that decrease in number and magnitude with depth. This fracturing also tends to be less extensive beneath adjacent hills. The extent of bedrock fracturing in valleys and adjacent hillsides varies from site to site. Therefore, an aquifer test of more than 24 hours needs to be done on valley wells proposed for public or commercial use to document if sufficient quantity of water exists for proposed needs. Such a test also can be used to document the possible interference of heavy pumping on nearby wells.

3. Locating fracture traces can help in choosing sites of optimum yield inasmuch as most wells are completed in bedrock and water mainly moves through fractures in the bedrock. The most conspicuous linear features can be identified and plotted on aerial photographs of the general area of interest. These aerial photographs can then be used to help locate possible fracture traces in the field. The best site for a well is at the intersection of two or more traces. Parizek and others (1971) determined that the width of fracture zones ranged from 15 to 60 ft and averaged 39 ft in the siltstones and shales of western Pennsylvania. A hydrogeologist could be consulted to locate such narrow zones by this method. The ground-water flow model indicated that a fracture zone beneath a hilltop or hillside may drain the shallow aquifers. So a well drilled to shallow depth on a hilltop fracture trace may not always be successful.

General information on the development of small well-supply systems may be obtained from a manual prepared by the U.S. Environmental Protection Agency (1975) entitled "Manual of Individual Water Supply Systems." The manual includes sections on drilled- and dug-well construction, spring development for domestic use, and sanitary protection of water supplies. The publication may be obtained from the Superintendent of Documents, Government Printing Office (Stock number 055-001-00626-8), Washington, D.C. 20402.

SURFACE WATER

Low-Flow Frequency

Understanding low-flow characteristics of streams is essential in determining the adequacy of streamflow for particular uses and for use during periods of little or no rainfall. Low-flow-frequency data may be used to: (1) design industrial and domestic water-supply systems, (2) classify streams as to their potential for waste dilution, and (3) maintain channel flows as required by agreement or by law. Low-flow characteristics of a stream also are good indicators of the amount of ground-water flow to the stream. Low flows in areas with similar geology and basin size are usually of the same order of magnitude.

The low-flow characteristics at a streamflow-gaging station generally are described by a low-flow frequency curve, which is a graph relating the magnitude and frequency of annual minimum flows for a given number of consecutive days. The 7-day, 10-year low flow is the low-flow index most commonly used as a critical-flow factor and as a minimum dilution flow in the design of waste-water treatment plants. The 7-day low flow will be less than the 7-day, 10-year low flow at intervals averaging 10 years in length; or the probability is 1/10 that the 7-day low flow in any one year will be less than the 7-day, 10-year low flow. The reliability of a low-flow frequency curve, based on natural flows, is related closely to the length of streamflow record; the longer the period of record, the more reliable the curve.

The longest records of daily flows for an unregulated stream in the study area are those for Brush Run (site 25). Twenty years of streamflow record (1962-78 and 1983-85) are available at this site. Figure 11 shows the family of low-flow frequency curves for 7, 14, 30, and 60 consecutive days for Brush Run (site 25) for 1968-78 and 1983-85. The period 1962-67 was not used in this analysis because it was statistically different from the long-term record. Inspection of the daily discharge data from Brush Run revealed many consecutive days of no flow in 1962-67 because of a drought. Figure 11 shows that the 7-day, 10-year low flow for Brush Run is 0.12 ft^3/s (cubic feet per second). If the drought period was used in the analysis, the 7-day, 10-year low flow would have been 0.0 ft^3/s.

The 7-day, 10-year low flows for three short-term streamflow-gaging stations (sites 20, 21, and 22) were assumed to be zero because of their small drainage areas and their proximity to Brush Run.

The computed 7-day, 10-year low flow for Enlow Fork near West Finley (site 16) of 0.30 ft^3/s was determined from a regression analysis with Wheeling Creek at Elm Grove, W. Va. (site 37), a long-term gaging station about 28 mi downstream from site 16.

The computed 7-day, 10-year low flow for Daniels Run near West Zollarsville (site 11) was 0.17 ft^3/s and was estimated from a regression analysis with South Fork Tenmile Creek near Jefferson, Pa. (site 36), a long-term gaging station in Greene County about 3.7 mi south of the Daniels Run gage. Because Daniels Run is a highly regulated stream because of mine pumpage into the stream and water loss from the stream in areas where there has been long wall mining, the computed 7-day, 10-year low flow is not indicative of natural conditions.

One or more base-flow discharge measurements taken each year at partial-record stations can provide nearly as much low-flow information for comparison as a complete flow record of a few years (Riggs, 1972). Base-flow measurements made at the 29 partial-record stations throughout Washington County were compared with concurrent discharges from nearby long-term stations, and 7-day, 10-year low-flow discharge values were computed for the partial-record stations (fig. 12, table 7). The computed values for the partial-record stations are derived from limited data and the accuracy of the values may be questionable. Based on streamflow data from Brush Run (site 25) and long-term precipitation data from Burgettstown, the 7-day, 10-year discharge was assumed to be zero for the sites on unregulated streams with drainage areas less than 13 mi².

The low-flow frequency data (fig. 12 and table 7) generally indicate that low flows at sites in the south-central and southwestern part of the county were the lowest low flows per square mile in the study area, whereas sites in the eastern and northern parts of the county had the highest low flows.

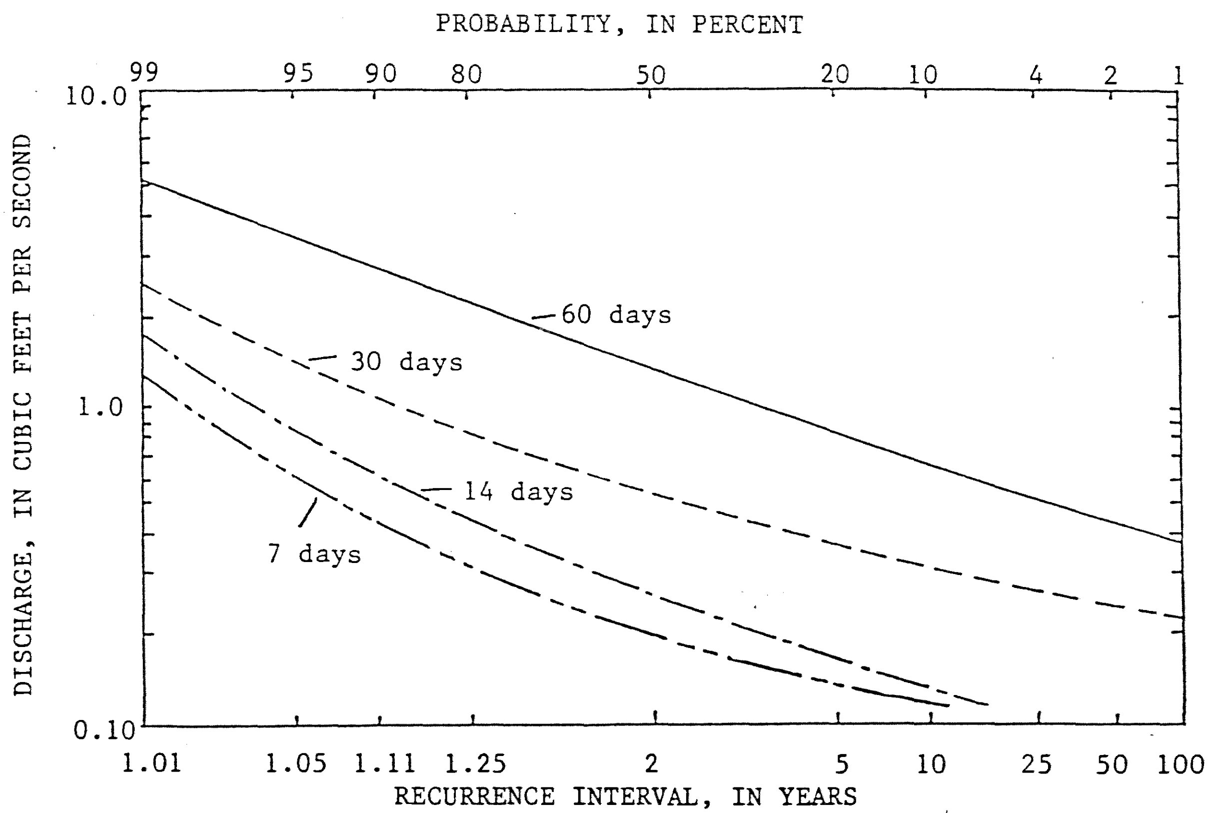
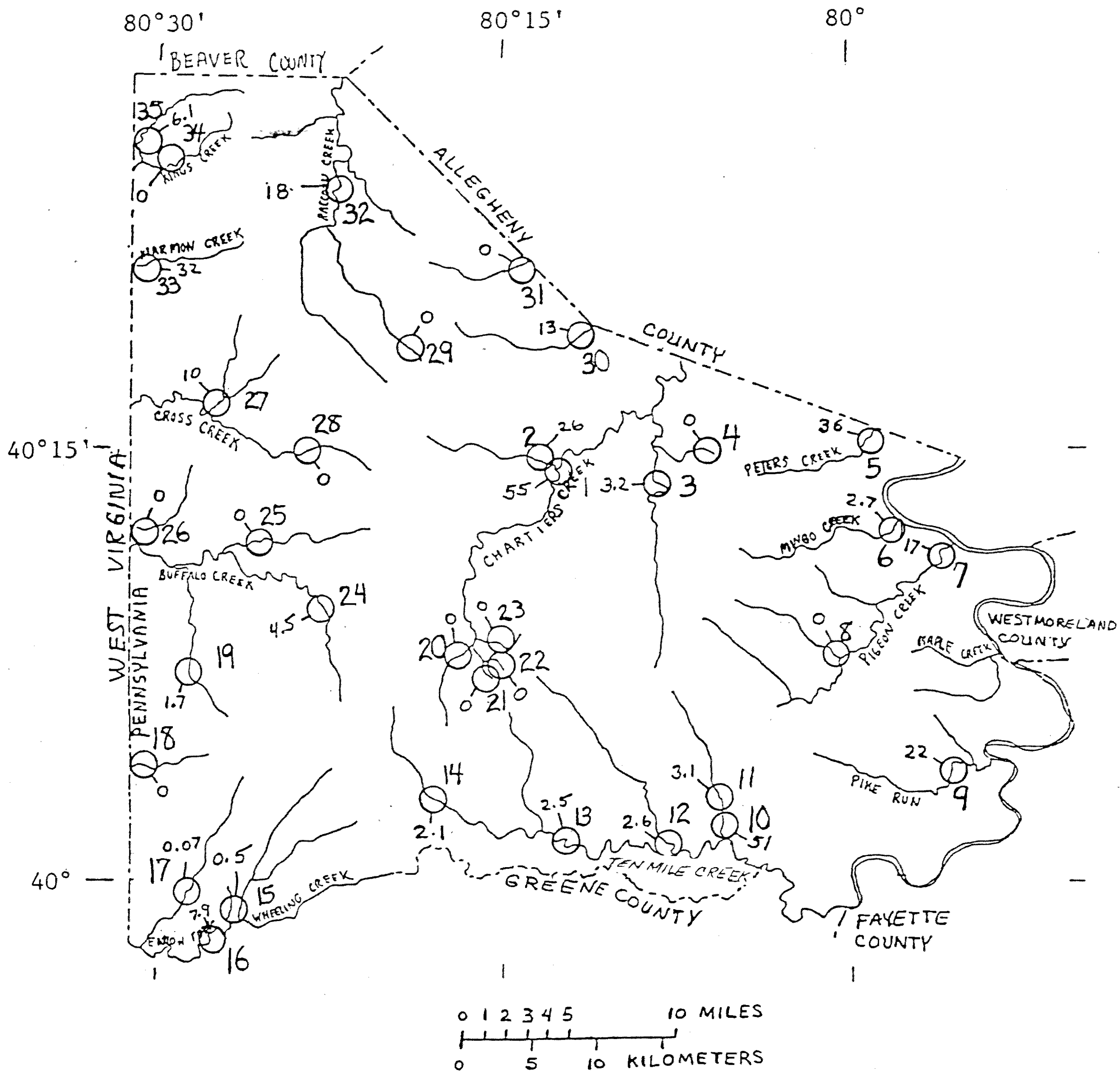


Figure 11.--Low-flow-frequency curves for 7, 14, 30 and 60 consecutive days for Brush Run near Buffalo (site 25), for 1968-78 and 1983-85.



EXPLANATION

15 — SITE LOCATION AND NUMBER

2.1 — 7-DAY, 10-YEAR DISCHARGE PER SQUARE MILE x10^{-3}

Figure 12.--The 7-day, 10-year discharges per square mile for the surface-water sites. (See table 7.)

Table 7.--Computed 7-day, 10-year low flows for long-term, short-term, and partial-record sites

[ft^3/s, cubic feet per second; mi^2, square miles; $(ft^3/s)/mi^2$, cubic feet per second per square mile]

Site number	7-day, 10-year discharge (ft^3/s)	Drainage area (mi^2)	7-day, 10-year discharge per square mile ($[(ft^3/s)/mi^2] \times 10^{-3}$)
1	3.0	54.5	55
2	.57	22.3	26
3	.12	37.0	3.2
4	0	.75	0
5	.49	13.6	36
6	.06	22.2	2.7
7	.89	52.6	17
8	0	11.1	0
9	.45	20.9	22
10	.62	12.2	51
*11	.03	8.47	3.1
12	.07	27.2	2.6
13	.13	51.6	2.5
14	.03	13.5	2.1
15	.01	20.8	.53
*16	.30	38.1	7.9
17	.001	14.8	.07
18	0	10.4	0
19	.02	13.8	1.7
*20	0	3.97	0
*21	0	.38	0
*22	0	.90	0
23	0	.98	0
24	.14	30.9	4.5
+25	0	10.3	0
26	0	9.17	0
27	.17	16.3	10
28	0	4.17	0
29	0	3.73	0
30	.18	13.9	13
31	0	7.84	0
32	.34	18.9	18
33	.64	19.9	32
34	0	7.10	0
35	.087	14.2	6.1
#+36	.37	180	2.0
°+37	.62	282	2.2

+ Long-term station.
* Short-term station.
# Site 36 is in Greene County, Pa.
° Site 37 is in Ohio County, W. Va.

Flow Duration

The flow distribution and variability of streams may be shown by a flow-duration curve (fig. 13). This curve is a cumulative-frequency curve at a stream site that shows the percentage of time a specific daily discharge was equaled or exceeded during a given period of record (Searcy, 1959). The flow-duration curve shows the integrated effect of the various factors that affect runoff, such as precipitation, topography, geology, mining, urbanization, and agriculture. This curve also provides a convenient means for studying the flow characteristics of streams and for comparing one basin with another. The shape of the duration curve is indicative of the hydrologic and geologic characteristics of the drainage basin. A curve with a steep slope denotes a highly variable streamflow that is mainly from surface runoff. A curve with a flat slope indicates streamflow that is mainly from surface-water or ground-water storage, such as lakes, reservoirs, and permeable rocks. The low end of the duration curve characterizes the low flows of the stream. A flat slope at the low end of the curve indicates sustained base flow, and a steep slope indicates negligible base flow.

Duration curves that are used to compare streamflows in different basins must represent concurrent periods so that the differences between the curves are because of differences in climatic or drainage-basin characteristics and not because of the differences in flows for different periods of time. An example of this is illustrated in figure 13. The duration curve for Brush Run for 1983-85 is different than the curve for the period of record (1962-78 and 1983-85). The duration curve for the period of record includes 7 years (1962-67, 1973) when periods of no flow were common. The extremely steep slope at the lower end of the curve reflects the no-flow conditions. However, the shape of the lower end of the duration curve for 1983-85 indicates a sustained base flow for those 3 years of record.

Figure 14 shows the flow-duration curves developed for Brush Run (site 25), Enlow Fork (site 16), and Chartiers Creek (site 20) based on data collected from October 1982 through September 1985. Chartiers Creek had the most sustained base flow and Enlow Fork had the least sustained base flow. The steepness of the Enlow Fork curve indicates that this drainage basin has little ground-water storage.

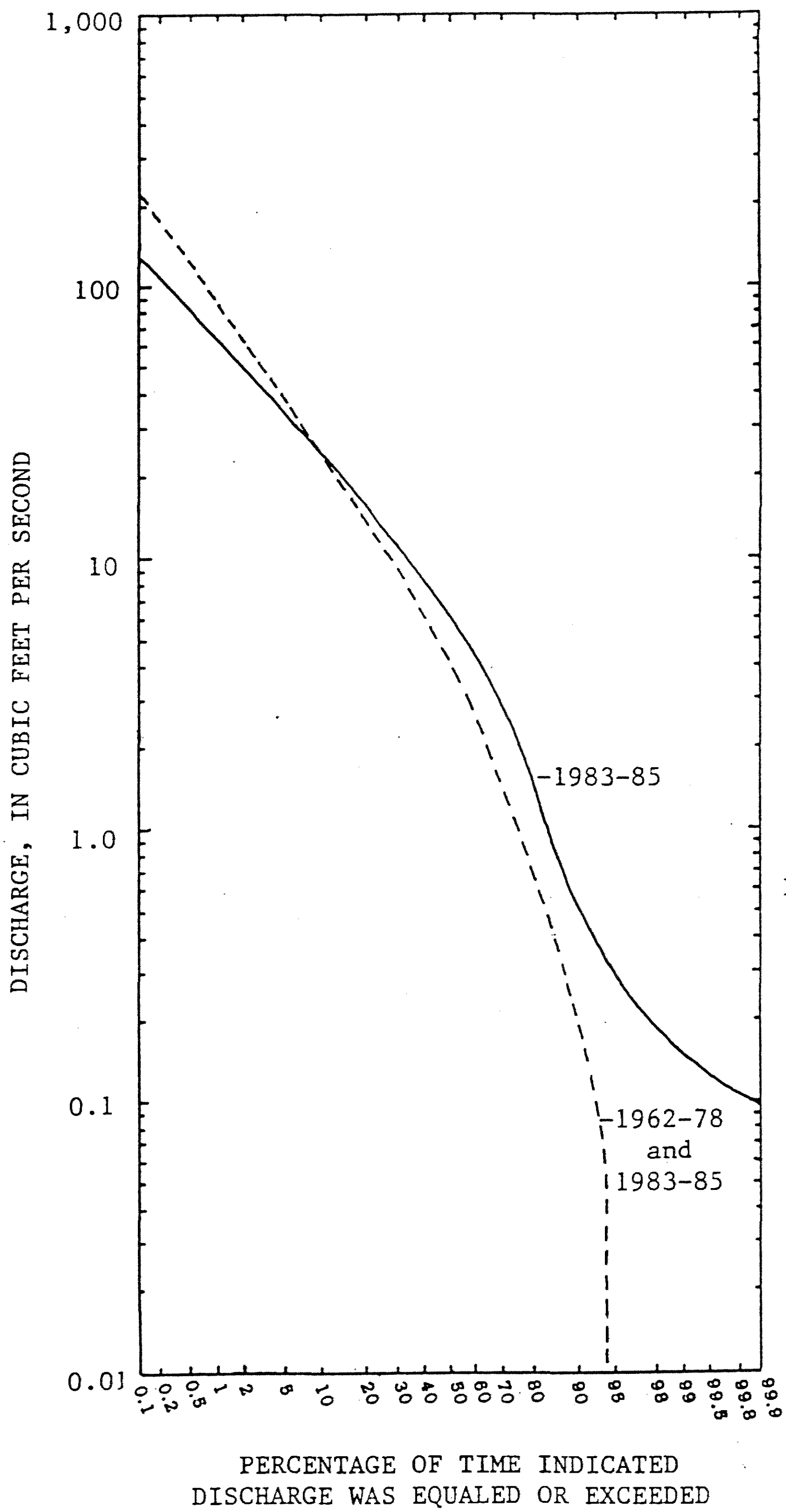


Figure 13.--Flow-duration curves for Brush Run (site 25) for the period of record 1962-78 and 1983-85 and the period of study 1983-85.

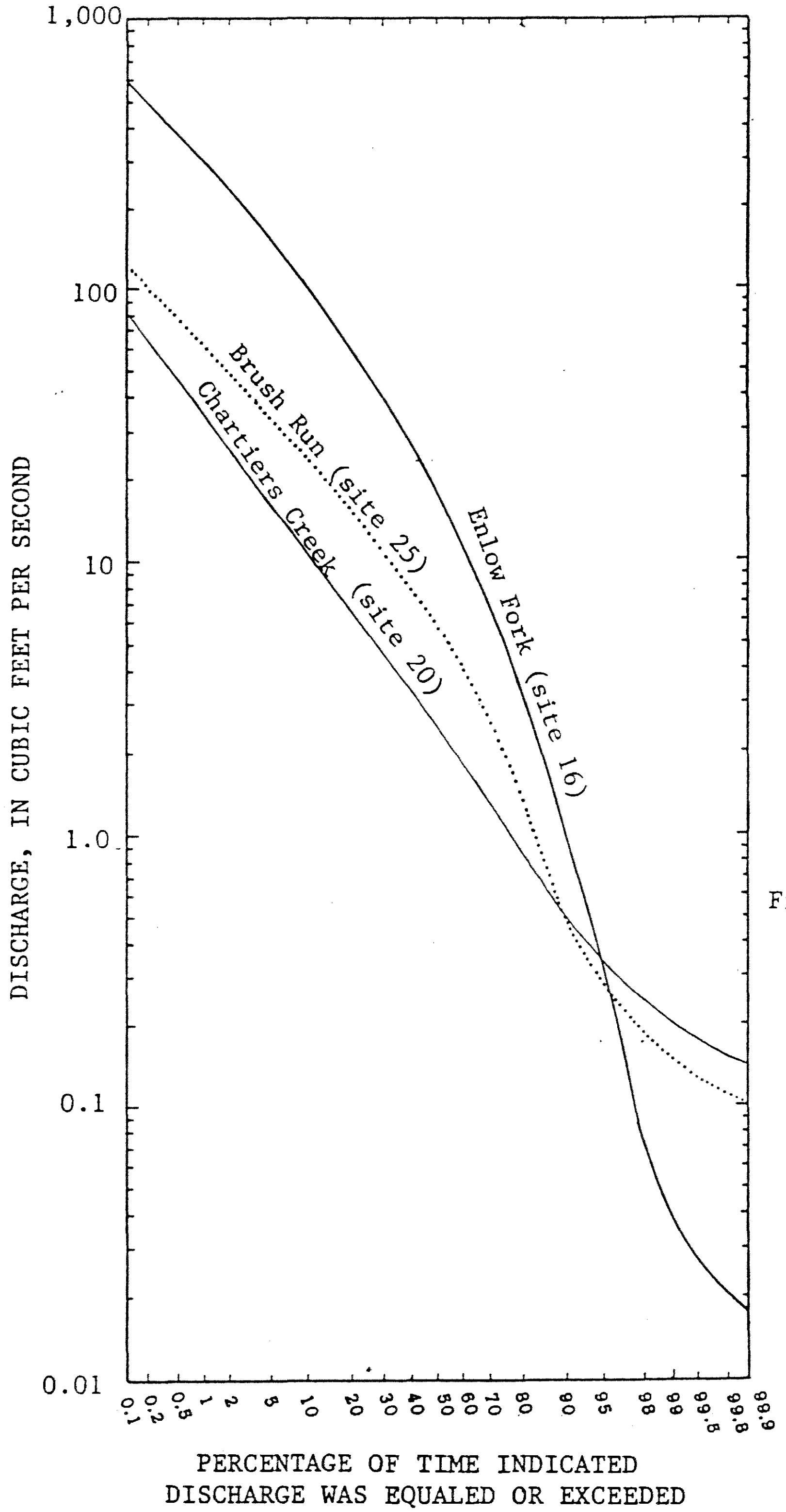


Figure 14.--Flow-duration curves for Brush Run, Chartiers Creek, and Enlow Fork for 1983-85.

Runoff Analyses

Total runoff in a stream consists of ground-water discharge (base flow) from the exposed or shallow aquifers plus surface runoff that travels over or through the soil to the stream. Runoff has a distinct seasonal variability. Highest runoffs normally occur in late winter and early spring because of ground-water discharge, icemelt, snowmelt, and high precipitation. Runoff generally decreases with the onset of warmer weather in response to increased rates of evaporation, transpiration, and soil absorption. Lowest runoffs generally occur in late summer and early fall. Table 8 shows the variation in runoff and precipitation measured at five Washington County gaging stations for 1983-85. Only 1 complete year of data (1985) was available for site 21, one of the two main inflows to Water-Supply Reservoir Number 4 in North Franklin Township. Mean runoff, in inches, in table 8 refers to the equivalent amount of water throughout the upstream drainage basin that would produce the corresponding mean runoff in cubic feet per second. The measured precipitation at all five sites was from 2 to 4 times greater than the mean runoff, and the annual water loss (difference between precipitation and runoff) ranged between 52 and 75 percent. Water loss is affected by evaporation, transpiration, diversion, mines, ground-water outflow, and plant and animal consumption. The annual water losses at the five gaging stations, represented as a percentage of precipitation, are:

	1983	1984	1985	AVERAGE
Brush Run at Buffalo (site 25)	69.5	62.9	62.6	65.0
Chartiers Creek at Lagonda (site 20)	61.5	51.8	64.8	59.4
Enlow Fork near West Finley (site 16)	54.9	59.7	67.2	60.6
Daniels Run near West Zollarsville (site 11)	69.4	60.4	75.0	68.3
Unnamed Tributary 2B to Chartiers Creek at Lagonda (site 21)	No data	No data	62.6	

When surface water in a particular area is being considered as a potential source of water supply, water losses can be used to determine the most productive areas of runoff.

Table 8.--Measured runoff and precipitation for five Washington County streamflow-gaging stations for water years 1983-85

[mi^2, square miles; ft^3/s, cubic feet per second; (ft^3/s)/mi^2, cubic feet per second per square mile; in., inches; --, no data]

Station	Drainage area (mi^2)	1983 Mean runoff ft^3/s	1983 Mean runoff [(ft^3/s)/mi^2]	1983 Mean runoff in.	1983 Measured precipitation (in.)	1984 Mean runoff ft^3/s	1984 Mean runoff [(ft^3/s)/mi^2]	1984 Mean runoff in.	1984 Measured precipitation (in.)	1985 Mean runoff ft^3/s	1985 Mean runoff [(ft^3/s)/mi^2]	1985 Mean runoff in.	1985 Measured precipitation (in.)
Brush Run near Buffalo, Pa. (site 25)	10.3	8.45	0.82	11.40	37.34	10.4	1.01	13.80	37.23	9.00	0.87	11.86	31.73
Chartiers Creek[1] at Lagonda, Pa. (site 20)	3.97	4.34	1.09	13.33	34.66	5.23	1.32	17.94	37.23	3.27	.82	11.18	31.73
Enlow Fork near West Finley, Pa. (site 16)	38.1	40.8	1.07	14.52	32.19	39.1	1.03	13.99	34.72	32.9	.86	11.74	35.78
Daniels Run near West Zollarsville, Pa. (site 11)	8.47	6.73	.80	10.78	35.27	9.08	1.07	14.60	36.86	4.94	.58	7.92	31.74
Unnamed Tributary 2B to Chartiers Creek at Lagonda, Pa. (site 21)	.38	--	--	--	--	--	--	--	--	.32	.86	11.86	31.73

[1]No streamflow record from October 1 through November 21, 1982.

WATER QUALITY

Ground-Water Characteristics

Acidity, alkalinity, pH, specific conductance, iron, manganese, hardness, chloride, and sulfate are constituents and properties commonly used to evaluate ground-water quality. The analyses of ground-water samples from wells and springs in the county are shown in Appendixes E and F. Besides the wells and springs sampled during this study, two wells were sampled in the late 1960s and early 1970s, and 13 wells were sampled by Piper (1933).

The U.S. Environmental Protection Agency (USEPA) has established maximum contaminant levels (MCLs)[1] and recommended maximum contaminant levels (RMCLs)[1] for selected contaminants of drinking water for public supply systems (table 9). The major ground-water-quality problems are elevated concentrations of iron, manganese, and dissolved solids, and high hardness. Minor ground-water-quality problems include elevated concentrations of fluoride, chloride, and sulfates. The source and significance of these and other constituents and properties of natural water are shown in table 10.

Table 9.--Federal maximum contaminant levels and recommended maximum contaminant levels for selected contaminants of drinking water for public supply systems[1]

[Limits in milligrams per liter except as indicated; --, no data available]

Contaminant	Maximum contaminant levels (MCLs)	Recommended maximum contaminant levels (RMCLs)
Arsenic (As)	0.05	--
Barium (Ba)	1	--
Cadmium (Cd)	.010	--
Chromium (Cr)	.05	--
Lead (Pb)	.05	--
Mercury (Hg)	.002	--
Nitrate (N)	10	--
Selenium (Se)	.01	--
Silver (Ag)	.05	--
Chloride (Cl)	--	250
Color (color units)	--	15
Copper (Cu)	--	1
Corrosivity	--	Noncorrosive
Foaming agents	--	.5
Iron (Fe)	--	.3
Manganese (Mn)	--	.05
Odor (threshold odor number)	--	3
pH (units)	--	6.5 - 8.5
Sulfate (SO_4)	--	250
Total dissolved solids	--	500
Zinc (Zn)	--	5
Fluoride (F)	1.4 - 2.4	Limit dependent on air temperature

[1]U.S. Environmental Protection Agency, 1983, Drinking Water Standards (Information from Code of Federal Regulations #40, 1983, parts 141.11 and 143.3).

[1]Maximum contaminant levels (MCLs) are levels of drinking-water contaminants that could cause health effects if exceeded and are enforceable by law. Recommended maximum contaminant levels (RMCLs) are levels of drinking-water contaminants that are not health related and are intended to protect public welfare by establishing unenforceable guidelines on the taste, odor, or color of drinking water.

Table 10.--Source and significance of constituents and properties of natural waters

[Adapted from Lloyd and Growitz (1977), p. 51-54; mg/L, milligrams per liter]

Constituent or physical property	Source or cause	Significance
Acidity	Primarily free mineral acids and carbonate acid. Common in areas where coal has been mined.	A limiting factor to aquatic organisms, especially fish life. Corrodes pipes, pumps, etc.; dissolves minerals, notably iron-bearing minerals.
Alkalinity	Primarily due to the presence of bicarbonate, carbonate, and hydroxide.	Ability to neutralize acids. Alkalinity may be undesirable for public supplies when in excessive concentrations.
Calcium (Ca) and magnesium (Mg)	Dissolved from almost all soils and rocks, especially limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Large quantities of magnesium are present in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness).
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage. Found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium gives salty taste to drinking water. In large quantities increases the corrosiveness of water. Above-average levels can indicate contamination by sewage, industrial wastes, or road-deicing chemicals.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils; may include organic matter. Frequently excessive in coal-mining areas.	Excessive hardness, taste, mineral deposition, or corrosion are common properties of water high in dissolved solids. Waters with very low concentrations of dissolved solids often do not support aquatic life due to lack of nutrients and essential elements. Water becomes unsuitable for many purposes when it contains more than 1,000 mg/L dissolved solids.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Also, often added to public water supplies with chlorine.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, age of the child, amount of drinking water consumed, and susceptibility of the individual.
Hardness as calcium carbonate ($CaCO_3$)	Nearly all the hardness in most waters is due to calcium and magnesium. Iron, manganese, aluminum, and free acid also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness up to 60 mg/L are considered soft; 61-120 mg/L, moderately hard; 121-180 mg/L, hard; more than 180 mg/L, very hard.
Iron (Fe)	From practically all rocks and soils. High in coal-mine drainage, from coal preparation plants, and from landfills. Most high concentrations are a result of oxidation processes and are usually unrelated to coal mining.	In streams affected by coal-mine drainage, reddish-brown iron precipitates blanket stream bottoms. More than about 0.3 mg/L of iron stains laundry and porcelain. In higher concentrations, gives an unpleasant taste (Durfor and Becker, 1964). Methods to remove from drinking water include water treatment by oxidation followed by filtering or ion exchange processes.
Manganese (Mn)	From many rocks and soils. Can be found in unusually high concentrations in coal-mine drainage. Most high concentrations are a result of oxidation processes and are usually unrelated to coal mining.	More than 0.05 mg/L can cause brown spots in laundry and dark precipitates. Imparts an unpleasant taste. May coat rocks on stream bottoms.
Sodium (Na) and potassium (K)	Dissolved from almost all rocks and soils. Found in ancient brines, sea water, some industrial brines, and sewage.	Large amounts in combination with chloride give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes.

Table 10.--Source and significance of constituents and properties of natural waters--Continued

[Adapted from Lloyd and Growitz (1977), p. 51-54]

Constituent or physical property	Source or cause	Significance
pH	Summary effect of the acid and alkaline constituents in solution. Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonate, bicarbonate, hydroxide and phosphate, silicate, and borate raise the pH.	pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. The pH is a measure of hydrogen-ion activity. The corrosive properties of water generally increase with decreasing pH; however, excessively alkaline water may also attack metals.
Silica (SiO_2)	Dissolved from almost all rocks and soils, generally in small amounts from 1-30 mg/L. High concentrations--as much as 100 mg/L--generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of steam turbines.
Specific conductance (microsiemens per centimeter at 25 °C)	Mineral content of the water.	Specific conductance is a measure of the capacity of water to conduct an electric current; varies with concentration and degree of ionization of the constituents. Varies with temperature; reported at 25 °C.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfide, and other sulfur compounds. Generally present in mine waters and in some industrial wastes and sewage.	Chief anion in mine drainage and in all high dissolved-solids water. Forms sulfuric acid. May cause detectable tastes at concentrations of 300-400 mg/L. At concentrations above 600 mg/L may have laxative effect.
Temperature	Shallow wells show some seasonal fluctuations in water temperature. Ground water from moderate depths generally is nearly constant in temperature, which is near the mean annual air temperature of the area. In very deep wells the water temperature generally increases on the average about 1 °F with each 100-foot increment of depth. Seasonal fluctuations in temperature of surface water are comparatively large--depending on the depth of water--but do not reach the extremes of air temperature.	Affects the usefulness of water for many purposes. For most uses, a water of uniformly low temperature is desired.

General Ground-Water-Quality Constituents

Concentrations of iron and manganese above USEPA RMCLs (table 9) are common in the ground water in the county. More than 33 percent of the water samples had iron concentrations greater than the USEPA RMCL; 30 percent had manganese concentrations greater than the limit.

Hard water is a common water problem in the county. More than 75 percent of the wells and all of the springs sampled had very hard water. Water from seven wells had fluoride concentrations greater than the MCL; the maximum concentration was 7.0 mg/L. Six of the seven wells were in valleys, and four tapped the Pittsburgh Formation.

Water sampled from five wells had chloride concentrations that exceeded the RMCLs; the maximum concentration was 1,200 mg/L. Several wells sampled had sulfate concentrations that exceeded the RMCLs; the maximum concentration was 600 mg/L.

Concentrations of arsenic, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc for wells sampled were less than drinking-water levels established by the USEPA (table 9). These and other trace-element concentrations are shown in Appendix F.

Dissolved-solids concentrations have been used to determine the salinity of water. The following are salinity terms assigned for water containing elevated concentrations of dissolved solids (Hem, 1985, p. 157):

Term	Dissolved solids (mg/L)
Slightly saline	1,000 - 3,000
Moderately saline	3,000 - 10,000
Very saline	10,000 - 35,000
Briny	More than 35,000

Seven wells sampled had slightly saline water. Four of the seven wells with slightly saline water tap the Washington Formation. Saline water is found at variable depths. Saline water generally is closest to land surface in the larger stream valleys where there is regional discharge of ground water.

The USEPA RMCL for total dissolved-solids concentration is 500 mg/L (table 9). Dissolved-solids concentrations (not total dissolved solids) for wells and springs sampled are in Appendix E. The dissolved-solids concentrations in more than one-third of the wells sampled exceeded 500 mg/L. The water in half of the wells sampled that tap the Pittsburgh Formation had concentrations greater than 500 mg/L. The maximum dissolved-solids concentration (2,460 mg/L) was also from a well that taps the Pittsburgh Formation.

Specific conductance can be used to estimate dissolved-solids concentrations. The mean ratio of dissolved-solids concentration to specific conductance ranged from 0.56 (Glenshaw Formation) to 0.64 (Casselman Formation). The mean ratio for 82 well analyses was 0.60, and the mean ratio for six spring analyses was 0.59. Therefore, the dissolved-solids concentration of the ground water may be estimated by multiplying the specific conductance by 0.60.

Specific conductance and pH were measured at inventoried water wells whenever possible. The specific conductance of inventoried wells ranged from 120 to 2,750 μS/cm (microsiemens per centimeter at 25 degrees Celsius). The pH of inventoried wells ranged from 5.7 to 9.1. Although the range of pH is outside the USEPA RMCLs, most pH values were less than the RMCLs.

Water Quality of Bedrock Formations

Glenshaw Formation

All four sampled wells tapping the Glenshaw Formation had soft to moderately hard water. The pH ranges from 7.4 to 8.3. Specific conductance ranges from 520 to 1,400 μS/cm.

Casselman Formation

Three wells were sampled from the Casselman Formation. One well had iron concentrations that exceeded USEPA RMCLs (table 9). Water from two wells had manganese concentrations that exceeded USEPA RMCLs (table 9). Well WS-324 had concentrations that exceeded USEPA RMCLs for sulfate (530 mg/L) and dissolved solids (1,000 mg/L). The pH ranged from 6.2 to 7.5. Specific conductance ranged from 470 to 1,750 μS/cm.

Pittsburgh Formation

Water-quality problems in the Pittsburgh Formation include elevated concentrations of dissolved solids, iron, fluoride, manganese, and chloride, and hardness. Water in half of the wells sampled in the Pittsburgh Formation had dissolved-solids concentrations that exceeded USEPA RMCLs (table 9). The water in well WS-240 had the maximum dissolved-solids concentrations (2,460 mg/L) of all the wells sampled. Samples from one-fourth of the wells had iron concentrations greater than USEPA RMCLs; the maximum concentration was 850 μg/L (micrograms per liter) in well WS-914. Water in four of the 20 wells sampled had fluoride concentrations that exceeded USEPA MCLs; the maximum concentration was 7.0 mg/L in well WS-289. Manganese concentrations exceeded USEPA RMCLs (table 9) in the water of three wells. The water in well WS-240 had the maximum chloride concentration (1,200 mg/L) of all wells sampled. Very hard water was found in 70 percent of the wells sampled. The pH ranged from 5.9 to 8.6. The specific conductance ranged from 365 to 4,400 μS/cm.

Uniontown Formation

Elevated iron and manganese concentrations are common in the ground water in the Uniontown Formation. About one-third of the samples had an iron concentration that exceeded USEPA RMCLs; the maximum concentration was from well WS-219, 4,300 μg/L. Samples from almost half of the wells had a manganese concentration greater than the USEPA RMCLs; the maximum, 370 μg/L, was from well WS-265. More than 80 percent of the wells sampled that tap the

Uniontown Formation had very hard water. Spring WS-72 had a sulfate concentration of 440 mg/L. The pH ranged from 5.9 to 9.1. The specific conductance ranged from 287 to 2,000 μS/cm.

Waynesburg Formation

Iron and manganese concentrations exceeded USEPA RMCLs in samples from one-third of the wells. The maximum concentration for iron and manganese were 3,300 μg/L in well WS-189 and 1,100 μg/L in well WS-586, respectively. Water in almost 30 percent of the sampled wells had dissolved-solids concentrations that exceed USEPA RMCLs; the maximum concentration was 1,110 mg/L in well WS-609. Water from well WS-609 also had elevated fluoride and chloride concentrations. Very hard water was found in more than 85 percent of the wells sampled. The pH ranged from 6.1 to 8.2. The specific conductance ranged from 225 to 1,600 μS/cm.

Washington Formation

The Washington Formation had more water-quality problems than any other formation tested. Iron concentrations in samples of more than half the wells exceeded USEPA RMCLs; the maximum iron concentration (4,500 μg/L) was in well WS-322. Samples in more than 40 percent of the wells had manganese concentrations that exeeded USEPA RMCLs; the maximum concentration (350 μg/L) was in well WS-271. Dissolved-solids concentrations in samples from about one-third of the wells exceeded USEPA RMCLs. The maximum chloride concentration (950 mg/L) was collected from well WS-579. Water sampled from well WS-297 had the maximum concentration of sulfate (600 mg/L). Almost 80 percent of the wells sampled in the Washington Formation had very hard water. The pH ranged from 5.7 to 7.9. Specific conductance ranged from 270 to 1,550 μS/cm.

Greene Formation

Iron concentrations exceeded USEPA RMCLs in water from three of the seven wells sampled. Water in two wells had elevated dissolved-solids concentrations. The water in all seven wells was very hard. The pH ranged from 6.4 to 7.4. Specific conductance ranged from 120 to 1,420 μS/cm.

Water Quality of Unconsolidated Deposits

Carmichaels Formation

Because of limited areal extent and the small number of wells completed in the Carmichaels Formation, water-quality data were not available.

Alluvium

Of the sparse data available, some indicate the water in the alluvium may exceed USEPA RMCLs for iron and manganese.

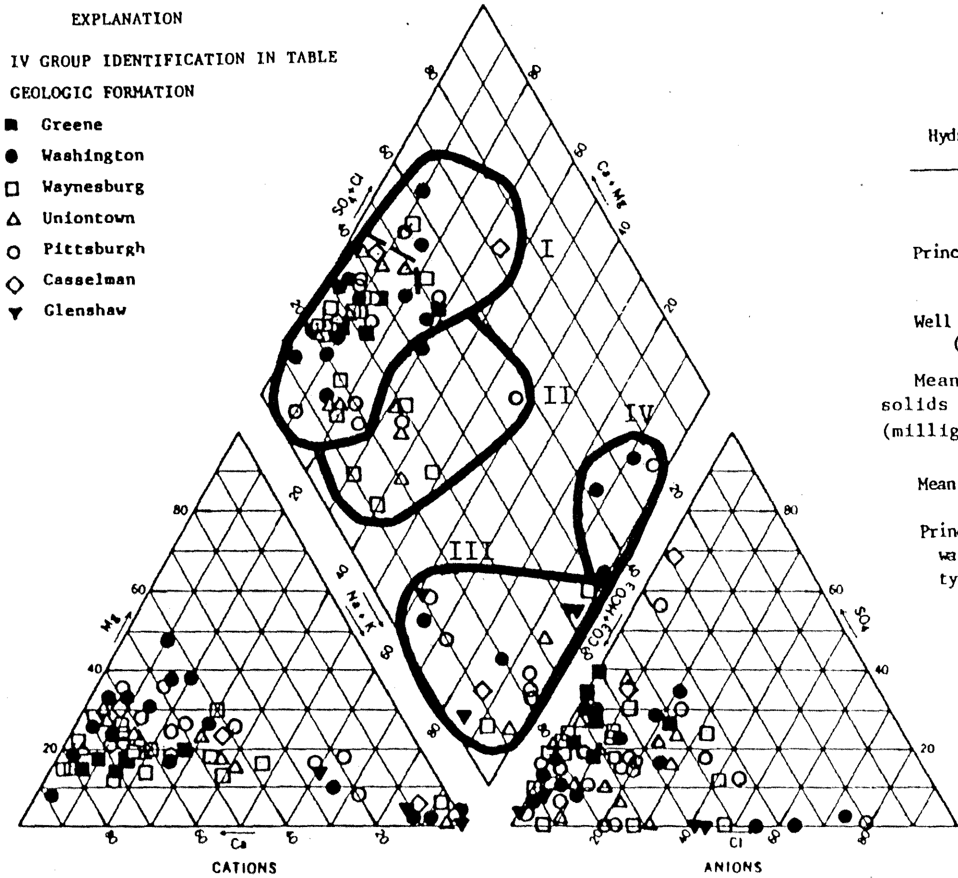
Changes Along Flow Path

A trilinear diagram, figure 15, is one method of comparing results of chemical analyses of water. This diagram consists of two lower triangles that show the percentage distribution, on a milliequivalent basis, of the major cations [magnesium (Mg^{++}), calcium (Ca^{++}), and sodium (Na^{+}) plus potassium (K^{+}), and the major anions; chloride (Cl^{-}), sulfate (SO_4^{--}), and carbonate (CO_3^{--}) plus bicarbonate (HCO_3^{-})], and a diamond-shaped part above that summarizes the dominant cations and anions to indicate the overall water type.

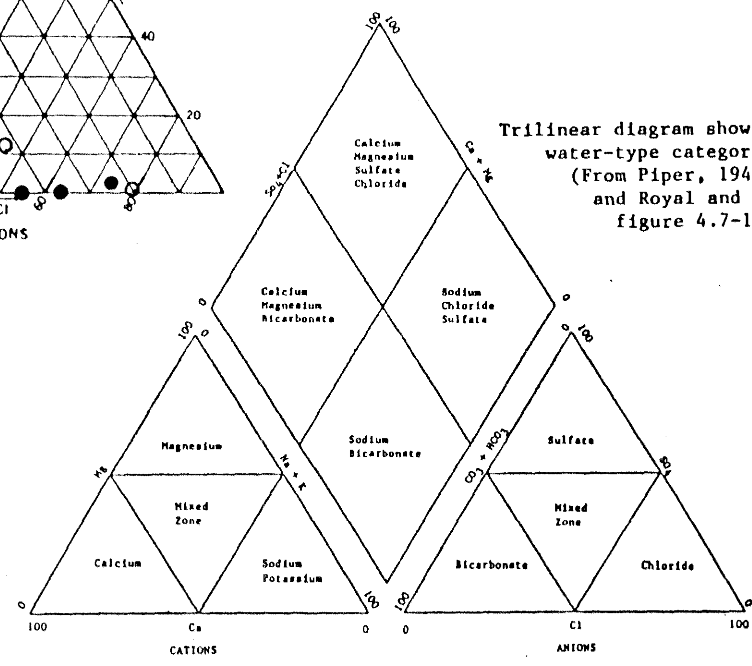
The water types are designated according to the area in which they occur on the diagram segments. For example, sea water and brine would lie in the sodium chloride-sulfate segment, and acid mine drainage would lie in the calcium-magnesium sulfate-chloride segment. Water types are determined by the cations and anions with concentrations greater than 50 percent. In figure 15, the water type for hillside and valley wells, Group III, is sodium bicarbonate. If no cation or anion concentration exceeds 50 percent, then the water type is described by the two ion concentrations with the highest percentages. For example, in the hillside wells, Group II, the water type is calcium-sodium bicarbonate.

Group I contains a Subgroup IA. The predominant water types in Subgroup IA are calcium-bicarbonate-chloride and calcium-magnesium-bicarbonate-sulfate. Subgroup IA has a mean dissolved-solids concentration of 838 mg/L and a mean sulfate concentration of 258 mg/L. These mean concentrations exceed USEPA RMCLs (table 9). The elevated sulfate concentrations may partly reflect the presence of abundant pyrite in coal beds, which are part of the aquifer.

Water types were found not to be related to geologic units except for the Greene and Glenshaw Formations. The water type for all six wells sampled from the Greene Formation was calcium bicarbonate. The water type for all four wells sampled from the Glenshaw Formation was sodium bicarbonate. The small number of wells sampled in the Greene and Glenshaw Formations may account for the apparent relation of water type to these geologic units. Water types appear to be unrelated to rock lithologies such as sandstone, limestone, and shale. The vertical movement and mixing of ground waters passing through fractured bedrock composed of a variety of rock types probably contribute to the variability of water types within lithologies and formations.



Hydrologic Setting	Recharge	Intermediate		Discharge
	Residence Time			
Group	I	II	III	IV
Principal topographic setting	Hilltop, hillside	Hillside	Hillside, valley	Valley
Well depth range (feet)	21-301	75-200	60-210	48-185
Mean of dissolved solids concentrations (milligrams per liter)	454	404	611	1870
Mean of pH	7.1	7.4	8.2	7.5
Principal water type	Calcium-bicarbonate	Calcium-sodium-bicarbonate	Sodium-bicarbonate	Sodium-chloride



Trilinear diagram showing water-type categories. (From Piper, 1944, figure 1, and Royal and others, 1983, figure 4.7-1.)

Figure 15.--Trilinear diagram of chemical composition of ground water.

Changes Over Time

Two wells that were sampled for water quality during this investigation had been sampled previously. Well WS-155 near Good Intent was sampled in July 1971 and again in August 1983. The water quality had not changed appreciably in 12 years (Appendixes E and F). Well WS-74, located at the middle school in Hickory (inset J Hickory, plate 3a), was sampled by Piper (1933) in September 1926. The well was resampled in August 1983. The schools' present water system combines the water from wells WS-74 and WS-440. Analyses show significant increases in concentrations of calcium, sulfate, chloride, and dissolved solids from 1926 to 1983. The chloride concentration of the 1983 sample was almost five times greater than the chloride concentration of the 1926 sample. Newport (1973, p. 27) stated that the water quality of shallow freshwater aquifers has been degraded by saltwater that moved upward under artesian pressure through oil and gas boreholes that have no well casings or have casings that are severely corroded.

Surface-Water Characteristics

A network of 35 sampling sites was established throughout the county to assess the surface-water quality (table 3, fig. 1). The sampling sites selected were on: (1) main streams in the county; (2) streams considered to have a high recreational value (such as those designated by the Pennsylvania Fish Commission as approved trout waters and other such streams inhabited by warm-water species of game fish); (3) inflows to public surface-water supply reservoirs; or (4) streams where AMD has had a detrimental effect on the water quality.

All 35 sites were sampled at high base flow in May 1983 and at low base flow in August 1983, 1984, and 1985. Sites 11, 16, 20, 21, 22, and 25 were at streamflow-gaging stations and were sampled more often than other sites throughout the study period. Sites 11 and 25, at the outflows of a mined and an unmined basin, respectively, were sampled 11 times. Sites 16, 20, 21, and 22 were sampled 6 times. Site 16 also was sampled 29 times from August 1979 through August 1982 as part of the Greene County water-resources study. Site 15, which was also a water-quality site for the Greene County study, was sampled 9 times from March 1980 through August 1981. Sites 1, 2, 3, 6, 8, 10, 13, 27, 28, 32, 33, and 34 were sampled 6 times from June 1979 through August 1981 when they were part of the U.S. Geological Survey Coal Hydrology Network. All water-quality data collected during the study are shown in Appendix G. Data collected prior to October 1982 were published by the U.S. Geological Survey (1979, 1980, 1981, 1982) in annual water-resource data reports.

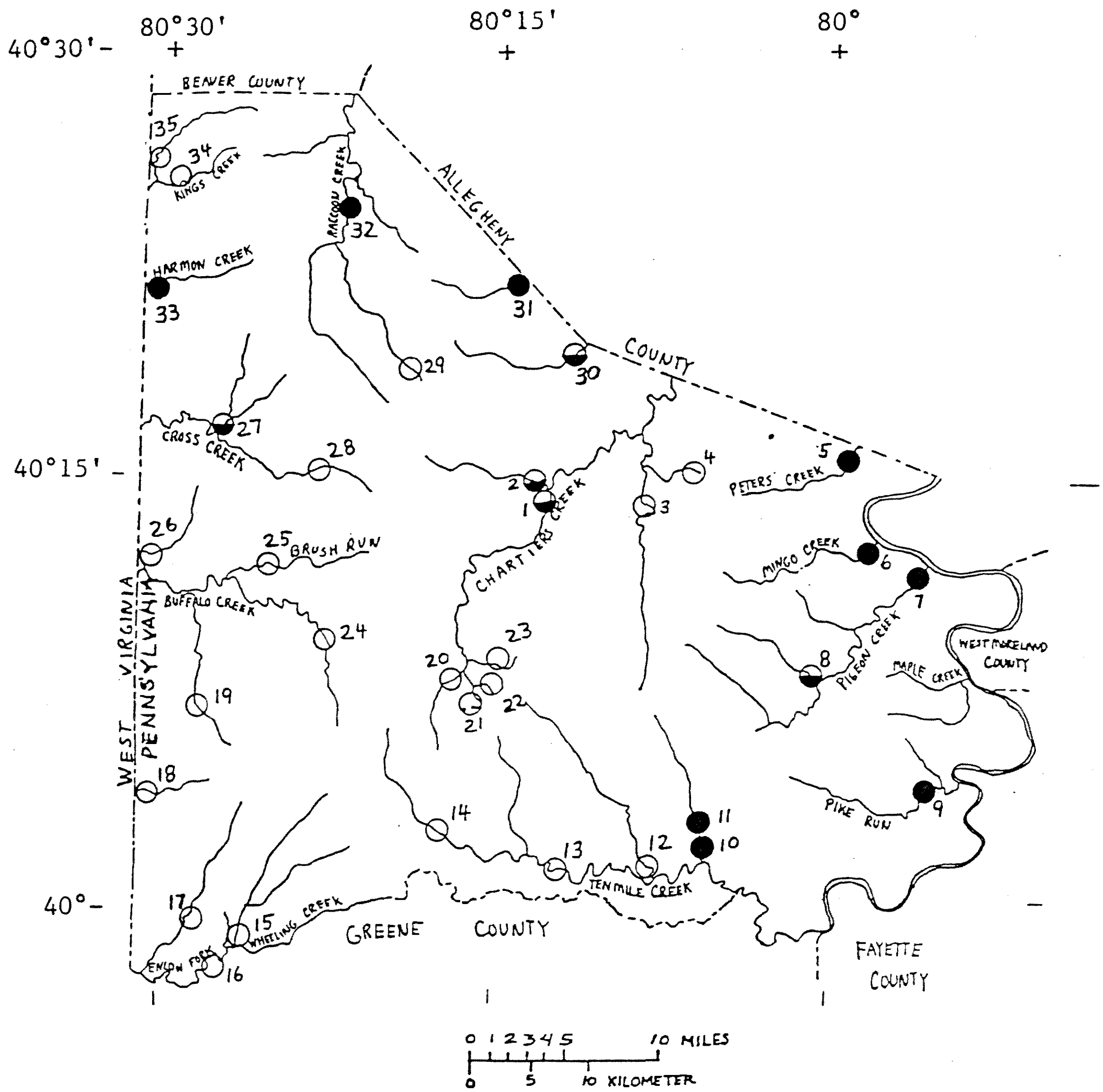
The constituents and properties used to evaluate the water quality include pH, acidity, alkalinity, specific conductance, dissolved solids, calcium, magnesium, sodium, potassium, fluoride, chloride, sulfate, silica, iron, and manganese. Table 10 shows some of the sources and significance of the constituents and properties used to evaluate the water quality. This information is helpful in understanding the controls on quality of water and the possible consequences if concentrations of certain constituents were to exceed RMCLs. Table 9 gives the USEPA MCLs and RMCLs for selected contaminants of drinking water for public supply systems.

The four base-flow samples collected in May 1983 and August 1983, 1984, and 1985 are used to assess the countywide water-quality conditions. All samples were collected under the same climatic and hydrologic conditions. Base-flow samples generally contain the highest concentrations of dissolved constituents because they are least affected by dilution from surface runoff and are therefore often indicative of the poorest water-quality conditions for that particular stream. Figure 16 shows the relative magnitude areally of dissolved solids.

The dissolved-solids concentration often is used in evaluating the overall water-quality condition of a stream and is a convenient means of comparing the surface-water quality throughout the county. Individual ions, pairs of ions, and complexes made up of several ions all contribute to the dissolved-solids concentration. The principal inorganic anions in surface water include the carbonates, chloride, and sulfate. The principal cations include calcium, magnesium, sodium, and potassium. In coal-mined areas, the weathering and oxidation of pyrite and other minerals produce elevated concentrations of iron, manganese, and sulfate, which can contribute to unusually high dissolved-solids concentrations. The USEPA RMCL for dissolved solids in drinking water is 500 mg/L; water becomes unsuitable for many other purposes when dissolved-solids concentration exceeds 1,000 mg/L. Figure 16 shows the sites where the maximum measured concentrations of dissolved solids were less than 500 mg/L, from 500 to 1,000 mg/L, and greater than 1,000 mg/L. Dissolved-solids concentrations greater than 1,000 mg/L generally were found in northern and eastern Washington County where coal mining and AMD are most prevalent. Concentration of dissolved solids generally varies inversely with stream discharge. During base flow, stream discharge is sustained by ground-water discharge that generally has an elevated concentration of dissolved solids because of its prolonged contact with minerals in soils and rocks. During high flow, stream discharge is mostly from precipitation and surface runoff that have relatively low concentrations of dissolved solids because the short period of contact with soluble minerals at the surface. This is illustrated in figure 17, which shows the relation between discharge and dissolved-solids concentration at Enlow Fork near West Finley (site 16).

The pH in natural streams normally ranges between 6.5 and 8.5 and the pH of almost every stream sampled in Washington County fell within that range. In coal-mined areas, a pH below 6.5 usually indicates the presence of AMD and a pH less than 4.5 usually indicates the presence of untreated AMD. The pH of only two sampled streams was less than 6.5. The pH of four samples collected on Robinson Run at McDonald (site 31) ranged from 6.2 to 6.5. The pH of four samples collected on Raccoon Creek at Raccoon, Pa. (site 32) ranged from 4.4 to 6.8. Both of these streams drain areas with numerous abandoned deep and surface mines. Other sites sampled in the northern and eastern part of the county are in areas of active and abandoned coal mines, but a combination of AMD treatment or natural stream alkalinities and dilution appear to be capable of raising stream pH to above 7.0.

Acidity and alkalinity of a stream are measures of the stream's buffering capacity or its ability to resist a pH change upon the addition of a base (acidity) or an acid (alkalinity). A stream having a pH of 4.5 to 8.3 has both acidity and alkalinity. If the acidity exceeds the alkalinity, the stream is considered to be acid, whereas if alkalinity exceeds the acidity,



EXPLANATION

SITE LOCATION AND NUMBER	MAXIMUM DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER
10 ●	GREATER THAN 1,000
27 ◒	500 to 1,000
17 ○	LESS THAN 500

Figure 16.--Maximum dissolved-solids concentrations measured in streams.

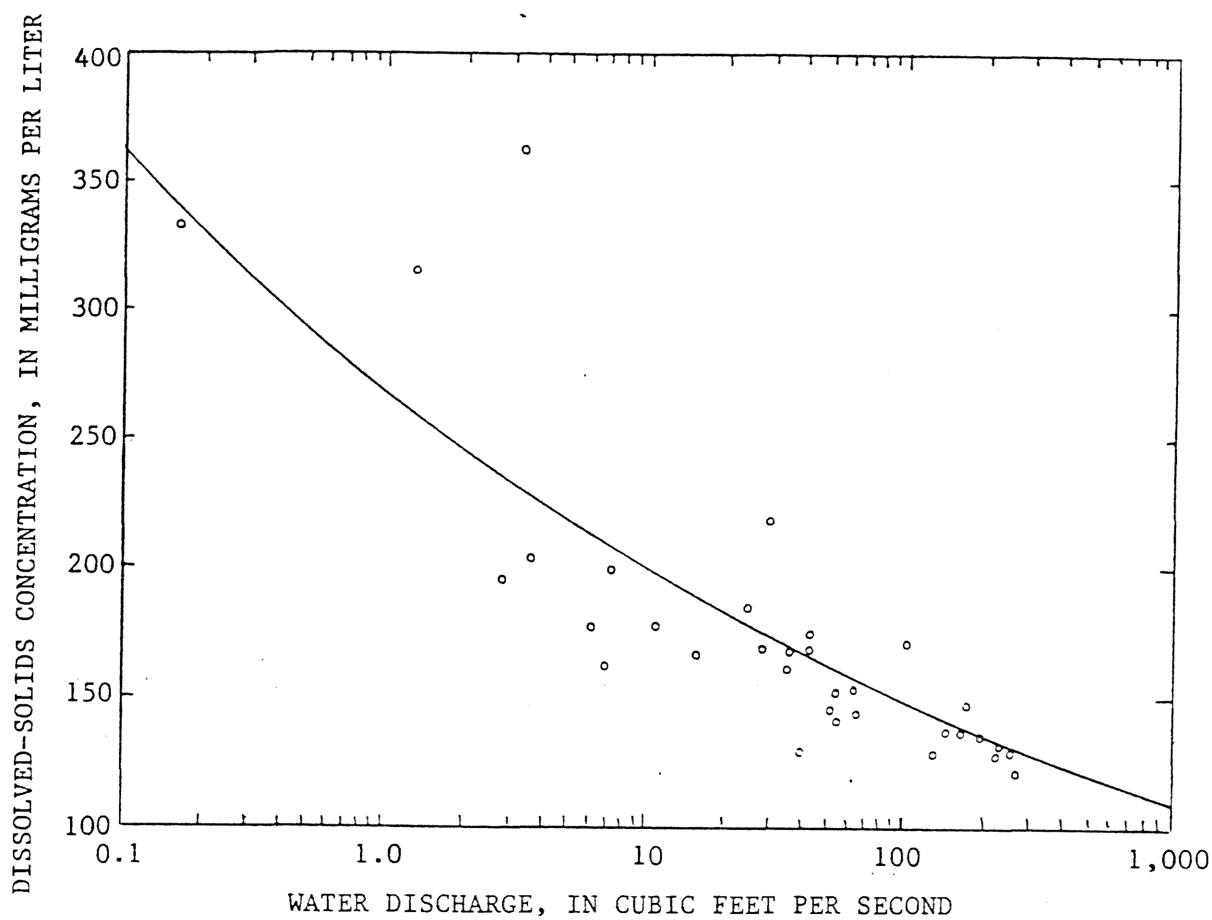


Figure 17.--Relation between water discharge and dissolved-solids concentrations at Enlow Fork near West Finley, Pa. (Site 16).

the stream is considered to be alkaline. In this report, acidity and alkalinity are expressed as equivalent concentrations of calcium carbonate ($CaCO_3$) in milligrams per liter. At site 31, the mean acidity was 69 mg/L, and the mean alkalinity was 22 mg/L. At site 32, the mean acidity was 63 mg/L, and the mean alkalinity was 24 mg/L. At the other 33 sites, the alkalinity greatly exceeded the acidity. The mean alkalinity at these sites ranged from 86 to 345 mg/L, and the mean acidity ranged from 0 to 8.8 mg/L.

Beall (1975), in a reconnaissance of water quality of streams in the six-county Greater Pittsburgh Region, found the highest alkalinities (greater than 200 mg/L) in a group of streams in central Washington County that includes Pike Run (site 9), Pigeon Creek (site 7), Mingo Creek (site 6), Little Chartiers Creek (site 3), and Buffalo Creek (site 24). He also observed high alkalinity in southern and western Washington County streams.

According to Biesecker and George (1966), alkalinities of less than 50 mg/L are relatively incapable of neutralizing large quantities of acid mine drainage that enter the receiving stream. The alkalinities at 33 sites greatly exceeded 50 mg/L; these streams probably would have a neutralizing effect on most acidic inflow.

Sulfate, iron, and manganese are three constituents often associated with AMD. AMD is produced by the oxidation of pyrite (FeS_2) normally present in coal and adjacent rock strata. The oxidation of pyrite usually is described by the following reaction in which pyrite, oxygen, and water form sulfuric acid and ferrous sulfate:

$$2FeS_2 + 7O_2 + 2H_2O = 4H^+ + 2Fe^+ + 4SO^{2-}. \qquad (2)$$

Oxidation of ferrous iron (Fe^{2+}) produces ferric ions (Fe^{3+}) according to the following reaction:

$$2Fe^{2+} + 1/2\ O_2 + 2H^+ = 2Fe^{3+} + H_2O. \qquad (3)$$

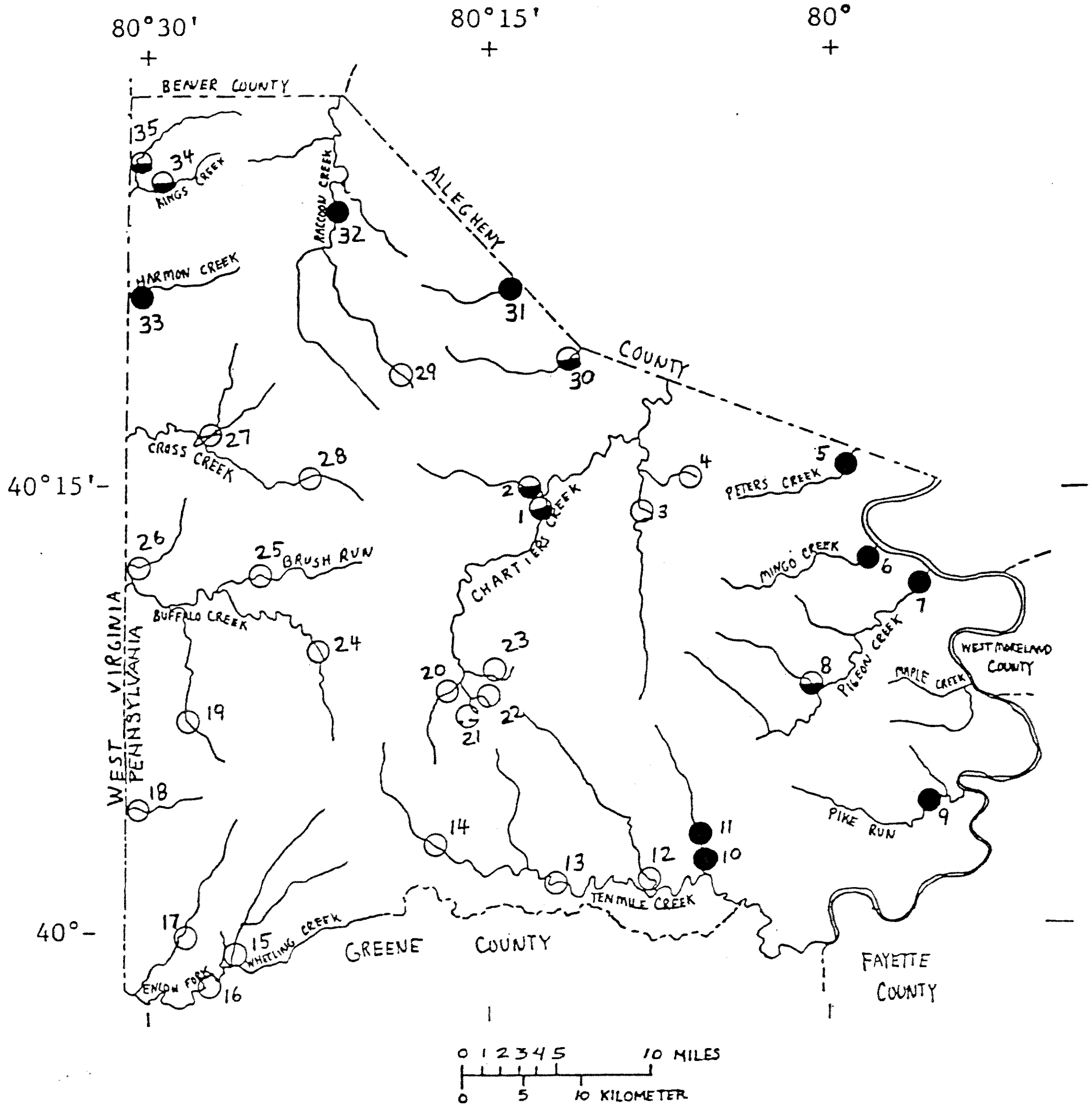
When the ferric ions react with water, it produces an insoluable ferric hydroxide [$Fe(OH)_3$], also referred to as "yellow boy," and more acid:

$$Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+. \qquad (4)$$

The above reactions produce elevated concentrations of ferric hydroxide [$Fe(OH)_3$], sulfate (SO_4^{2-}), and acid (H^+). Secondary reactions of the acidic water dissolve many other constituents associated with coal deposits, such as manganese, aluminum, and zinc. Laboratory analyses for aluminum and zinc were not done in this study. The highly mineralized water collects in mine impoundments and spoils where it eventually evaporates, percolates downward into underlying aquifers, or runs off into streams. If the receiving stream is sufficiently alkaline, the acidic water may exist only for a short time before being neutralized. However, natural neutralization or deliberate neutralization (treatment with an alkaline agent) does not change the concentration of sulfate, and therefore, sulfate persists as an indicator of mine drainage. A good example of this is seen from data collected on Daniels Run at West Zollarsville, Pa. (site 10). This site is downstream from two treated deep-mine discharges. The sulfate concentrations there were the highest measured at any site (2,600 mg/L maximum, 1,900 mg/L mean), and yet the pH ranged from 8.1 to 8.8, and the alkalinity ranged from 180 to 460 mg/L. According to Toler (1982), sulfate concentrations in excess of 100 mg/L in base-flow conditions can be attributed to drainage from coal-mined areas.

Maximum sulfate concentrations measured in streams throughout Washington County ranged from 40 to 2,600 mg/L. Mean concentrations ranged from 35 to 1,900 mg/L. Figure 18 shows that sulfate concentrations were highest in northern and eastern Washington County where most of the active and abandoned coal mines are located. There is evidence of either active or abandoned, surface- or deep-mining activity upstream from every sampling site where the maximum measured sulfate concentrations exceeded 100 mg/L.

At all sites except 31 and 32, maximum total-iron concentrations ranged from 240 to 9,200 $\mu g/L$, and maximum dissolved-iron concentrations ranged from 9 to 160 $\mu g/L$. Although elevated concentrations of dissolved iron usually are associated with acid mine discharges, quite often the iron precipitates out a short distance downstream from where the acid mine discharge enters the receiving stream. Therefore, dissolved-iron concentration is not a reliable indicator of AMD. Dissolved iron in waters void of dissolved oxygen that originate from ground water or deep mines usually is in the ferrous form



EXPLANATION

SITE LOCATION AND NUMBER	MAXIMUM DISSOLVED-SULFATE CONCENTRATION IN MILLIGRAMS PER LITER
33 ●	GREATER THAN 500
2 ◒	100 TO 500
17 ○	LESS THAN 100

Figure 18.--Maximum dissolved-sulfate concentrations measured in streams.

(Fe^{2+}). When this water is pumped from the deep mines or seeps to the land surface, the ferrous iron (Fe^{2+}) is readily oxidized to the ferric form (Fe^{3+}) and usually precipitates out as ferric hydroxide, a yellow-orange precipitate usually referred to as "yellow boy" (see reactions on p. 64). This precipitate is noticeable in many streams in the northern and eastern part of the county where AMD is common. At sites 31 and 32, the maximum dissolved-iron concentrations were 29,000 and 13,000 μg/L, respectively, and the maximum total-iron concentrations were 33,000 and 14,000 μg/L, respectively. Although iron precipitates out in these two streams, as is apparent from the large deposits of yellow boy, elevated concentrations of iron remain in the dissolved phase because of low pH and incomplete neutralization.

Manganese is found in various salts and minerals, commonly in association with iron compounds. In mined areas, the consumption of oxygen in the oxidation of pyrite produces a reducing environment that increases the concentration of soluble manganese. Dissolved-manganese concentrations usually persist in streams for greater distances downstream from the source than do dissolved-iron concentrations (Hem, 1985). This was observed at Harmon Creek near Hanlin Station (site 33) where numerous abandoned mines are located throughout the basin. Elevated sulfate concentrations and elevated pH indicate that a large volume of treated acidic mine water enters the stream above the site. The average dissolved-iron concentration was low (17 μg/L), but the average dissolved-manganese concentration was rather high (650 μg/L), indicating that much of the iron had precipitated out. This was observed at site 33 in the four base-flow samples collected during the study and in six samples collected from June 1979 through August 1981 during various streamflow conditions.

HYDROLOGIC EFFECTS OF COAL MINING

Surface mining and underground mining of coal have affected ground-water resources and streamflow, depending on the siting of the mining operation and the geology of the area.

Aquifers in the overburden are affected by surface-mine operations causing water supplies from wells to be reduced or eliminated, as evidenced by declining water levels and wells going dry. In areas of mine spoils and refuse piles, infiltration of precipitation causes rapid weathering of minerals and the production of AMD, which has a low pH and contains elevated concentrations of iron, manganese, sulfate, and dissolved solids. The AMD commonly flows into nearby streams and local aquifers. In the area of surface mining, the water from these mine spoils also extends the period of increased base flow compared with areas of little or no mining activity.

In areas of underground mine operations, water resources are affected when fractures in the bedrock are connected with aquifers and streams. These effects depend on the thickness between the underground mine operation and the overlying water resource, and on the permeability of the overburden material. Overburden of large thickness and low permeability will minimize the effects of deep mining on overlying water resources.

Ground-Water Quantity

Known Hydrologic Effects

Water levels in mined areas

Water levels were measured in domestic water wells located over underground coal mines to ascertain the effects of coal mining on the domestic ground-water supply. A room and pillar mine (generally uncollapsed roof rock) is about 350 ft below the town of Hickory. Water levels in 25 Hickory wells showed no recognizable decline from past mining during the 3 years of measurement. However, premining water-level data were not available to compare with the post-mining water-level data collected during the study. Underground mining in the Hickory area had ceased approximately 1 year prior to the beginning of this study.

Water levels in 14 domestic water wells were measured for 3 years in the partly mined Daniels Run basin (plate 4B). The minimum depth to coal in the basin is 400 ft. The only domestic well in the Daniels Run basin known to have gone dry because of mining was well WS 210. This well was 30 ft deep and in the main valley of the basin. The bottom of the well was about 400 ft above an active coal mine. According to the well owner, the well became dry when the roof rock collapsed in the mine.

Mine inflows

Determining mine inflow is difficult because abandoned mines may be contributing to mine inflow in an active mine, and commonly the quantity of this contribution is not known. Furthermore, variations and fluctuations of mine inflow into an active mine are often not known or reported. The quantity of mine inflow depends on depth to coal, thickness of the coal removed, mining methods, rock mechanics, overburden, lithology and structure, and the aquifer properties. Figures reported to the Pennsylvania Department of Environmental Resources (Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation, McMurray District Office, oral commun., 1984) of inflow to mines in Washington County, ranged from 0.05 to more than 0.7 $(ft^3/s)/mi^2$ (cubic feet per second per square mile) of mined area. The measured mine inflow in the Daniels Run basin was 300,000 gal/d (Vesta Mining Company, oral commun., 1984), which is about 0.15 $(ft^3/s)/mi^2$ of mined area--an inflow on the low end of the range.

Simulation of a Mined Basin

The objective of simulating an underground coal mine is to evaluate the effect of mining on hydrology in general and on the ground-water supplies overlying subsurface coal not yet mined.

A three-dimensional computer model (Appendix B) was used to simulate several possible underground mine situations. Model sensitivity to the following conditions was studied:

- aquifers of varying hydraulic conductivity above and below the mine
- permeability changes caused by fracturing from mine subsidence
- depth to mining
- vertical fracture zones

Summary of results of the mined-basin simulation

(1) Hydrologic information about the bedrock aquifers beneath the shallow ground-water system (greater than 150 ft deep) generally is lacking. However, the geologic and hydrologic characteristics of these deep aquifers control the effect of deep coal mining on the shallow ground-water system. (2) The magnitude of the vertical hydraulic conductivity (either preexisting or induced by mine subsidence) between the shallow aquifers and the mine largely controls the amount of ground water entering the mine and the effects on the shallow aquifers. When the vertical hydraulic conductivity was increased by a factor of four, the mine inflow increased by almost the same factor. (3) The depth to an uncollapsed mine was a sensitive variable; the ground-water model indicated that increasing the depth to a mine by 200 ft caused mine inflow to be reduced by one order of magnitude. (4) The source for most of the ground water flowing into a mine is the strata overlying it. Model results indicate that, for a mine situated in excess of 300 ft below land surface, the combined horizontal and vertical contribution from the regional ground-water system comprises less than 0.5 percent of the total mine inflow. (5) The shallow ground-water system may be independent of the underground mining system. If there are no vertical fracture zones and the mine has not collapsed, then the model results indicate that there would be a poor connection between the shallow aquifer and the mine when the vertical hydraulic conductivity is low and the vertical distance between the shallow aquifer and the mine exceeds about 250 ft. Drawdown of head in shallow aquifers and reduction in base flow of overlying streams because of mining may be minimal, but drawdowns of head in deeper aquifers closer to the deep coal mine may be significant (200 to 300 ft vertical distance). Varying the values of the hydrologic factors of the shallow aquifers (such as recharge, stream drainage, ground-water flow entering from surrounding basins) had little effect on the amount of mine inflow. Increased ground-water recharge because of mine subsidence fractures may also offset the detrimental effects of the head drawdown in the shallow aquifers and reduction of stream base flow. (6) Location and amount of mine inflow determines how much and where the shallow aquifer system will be affected. If mine inflow is distributed evenly over a large area, drawdowns in the shallow aquifer system will be distributed evenly in the area over the mine; however, if the mine inflow is localized, such as at mine collapsed areas and fracture zones, the effects of mining on the shallow ground-water system will also be localized. The greater the amount of water flowing into a mine, the greater will be the drawdown of head in the shallow aquifer system. (7) Drawdown of the head in the shallow aquifers did not vary according to topography but was distributed evenly when an uncollapsed mine was postulated to be about 250 ft below land surface in the main valley. However, in the area over a collapsed mine, drawdowns of head in the valley wells may be smaller than those in hillside wells because the increased fracturing allows ground water to move more easily from the hillsides to discharge areas in the valley streams.

Ground-Water Quality in Mined Areas

In order to document any changes underground mining might have on ground-water quality, ground water should be sampled several years before mining, during mining, and several years after mining. Premining and postmining sampling should include periods of above-average, average, and below-average recharge. Establishment of a premining water-quality data base is necessary in order to compare it with the during- and postmining collected data.

The premining, during-mining, and postmining samples necessary to determine the water-quality changes caused by mining could not be collected during this investigation. However, evaluation of the ground-water-quality data suggests the predominant water types for mined areas are the same as Subgroup IA (calcium bicarbonate chloride-type water and calcium magnesium bicarbonate sulfate-type water) and Group I (calcium bicarbonate-type water) of figure 15. Sulfate concentrations in Subgroup IA exceed USEPA RMCLs and are caused by aquifers containing coal beds with abundant pyrite.

Stoner and others (1987) report that well owners in Greene County reported an objectionable sulfur odor and an iron taste in their water during and after underground mining. Where mining lowers water levels in wells, iron and manganese in the shallow aquifer system may be oxidized. Water quality may be degraded by increased concentrations of iron, manganese, sulfur, and dissolved solids.

Surface Water in Mined Areas

The hydrologic effects of coal mining on streamflow can be significant, depending on the section of the stream being measured and the stream's location with respect to the mining operation. Other variables that can individually or collectively affect the streamflow as a result of mining include the geology, depth and type of mining, and the vertical distance between the stream and mine.

Streamflow and water quality of two small basins during 1983-85 were compared to understand the hydrologic effects of coal mining on surface-water quantity and quality. Brush Run basin (site 25), in west-central Washington County, was in the unmined section of the county, and Daniels Run basin (site 11), in southeastern Washington County, was in a partly mined section of the county. The drainage areas of the Brush Run and Daniels Run basins were 10.3 and 8.47 mi^2, respectively. The topography, geology, land-use, and geographical shape of both basins are similar. Precipitation amounts recorded in both basins throughout the study also were similar (table 4).

Streamflow

Continuous streamflow data were collected at a gaging station in each basin throughout 1983-85, and the data are in data reports for Pennsylvania published annually by the U.S. Geological Survey (1983, 1984, 1985). High and low base flow seepage-run data were collected throughout both basins on five separate occasions and are reported in tables 11 and 12. Daniels Run and Brush Run basins were divided into the subbasins shown in figures 19 and 20, respectively. Figure 19 also shows the type and extent of underground mining in the Daniels Run basin. On all five seepage runs, the data were collected on one day for one basin and on the next day for the other basin, and there was no appreciable amount of precipitation during the 3 days prior to each run. Most stream discharges were assumed to be from ground-water discharge and not to include overland runoff.

Data collected on October 19 and 20, 1982, best represent very low base-flow conditions in both basins. Conversations with permanent residents in both basins indicated that late summer and fall of 1982 was one of the driest periods experienced within the last 10 years. Stream discharges at the Brush Run mainstem sites (sites 8, 12, 25) progressively increased downstream.

Stream discharges at the Daniels Run main stem sites (sites 5, 8, 14, 17, 20, 11) both increased and decreased downstream and the total stream discharge at the gaging station (site 11) was 0.253 ft^3/s or 0.030 $(ft^3/s)/mi^2$ (table 12). From site 5 to site 8, the main stem discharge decreased 46 percent, and from site 17 to site 20, the main stem discharge decreased 13 percent. Figure 19 shows that mines underlie both of these main stem sections of the stream. A gradual decrease in streamflow from site 8 to where the tributary at site 9 entered the main stem was observed in the field. About 500 ft downstream from site 9, the main stem streamflow completely disappeared. The main stem streambed remained completely dry for about 1.3 mi until the tributary at site 10A entered the main stem. Contribution of streamflow from other tributary sites gradually increased streamflow in the main stem to site 17, but from site 17 to site 20, streamflow again decreased. Water losses in the mainstem sections were all attributed to underground mines. Complete water loss near site 9 on the main stem was attributed to mine collapse and rock fracturing as a result of longwall mining in that area of the basin. Water loss between sites 17 and 20 appeared to be caused by retreat mining in the lower part of the basin. Low-base-flow discharge data collected on June 23, 1983, and November 9, 1984, in Daniels Run also show a streamflow loss in the main stem in the area of longwall mining. Discharge measurements made on June 23, 1984, at additional main-stem sites between tributary sites 9 and 10 confirmed a streamflow loss in that specific reach. These data are not listed in table 12. High-base-flow data collected on April 13, 1984, and April 24, 1985, indicate that Daniels Run gained water in the area located over the longwall mine. The increased ground-water discharge to the stream during high base flow probably masked the stream discharge lost to the mine or to subsurface strata.

Table 11.--Seepage-run discharge data collected in the subbasins throughout Brush Run

[mi^2, square miles; ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile]

Subbasin number	Drainage area (mi^2)	Discharge: October 20, 1982 ft^3/s	October 20, 1982 $[(ft^3/s)/mi^2]\times10^{-2}$	June 24, 1983 ft^3/s	June 24, 1983 $[(ft^3/s)/mi^2]\times10^{-2}$	April 12, 1984 ft^3/s	April 12, 1984 $[(ft^3/s)/mi^2]\times10^{-2}$	November 8, 1984 ft^3/s	November 8, 1984 $[(ft^3/s)/mi^2]\times10^{-2}$	April 23, 1985 ft^3/s	April 23, 1985 $[(ft^3/s)/mi^2]\times10^{-2}$
1	0.46	0.012	2.6	0.139	30.2	0.589	128	0.135	29.3	0.283	61.5
2	.50	.027	5.4	.218	43.6	.806	161	.186	37.2	.478	95.6
3	.58	.006	1.0	.155	26.7	.681	117	.132	22.8	.305	52.6
4	.20	.009	4.5	.075	37.5	.441	220	.087	43.5	.194	97.0
5	1.31	.022	1.7	.334	25.5	2.02	154	.392	29.9	.803	61.3
6	.27	.003	1.1	.080	29.6	.377	140	.093	34.4	.180	66.7
7	.67	.018	2.7	.210	31.3	1.07	160	.258	38.5	.513	76.6
[1]8	3.71	.045	1.2	1.09	29.4	4.79	129	1.12	30.2	2.14	57.7
9	.20	.012	6.0	.122	61.0	.372	186	.065	32.5	.160	80.0
10	.24	.002	0.8	.045	18.8	.222	92.5	.064	26.7	.095	39.6
11	2.53	.093	3.7	.806	31.9	3.60	142	.904	35.7	1.46	57.7
[1]12	7.38	.154	2.1	2.35	31.8	9.56	130	2.30	31.2	4.78	64.8
13	.40	.004	1.0	.105	26.2	.609	152	.109	27.2	.246	61.5
14	.96	.011	1.1	.286	29.8	1.20	125	.312	32.5	.658	68.5
15	.54	.022	4.1	.133	24.6	.526	97.4	.112	20.7	.359	66.5
16	.36	.001	.3	.177	49.2	.777	216	.086	23.9	.320	88.9
[1]25	10.3	.189	1.8	2.99	29.0	13.4	130	3.25	31.6	6.52	63.3

[1]Mainstem sites.

Table 12.--Seepage-run discharge data collected in the subbasins throughout Daniels Run

[mi^2, square miles; ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile; <, less than]

Subbasin number	Drainage area (mi^2)	Discharge: October 19, 1982 ft^3/s	October 19, 1982 $[(ft^3/s)/mi^2]\times10^{-2}$	June 23, 1983 ft^3/s	June 23, 1983 $[(ft^3/s)/mi^2]\times10^{-2}$	April 13, 1984 ft^3/s	April 13, 1984 $[(ft^3/s)/mi^2]\times10^{-2}$	November 9, 1984 ft^3/s	November 9, 1984 $[(ft^3/s)/mi^2]\times10^{-2}$	April 24, 1985 ft^3/s	April 24, 1985 $[(ft^3/s)/mi^2]\times10^{-2}$
1	0.36	0.010	2.8	0.065	18.0	0.512	142	0.067	18.6	0.136	37.8
2	.25	.012	4.8	.062	25.0	.269	108	.067	26.8	.105	42.0
3	.23	0	0	.057	24.8	.100	43.5	.021	9.1	.063	27.4
4	.38	.008	2.1	.104	27.4	.392	103	.085	22.4	.218	57.4
[1]5	1.84	.050	2.7	.489	26.6	1.93	105	.442	24.0	.797	43.3
6	.22	.004	1.8	.080	36.4	.444	202	.036	16.4	.176	80.0
7	.26	0	0	.024	9.2	.224	86.2	.053	20.4	.095	36.5
[1]8	2.22	.027	1.2	.552	24.9	2.71	122	.380	17.1	1.00	45.0
9	.45	.014	3.1	.100	22.2	.881	196	.050	11.1	.319	70.9
10	.11	0	0	.002	1.8	.082	74.5	<.001	<.9	.044	40.0
10A	.29	.024	8.3	.077	[2]26.6	--	--	--	--	--	--
[1]11	8.47	.253	3.0	2.18	25.7	11.4	135	2.02	23.8	5.02	59.3
12	.97	.039	4.0	.216	22.3	1.39	143	.245	25.3	.630	64.9
13	1.09	.019	1.7	.264	24.2	1.37	126	.168	15.4	.570	52.3
[1]14	5.15	.055	1.1	1.09	21.2	6.06	118	.756	14.7	2.90	56.3
15	.13	0	0	.002	1.5	.080	61.5	DRY	DRY	.029	22.3
16	.26	.097	37.3	.265	102	.476	183	.362	139	.654	252
[1]17	5.67	.186	3.3	1.35	23.8	7.35	130	1.26	22.2	3.83	67.5
18	.10	.001	1.0	.017	17.0	.132	132	.040	40.0	.056	56.0
19	--	0	--	--	--	--	--	--	--	--	
[1]20	6.21	.162	2.6	1.62	26.1	8.61	139	1.37	22.1	3.26	52.5
21	.79	.017	2.2	.209	26.4	1.12	142	.186	23.5	.703	89.0
22	.70	.028	4.0	.152	21.7	.933	133	.108	15.4	.351	50.1
23	1.63	.041	2.5	.324	19.9	1.92	118	.235	14.4	.975	59.8
24	2.20	.054	2.4	.636	28.9	3.33	151	.518	23.5	1.64	74.5

[1]Mainstem sites.
[2]Site eliminated by a mine shaft.

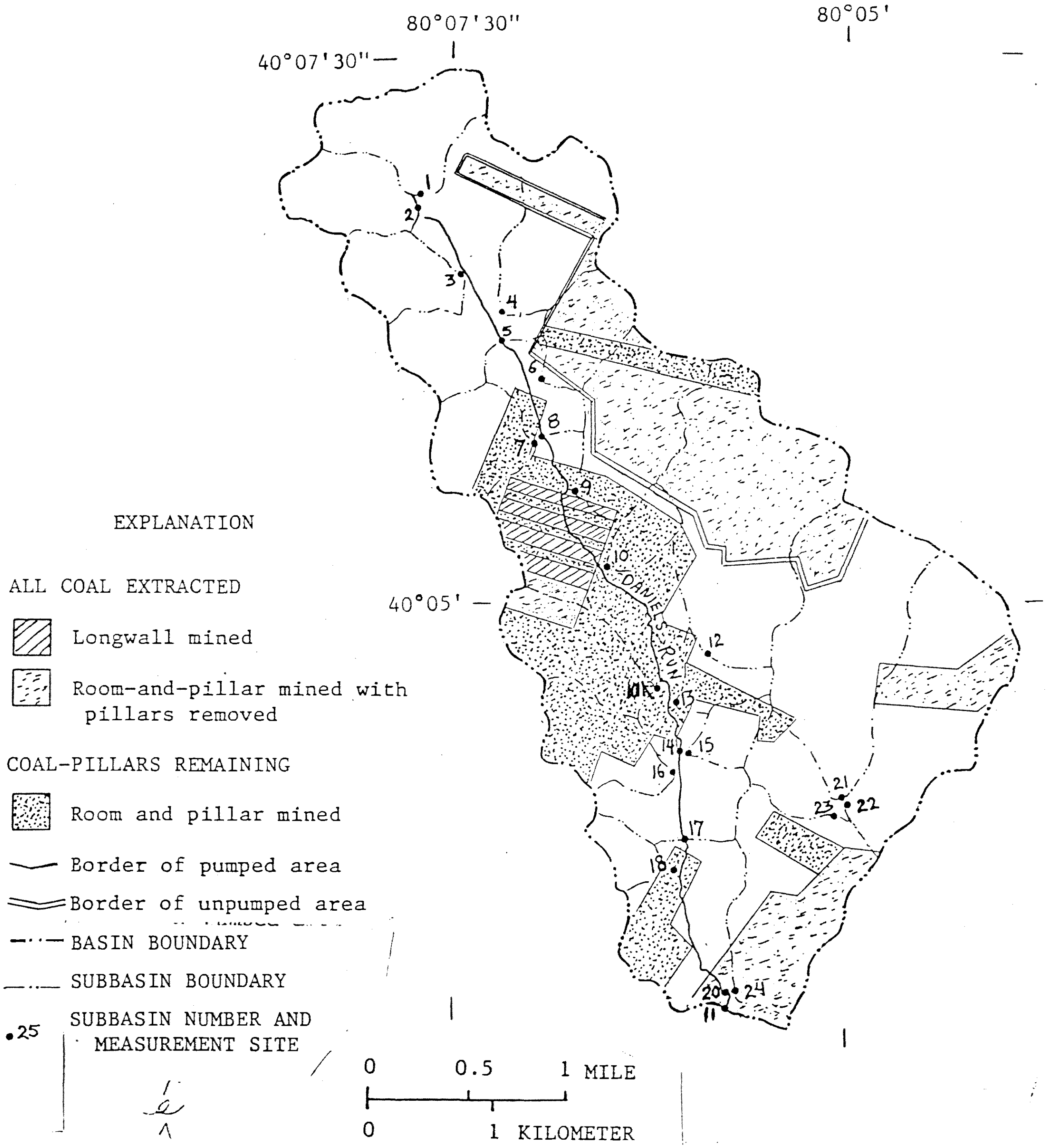
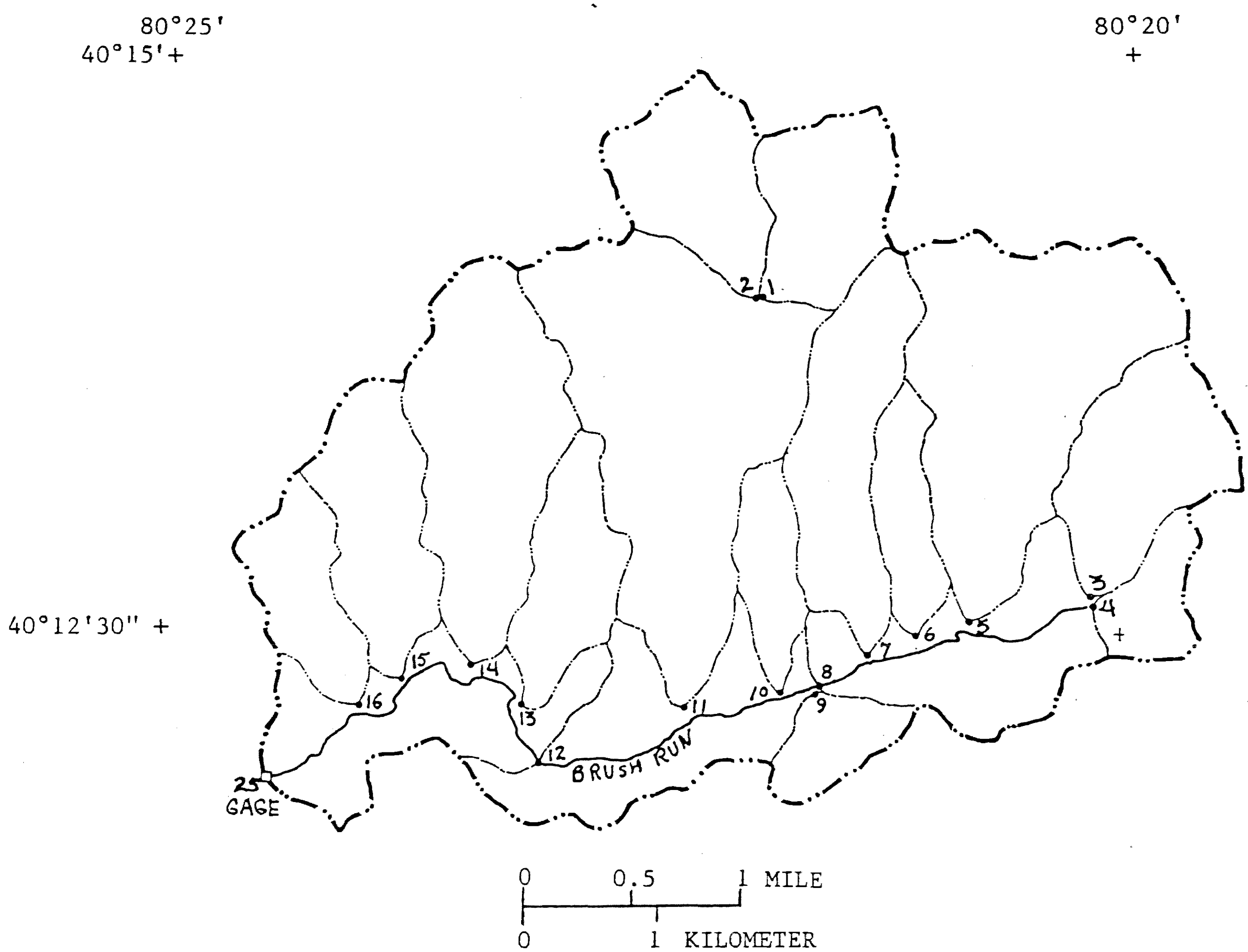


Figure 19.--Subbasins and mined areas in Daniels Run basin.



EXPLANATION

—··— SUBBASIN BOUNDARY

—··— BASIN BOUNDARY

• 8 SUBBASIN NUMBER AND MEASUREMENT SITE

Figure 20.--Subbasins in Brush Run basin.

The large streamflow contribution to Daniels Run from the tributary at site 16 resulted from pumping ground water that entered the deep mines into the tributary. If the stream discharge at site 16 was replaced by the stream discharge of site 2 (subbasins 2 and 16 are of equal size), the discharge at the mouth of the basin (site 11) on October 19, 1982, would be 0.020 $(ft^3/s)/mi^2$. This compares very closely with the stream discharge at the mouth of the unmined Brush Run basin on October 20, 1982, which was 0.018 $(ft^3/s)/mi^2$. When this same type of adjustment was made to Daniels Run outflows on three of the other four seepage runs, the discharge values for Daniels Run were equal to or slightly less than those for Brush Run. In comparing the outflow discharges of the Daniels Run and Brush Run basins, the deep-mining operations in Daniels Run did not substantially lower the streamflow during base flow, assuming that Brush Run basin is a typical unmined basin that reflects premining hydrologic conditions. Underground mining did affect the streamflow in the middle and lower parts of the basin. However, the streamflow lost because of mining in the middle and lower parts of the basin reappeared downstream as ground-water discharge and was part of the outflow at site 11.

Water Quality

Eleven water-quality samples were collected at site 25 on Brush Run and at site 11 on Daniels Run, and the results of the analyses are given in Appendix G. None of the subbasins within the two basins were sampled individually and the samples reflect the water quality at the outflow site of each basin. All samples were collected during base-flow conditions, ranging from a very low base flow in October 1982 (0.189 ft^3/s in Brush Run and 0.253 ft^3/s in Daniels Run) to a high base flow in April 1984 (13.4 ft^3/s in Brush Run and 11.4 ft^3/s in Daniels Run). Figure 21 shows the maximum, minimum, and mean concentrations of selected constituents, most of which are indicators of mine drainage.

The pH was above neutral in both basins, ranging from 7.8 to 8.5 in Brush Run and from 7.9 to 8.7 in Daniels Run. Alkalinity was elevated in both basins, ranging from 140 to 190 mg/L in Brush Run and from 140 to 270 mg/L in Daniels Run. The elevated alkalinity of Daniels Run is attributed, in part, to natural stream alkalinity and also to excess alkalinity as a result of chemical neutralization of acid mine water, particularly from subbasin 16. The alkalinity in both basins appears to be high enough to neutralize moderate amounts of mine drainage entering the streams.

There is a significant difference in the range of dissolved solids concentrations of both basins. In Brush Run the range was from 245 to 307 mg/L. The mean concentration was 266 mg/L. In Daniels Run the range was from 305 to 2,680 mg/L. The mean concentration was 1,000 mg/L. The four highest dissolved-solids concentrations coincided with the four lowest stream discharges at both sites. This generally is typical of natural streams because dilution from increased runoff decreases the dissolved-solids concentration. However, the range of dissolved-solids concentrations during base-flow conditions generally is more like the narrow range for Brush Run than the wide range for Daniels Run. The elevated dissolved-solids concentrations in Daniels Run are attributed to treated mine-water discharges entering the stream above site 11. Sulfate, sodium, and chloride are the constituents mainly responsible for the elevated dissolved-solids concentrations in Daniels Run.

Sulfate concentrations in Brush Run ranged from 40 to 58 mg/L and averaged 49 mg/L. Sulfate concentrations in Daniels Run ranged from 83 to 950 mg/L and averaged 310 mg/L, indicating a substantial amount of mine drainage in the stream at the sampling site.

Sodium and chloride ions are present in all natural waters, but concentrations generally are low. Exceptions occur when streams receive inflows from sources such as saline ground water or industrial wastes. The broad range and elevated concentrations of sodium and chloride ions in Daniels Run are attributed to saline water that is pumped from the deep mines into tributary streams.

The maximum and average fluoride concentrations in Daniels Run were greater than those in Brush Bun, but were less than 1.0 mg/L. The concentration of fluoride in most natural water, with a total dissolved-solids concentration less than 1,000 mg/L, is less than 1 mg/L (Hem, 1985, p. 122). The slightly elevated fluoride concentrations in Daniels Run are attributed to deep-mine discharges into tributary streams.

The range and average concentrations of dissolved and total iron were similar in both basins; however, the range and average concentration of dissolved iron were slightly higher in the unmined Brush Run basin. Most of the dissolved iron in the mine water being discharged into Daniels Run is assumed to be removed by treatment prior to being discharged into the tributary streams or into the main stem. There is no visual evidence that ferric hydroxide [$Fe(OH)_3$], or "yellow boy," precipitates out in any of the tributary streams or in the main stem.

The average and maximum dissolved-manganese concentrations in Daniels Run were about double those in Brush Run. Dissolved-manganese concentrations usually persist in streams for greater distances downstream from a contaminant source (such as mine drainage) than do iron concentrations (Hem, 1985, p. 88).

Concentrations of other constituents, such as calcium, magnesium, potassium, and silica differed very little between the two streams. Although biological sampling of the streams was not an objective of the project and was not performed, the aquatic environment of Daniels Run did not appear to be threatened by mine drainage entering the stream. Visual observation indicated that the minnow and the crayfish populations in the stream were extremely large. There also was evidence of a fairly diversified macroinvertebrate population on the stream bottom.

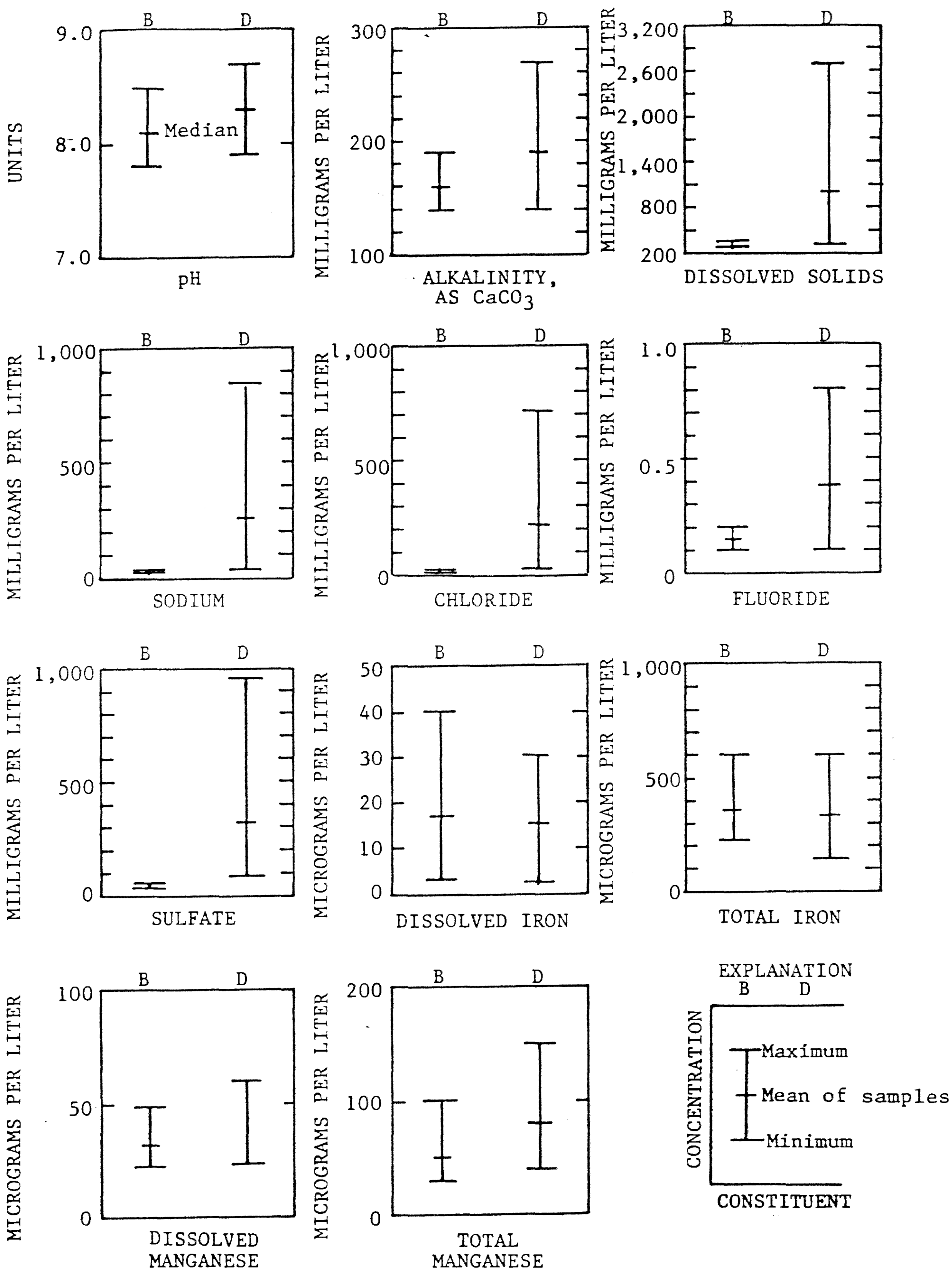


Figure 21.--Maximum, minimum, and mean concentrations of selected constituents measured at the outflows of the Daniels Run (D) and Brush Run (B) basins.

CONCLUSIONS

Much of the water-resources information collected in Washington County during this study can be used as baseline data for choosing sites for future water-resource development and for determining changes in water conditions, particularly in the unmined area of the county. About 69 percent of county residents are served by public water-supply systems, and 99 percent of the water for public supply systems comes from rivers, streams, and reservoirs. The Monongahela River is the source of greater than 78 percent of the water for the public supplies. Data for 1984 indicated that the public water-supply systems provided an average of 24.2 Mgal/d. Thirty-one percent of the county residents depend on wells, springs, and cisterns for their water supply.

The five principal water-bearing units being tapped for ground-water supplies are in the Greene, Washington, Waynesburg, Uniontown, and Pittsburgh Formations. The mean reported yield of the five formations ranges from 8.8 gal/min in the Pittsburgh Formation to 15 gal/min in the Uniontown Formation. Depths to water generally are shallow in valleys and increase beneath hilltops. Annual water-level fluctuations usually range from less than 3 ft beneath valleys to about 13 ft beneath upland draws.

The 7-day, 10-year low-flow discharge for the 35 surface-water sites ranged from 0.0 to 0.055 $(ft^3/s)/mi^2$. A low-flow-frequency analysis indicates that sites in the south-central and southwestern part of the county had the lowest low flows per square mile, whereas sites in the eastern and northern parts of the county had the highest low flows.

The major ground-water-quality problems throughout the county are elevated concentrations of iron, manganese, and dissolved solids. Minor ground-water-quality problems include elevated concentrations of fluoride, chloride, and sulfate. Chemical water types change along the ground-water flow path from calcium bicarbonate type in predominantly hilltop settings to sodium chloride type in valleys. Residence time and complex chemical reaction are the controlling factors for the changes in water types.

Streamwater quality generally was poorest in northern and eastern Washington County where most of the active and abandoned coal mines are located. Sulfate concentrations were used as an indicator of AMD because the sulfate ion does not readily precipitate after natural or induced neutralization.

Stream alkalinity exceeded 50 mg/L at 33 of the sites, indicating that those streams probably would have a neutralizing affect on most acid inflow. The neutralization capacity of the streams also was evident in stream pH, which exceeded 6.5 at all 33 sites.

The poorest water quality was measured on Robinson Run at McDonald (site 31) and Raccoon Creek at Raccoon (site 32). Both of these streams drain areas containing numerous active and abandoned mines, and AMD has greatly deteriorated the stream quality.

The hydrologic effects of coal mining on surface-water quantity and quality were shown specifically by comparing the unmined Brush Run basin with the mined Daniels Run basin. Streamflow measurements were made during base-flow conditions at numerous sites in each basin. Streamflow in the main stem of Brush Run progressively increased downstream, indicating little, if any, water loss in the main stem channel. On the contrary, streamflow in the main stem of Daniels Run first decreased and then increased downstream, indicating a definite water loss in the upper part of the main stem channel. The decrease in streamflow occurred in areas with underground mines, and the decrease was greatest where longwall mining had taken place.

Comparison of water-quality samples collected during base-flow conditions at the outflow site of Brush Run and Daniels Run showed that, although Daniels Run is affected by AMD, the water-quality degradation is not significant.

The ground-water-flow model of the unmined Brush Run basin shows that about 95 percent of the total ground-water recharge is retained in the top 80 to 110 ft of bedrock, and that less than 0.1 percent of the total amount of ground water recharged is lost to the regional flow system. The model also shows that the hydrologic characteristics of the regional flow system can vary considerably but have very little effect on the shallow aquifers that supply water to almost all domestic wells.

The simulated mined model of the Brush Run basin shows that the vertical hydraulic conductivity (either existing or induced by mine subsidence) between the shallow ground-water system and the mine, and mine depth largely control the amount of ground water entering the subsurface mine and the effects on the shallow aquifers. The model also indicates that an increase in the depth of mining (room-and-pillar mining, no pillar extraction) from 200 to 450 ft below land surface would cause mine inflow to decrease by one order of magnitude.

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APPENDIX A.--DETAILS OF HYPOTHETICAL UNMINED-BASIN MODEL

Flow Model and Results

Simulation of an Unmined Basin

A three-dimensional finite difference computer flow model (McDonald and Harbaugh, 1984) was utilized to simulate general premining ground-water flow and to estimate the hydrologic effects of a hypothetical coal-mine operation. The model is used to calculate the hydraulic head in an aquifer at specified locations under steady-state-flow conditions. This is achieved by solving a series of steady-state differential equations of ground-water flow, which require that the hydraulic properties, boundaries, and inflow and outflow be defined for the modeled area.

On the basis of model results in adjacent Greene County (Stoner, 1983), steady-state ground-water flow can be simulated within the fractured sedimentary rock aquifer systems. This model contains known hydrologic factors and estimates of poorly known factors. The model is calibrated by comparing the output of the simulated flow system with the known hydrologic data of the real ground-water flow system (such as hydraulic head, mine inflow, stream discharge, etc.). Input characteristics to the model (such as vertical and horizontal hydraulic conductivity) are then adjusted until a similitude is achieved. When this is achieved, the model is considered calibrated and can be used to simulate hypothetical stresses on the aquifer systems.

This calibrated model is known as the "hypothetical unmined-basin model," because of (1) the lack of sufficient and comprehensive hydrologic data, (2) the large variability of the data collected, and (3) the limited data base describing the regional flow system. If more data were available, model calibration could have been improved, and model reliability would have been enhanced.

Known Hydrologic Variables

The known hydrologic variables used to calibrate and evaluate the model include water levels from domestic wells (hydraulic head), vertical hydraulic gradients, aquifer properties, and base-flow discharge to the stream. Water levels from 40 domestic wells (35 to 150 ft deep) in the basin were used to calibrate the model. Well inventory in the county showed that most head fluctuations were less than 20 ft, although some heads fluctuated as much as 50 ft because of ground-water pumpage and natural discharge and recharge.

Few measured heads are available for deep aquifers in Washington County. Table A1 shows the water-level and well-bottom altitudes for seven deep wells in Washington and Greene Counties. Water well WS-825 is the only deep well within Brush Run basin. Data reported by Piper (1933) were used to evaluate computer-generated heads in the lower layers of the model. The condition of the wells and the accuracy of the water-level measurements given by Piper (1933) are not known; therefore, these data were used only as estimates of head in deep aquifers in the county.

Deep and shallow domestic wells located in close proximity were used to determine a range of vertical gradients. The gradient was calculated by dividing the difference between water-level altitudes by the difference between tops of well-opening altitudes. The results indicate the following ranges of vertical head gradients by general topographic setting: (1) 0.07 to 0.73 ft/ft (feet per foot) beneath hilltops (from six well pairs); (2) 0.55 to -0.04 ft/ft beneath hillside wells (from eight well pairs); (3) 0.56 to -0.14 ft/ft beneath upland valleys (from three well pairs); (4) 0.05 to -0.79 ft/ft beneath valleys (from three well pairs). A positive gradient indicates downward ground-water flow; negative gradient indicates upward ground-water flow.

Aquifer tests done in Washington County show that the hydraulic conductivity of aquifers in the same topographic setting and in the upper 175 ft of bedrock can differ by as much as three orders of magnitude (see table 7). The hydraulic conductivity of aquifers in Greene County (Stoner and others, 1987) have a similar variation. This wide variation in hydraulic conductivity is attributed to the variation in size and number of fractures in the rocks tested. Therefore, results from the aquifer tests can only be used as a guide in selecting hydraulic-conductivity values for the model.

Data from five seepage runs were used to evaluate model results. For a seepage run, stream discharge was measured at 17 stations in the basin when ground water was the dominant source of streamflow. These data were checked against the model streamflow output for model calibration and reliability. The stream discharge measured during a seepage run on April 23, 1985, was deemed representative of the runs during high base flow and was used for calibration.

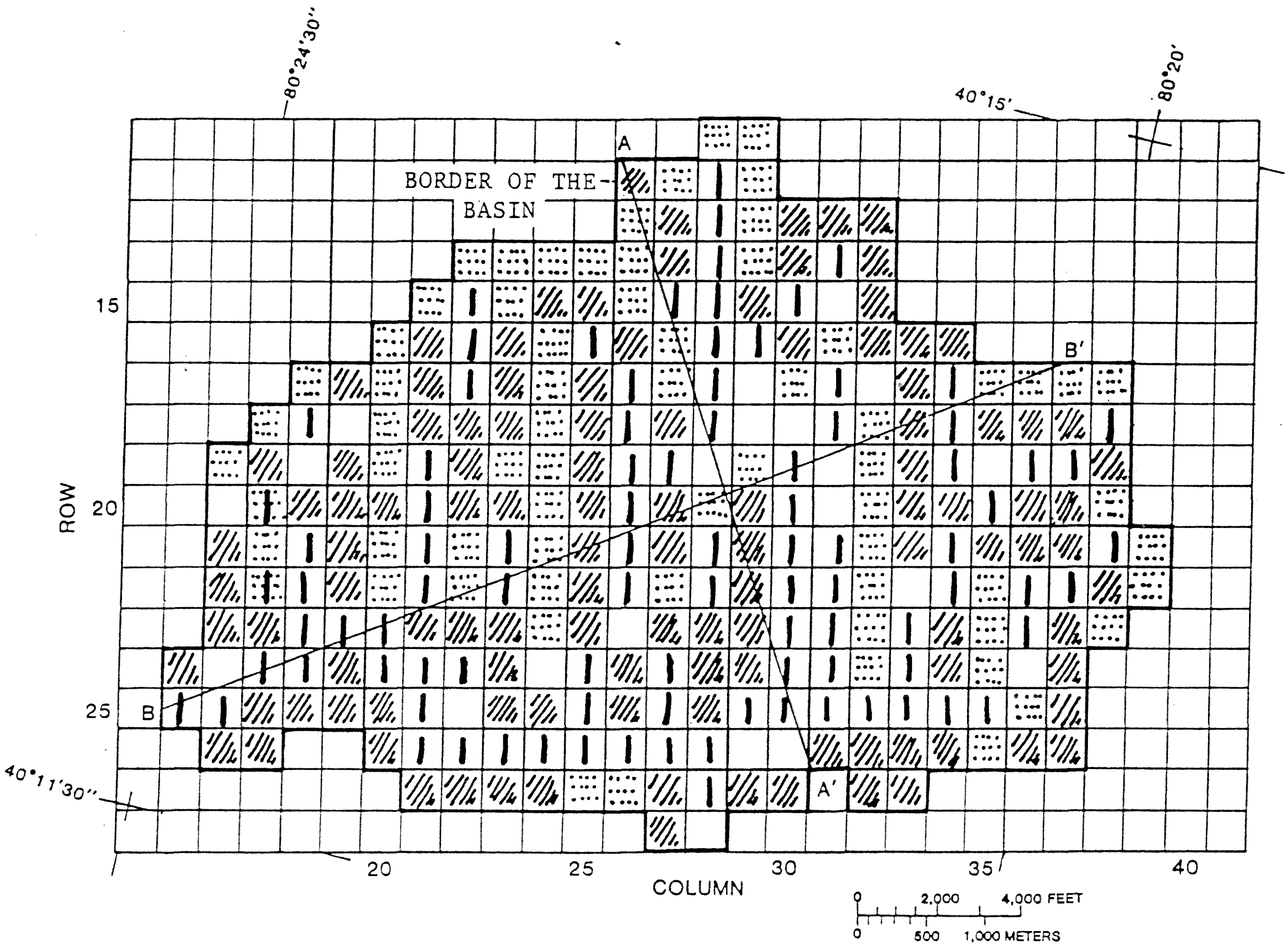
Details of the Model

Introduction

The 10.2-mi^2 Brush Run basin was divided into 291 cells, each 1,000 ft by 1,000 ft in size (fig. A1). This grid size provides a fair representation of actual conditions. However, in some places the topographic relief was somewhat subdued by the model because of the large grid size.

The head of the local ground-water system generally parallels the shape of topography and is simulated by layers 1 and 2 of the model. Figures A2 and A3 show geologic sections A-A' and B-B', respectively, across Brush Run basin and how the computer model simulates the same sections. The unsaturated zone above layer 1 is not simulated in the model. Layer 1 and the top of layer 2 of the model cut across the Washington, Waynesburg, Uniontown, and Pittsburgh Formations, and follow the topography. The bottom of layer 2 follows the bedding of the Pittsburgh Formation. Layer 1 is simulated as an unconfined aquifer, whereas layer 2 is a confined aquifer.

The ground-water flow of the regional (deep) ground-water system is assumed to follow the bedding of the formations, from the major watershed divides to the major river systems, and is simulated by the confined aquifers of layers 3 and 4 in the model (figs. A2 and A3). Layers 3 and 4 simulate the lower 30 ft of the Pittsburgh Formation and the upper 600 ft of the Conemaugh Group.



EXPLANATION

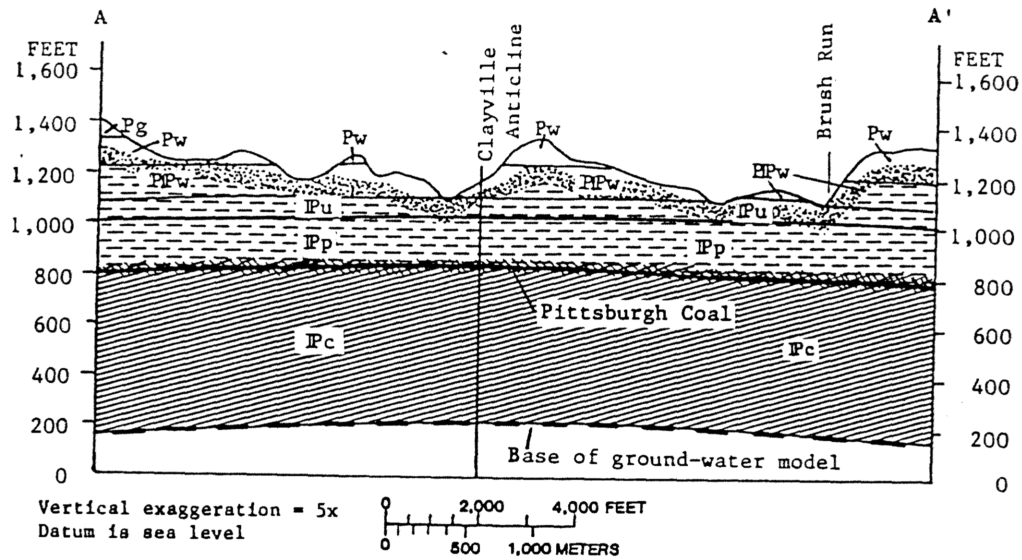
HILLTOP CELL, horizontal hydraulic conductivity = 0.6 feet per day

HILLSIDE CELL, horizontal hydraulic conductivity = 0.4 feet per day

VALLEY CELL, horizontal hydraulic conductivity = 2.0 feet per day

DRAIN (stream)

Figure A1.--Discretization of the Brush Run basin in layer 1 of the unmined-basin model. (Cross section A-A' and B-B' are shown in figures A2 and A3.)



EXPLANATION

Pg — Greene Formation-Zero to 60 feet thick, alternating sandstone, siltstone, limestone and mudstone with impure coal near base

Pw — Washington Formation-Average 170 feet thick, alternating shale, sandstone and limestone with basal coal

PIPw — Waynesburg Formation-Average 115 feet thick, alternating shale, siltstone, sandstone and minor limestone with basal coal

IPu — Uniontown Formation-Average 60 feet thick, alternating shale, siltstone, sandstone and limestone with discontinous basal coal

IPp — Pittsburgh Formation- Average 230 feet thick, alternating shale, limestone, and sandstone with basal Pittsburgh coal bed

IPc — Conemaugh Group-Upper 600 feet shown, alternating shale, sandstone and limestone

COMPUTER MODEL

UNSATURATED ZONE

Local ground-water system:

LAYER 1-About 70 feet thick, follows topography closely

LAYER 2-Varies in thickness from about 135 to 400 feet thick, top of layer follows topography, bottom follows geologic structure

Regional ground-water system:

LAYER 3-Fifty feet thick, contains lower 30 feet of Pittsburgh Formation and upper 20 feet of Conemaugh Group, follows geologic structure

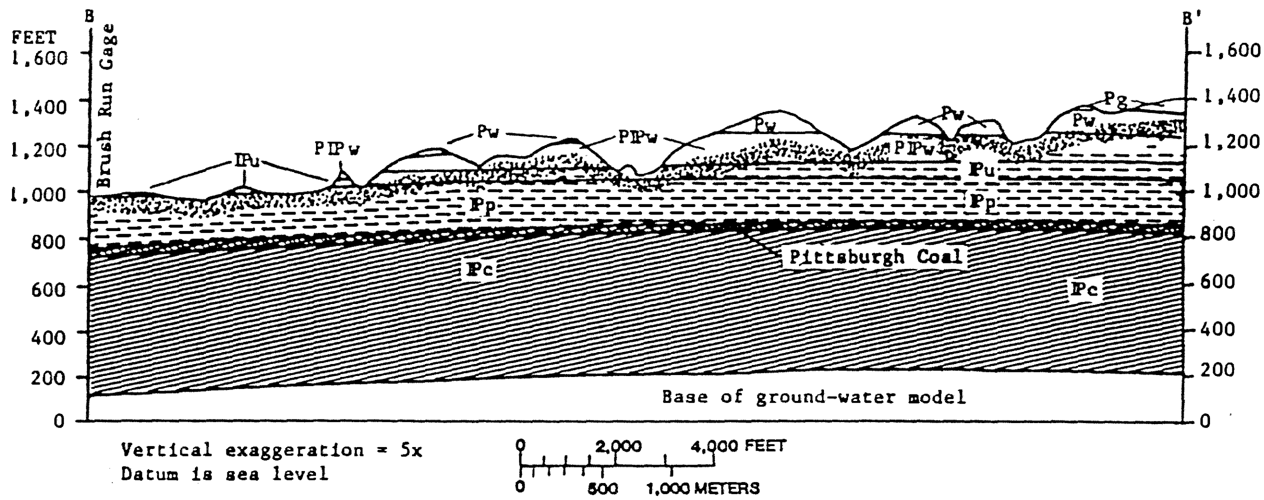
LAYER 4-Six hundred feet thick, simulates part of the Conemaugh Group, follows geologic structure

——— Base of ground-water model

——— Geologic contact

——— Pittsburgh coal bed (basal unit of Pittsburgh Formation)

Figure A2.--Geologic section A-A' of Brush Run basin showing bedrock geology and computer-model simulation, (see figure A1 for location of cross section).



EXPLANATION

Pg — Greene Formation-Zero to 60 feet thick, alternating sandstone, siltstone, limestone and mudstone with impure coal near base

Pw — Washington Formation-Average 170 feet thick, alternating shale, sandstone and limestone with basal coal

PPw — Waynesburg Formation-Average 115 feet thick, alternating shale, siltstone, sandstone and minor limestone with basal coal

Pu — Uniontown Formation-Average 60 feet thick, alternating shale, siltstone, sandstone and limestone with discontinous basal coal

Pp — Pittsburgh Formation- Average 230 feet thick, alternating shale, limestone, and sandstone with basal Pittsburgh coal bed

Pc — Conemaugh Group-Upper 600 feet shown, alternating shale, sandstone and limestone

COMPUTER MODEL

Local ground-water system

- UNSATURATED ZONE
- LAYER 1-About 70 feet thick, follows topography closely
- LAYER 2-Varies in thickness from about 135 to 400 feet thick, top of layer follows topography, bottom follows geologic structure

Regional ground-water system

- LAYER 3-Fifty feet thick, contains lower 30 feet of Pittsburgh Formation and upper 20 feet of Conemaugh Group, follows geologic structure
- LAYER 4-Six hundred feet thick, simulates part of the Conemaugh Group, follows geologic structure

Base of ground-water model

Geologic contact

Pittsburgh coal bed (basal unit of Pittsburgh Formation)

Figure A3.--Geologic section B-B' of Brush Run basin showing bedrock geology and computer-model simulation,(see figure A1 for location of cross section).

Boundaries of the model

The boundary conditions used for the layers in the model are important in simulation of this flow system and interpreting model results; therefore, the boundaries for each layer are discussed. The uppermost surface of the model is assumed to be a free-surface and a specified flux boundary (fig. A4). The free-surface boundary represents the water table. Flux is the volume of fluid per unit time crossing a unit cross-sectional surface area. In this case, the flux across the uppermost surface is considered uniform in space and constant with time and is, therefore, a specified flux boundary. The effects of topography, land use, and so forth, on recharge rates to the unconfined aquifer were not considered in the model. Layer 1 of the model represents an unconfined aquifer 80 to 110 ft thick that follows a subdued topography. Well inventory data suggest that depth to ground water on hilltops is about 40 ft, on hillsides is about 20 ft, and in the valleys is about 10 ft. The top of layer 1, as generated by the computer model, generally follows the water table surface described by the well inventory.

It is assumed that the local ground-water system is strongly influenced by the drainage basin divides while the regional ground-water system is controlled by geology. Therefore, the lateral boundary for the local ground-water system is located at the drainage divide of the Brush Run basin and is assumed to be a no-flow boundary (fig. A4). At the edge of the basin ground-water flow is assumed vertical, and therefore, no ground water flows across the basin divide. The basin divide is, therefore, a no-flow boundary.

The altitude of the bottom of layer 1 (also equal to the top of layer 2) was determined from a topographic map. An average land-surface altitude for each cell was determined from a 7 1/2-minute U.S. Geological Survey topographic map. The bottom of layer 1 was determined by subtracting the estimated depth to water (according to topographic setting) and thickness of layer 1 (70 ft) from the average land-surface elevation for each cell. Therefore, the altitude of the bottom of layer 1 was determined by subtracting from the land-surface elevation: 110 ft (40 + 70) for hilltop cells, 90 ft (20 + 70) for hillside cells, and 80 ft (10 + 70) for valley cells.

The boundaries of the bottom of layer 2 and of layers 3 and 4 follow geologic structure. The bottom of layer 2 is equal to the top of layer 3. The thickness, in feet, of each cell in layer 2 is shown in figure A5. Layer 3 represents the bottom 30 ft of the Pittsburgh Formation and the upper 20 ft of the Conemaugh Group. Therefore, the Pittsburgh coal bed is near the center of layer 3. Layer 4 simulates 600 ft of the Conemaugh Group. The upper boundary of layer 4 is equal to the bottom of layer 3.

The lowermost boundary of the modeled basin is assumed to be a no-flow boundary (fig. A4). The base of the model lies 900 to 1,200 ft below the land surface. The model shows that less than 0.02 percent of the total ground-water recharge enters the lowest layer of the model (layer 4).

Head-dependent flux boundaries are used to simulate ground-water flow in the regional flow system (layers 3 and 4) (fig. A4). The direction and amount of flux across a head-dependent boundary is contingent on, and proportional to, the head difference across the boundary. The regional flow system

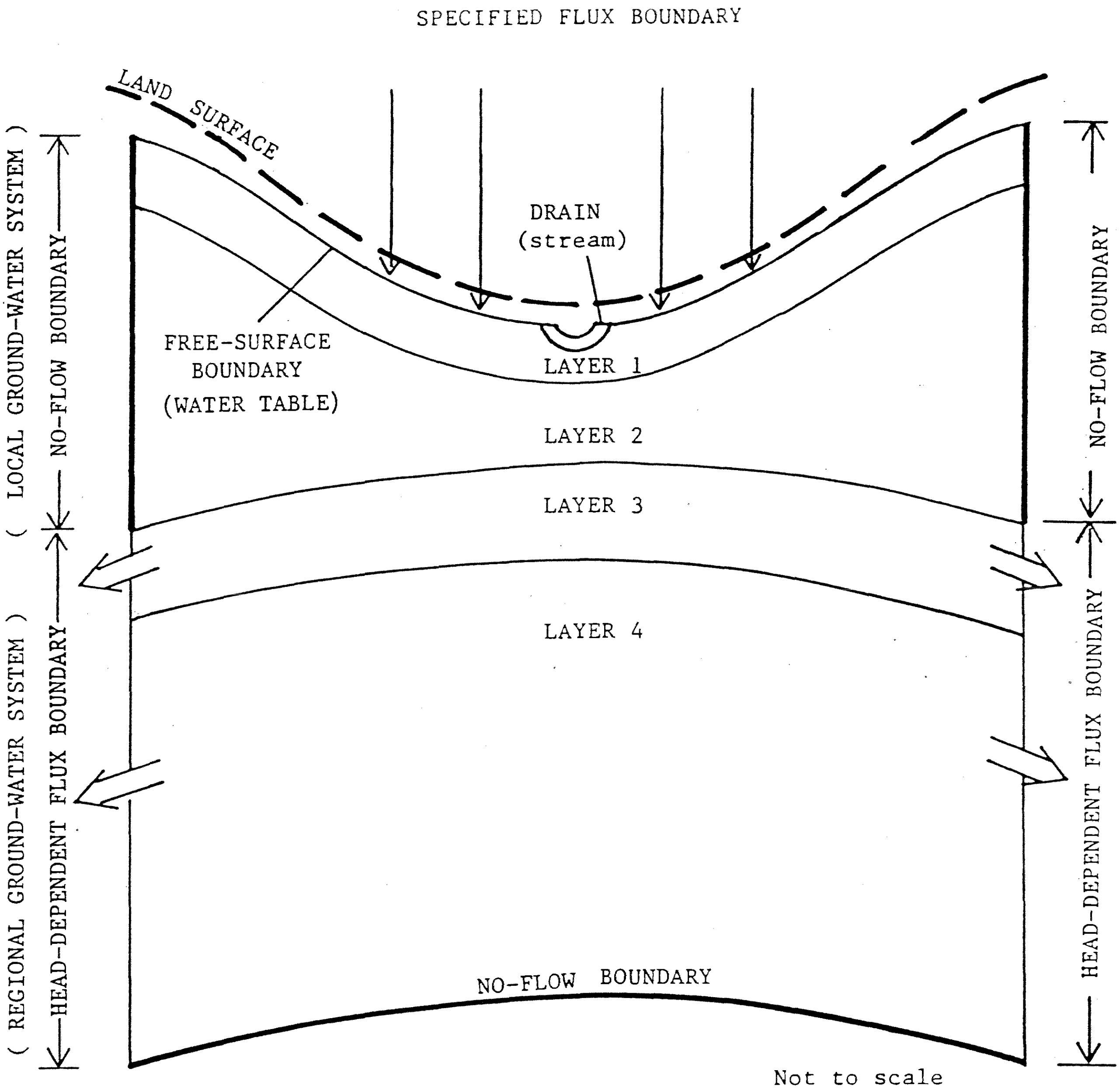
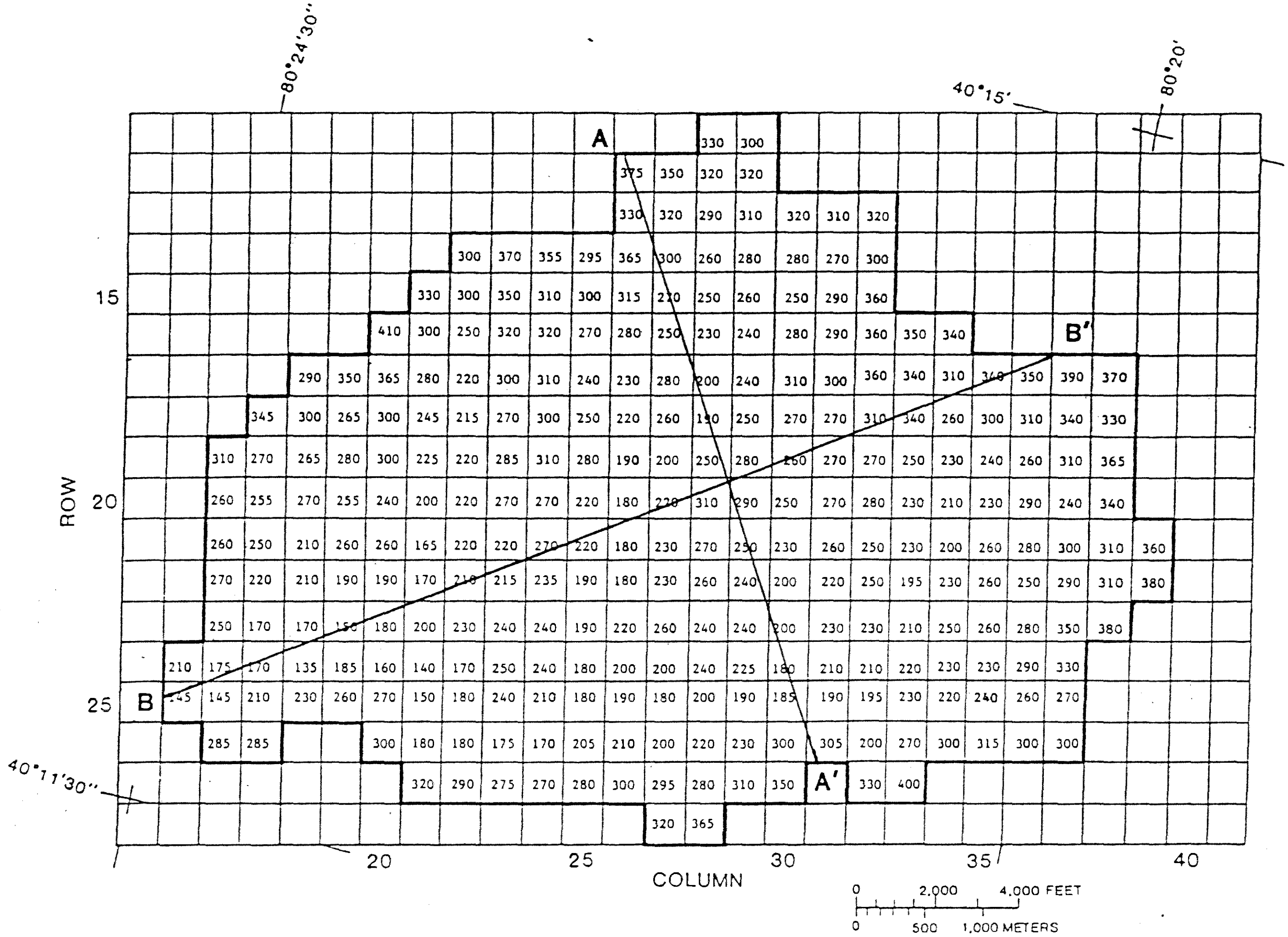


Figure A4.--Boundary conditions for the unmined-basin model.



EXPLANATION

A–A'
B–B' LOCATION OF CROSS SECTION

205	CELL-Number is thickness of layer, in feet

Figure A5.--Thickness of layer 2 in each cell of unmined-basin model.

encompasses those aquifers that carry most of ground-water flow between basins. Ground water in this deep system is thought to flow laterally along the rock layers from areas of recharge to discharge areas. Therefore, the direction of ground-water movement in these layers is dependent on the ground-water head.

The head-dependent boundaries (fig. A6) on the eastern side of the basin related to the cropping out of the Pittsburgh Formation and Conemaugh Group. The outcrops of the formations may be areas of recharge or discharge, depending on the head difference between the Brush Run basin and the elevation of the outcrop. For layer 3, the head-dependent flux boundary on the eastern side of the basin is related to outcropping of the Pittsburgh Formation, located about 5 mi from the Brush Run basin at an elevation of 1,100 ft above sea level. The horizontal hydraulic conductivity of the rocks between the outcrop and the basin was estimated to be 0.01 ft/d to account for the increased permeability of coal near the land surface. The head-dependent flux boundaries (fig. A6) on the eastern side of layer 4 of the model are based on the cropping out of the Conemaugh Group. The Conemaugh Group crops out about 6 mi to the east at an elevation of 1,000 ft above sea level. The horizontal hydraulic conductivity of the rocks between the basin and the outcrop was estimated to be 0.0003 ft/d and is based on data and a model published by Stoner and others (1987).

The head-dependent flux boundaries for the regional flow system (layers 3 and 4) that are on the western side of the basin are related to the Ohio River Valley. The Ohio River is the area of discharge for the regional flow system. The Ohio River is about 13 mi to the west of Brush Run basin at an elevation of 650 ft. The horizontal hydraulic conductivity of the rocks between the basin and the Ohio River for layer 3 was estimated to be 0.01 ft/d to account for the permeability of the Pittsburgh coal bed. The horizontal hydraulic conductivity of layer 4 was estimated to be 0.0005 ft/d. A no-flow boundary exists where a head-dependent boundary is not present, such as on the northern and southern sides of the model, where regional flow is in easterly and westerly directions.

Recharge

In a steady-state condition, the average annual ground-water discharge is equal to the average annual ground-water recharge to the basin. Therefore, the stream hydrograph from Brush Run was separated into baseflow and runoff (using a modified computer program published by Pettyjohn and Henning, 1979) for 2 typical years to determine the amount of ground-water contribution. An average of the computed ground-water discharges of these 2 years (8.5 in/yr) was used as recharge and was evenly distributed over layer 1 of the model.

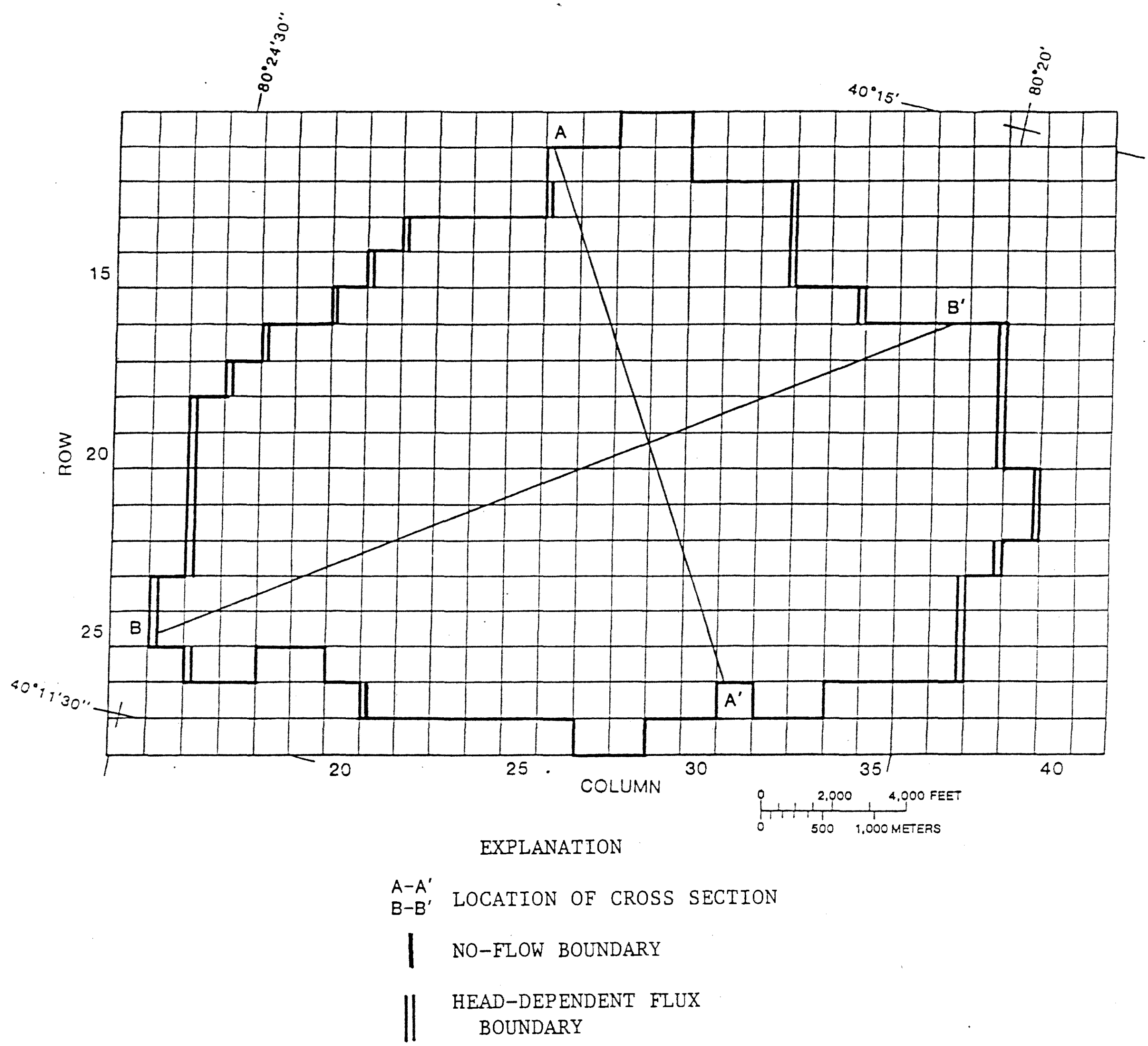


Figure A6.--Lateral boundaries for layers 3 and 4 of the unmined-basin model.

Streams (drains)

Streams of the Brush Run basin are represented in the model as drains because almost all seepage-run data showed that streams are gaining water (aquifers are discharging ground water into the streams). The hydraulic conductivity of the stream-aquifer interface controls the amount of water flowing into the stream (drain)[1]. The hydraulic conductivity of the interface represents the flow restriction caused by the vertical hydraulic conductivity in layer 1, converging flow lines, and vertical and horizontal hydraulic conductivity of the alluvial deposits. During model calibration, the hydraulic conductivity of the stream-aquifer interface was varied until the computer-generated heads matched the measured heads and until seepages were matched.

Hydraulic conductivity

Hydraulic conductivity of the bedrock aquifers represented in the model is assumed to be dominantly caused by stress-relief fractures. The horizontal hydraulic conductivity is assumed to decrease from valley to hilltops and with increasing depth. The vertical hydraulic conductivity also is assumed to decrease with depth because of the decrease in the number of vertical fractures with depth. In the deep-aquifer system, this would cause ground water to flow mostly along horizontal bedding-plane fractures from recharge areas to discharge areas.

Horizontal hydraulic conductivity for layer 1 of the model was varied according to the topographic setting (fig. A7). The cells in the Brush Run basin were classified by topographic setting as hilltop, hillside, or valley. Horizontal hydraulic conductivities were varied during model calibration until the computer-generated heads matched measured heads. The overall match was best when hilltop cells were assigned a horizontal hydraulic conductivity of 0.6 ft/d, hillside cells a hydraulic conductivity of 0.4 ft/d, and valley cells a hydraulic conductivity of 2.0 ft/d.

Aquifer test results indicate that horizontal hydraulic conductivity decreases from valley sites (2.0 ft/d) to hillside sites (1.0 ft/d) to hilltop sites (0.6 ft/d). However, because ground-water of the hillside cells must flow across the bedding planes (fig. A7), a reduced horizontal hydraulic conductivity of 0.4 ft/d was used, and this provided the best overall match with the measured heads.

The hydraulic conductivity for cells in layers 2, 3, and 4 of the model depends on the depth from the top of layer 1 and the topographic setting above the cell. The horizontal hydraulic conductivity decreases with depth because of the decrease in number of fractures with depth. The best overall fit of the model was achieved when the values for horizontal hydraulic conductivity of layer 1 were decreased at a rate of one order of magnitude per 175 ft of depth for the three topographic settings (fig. A8). A minimum hydraulic conductivity of 5×10^{-6} ft/d was used for all topographic settings.

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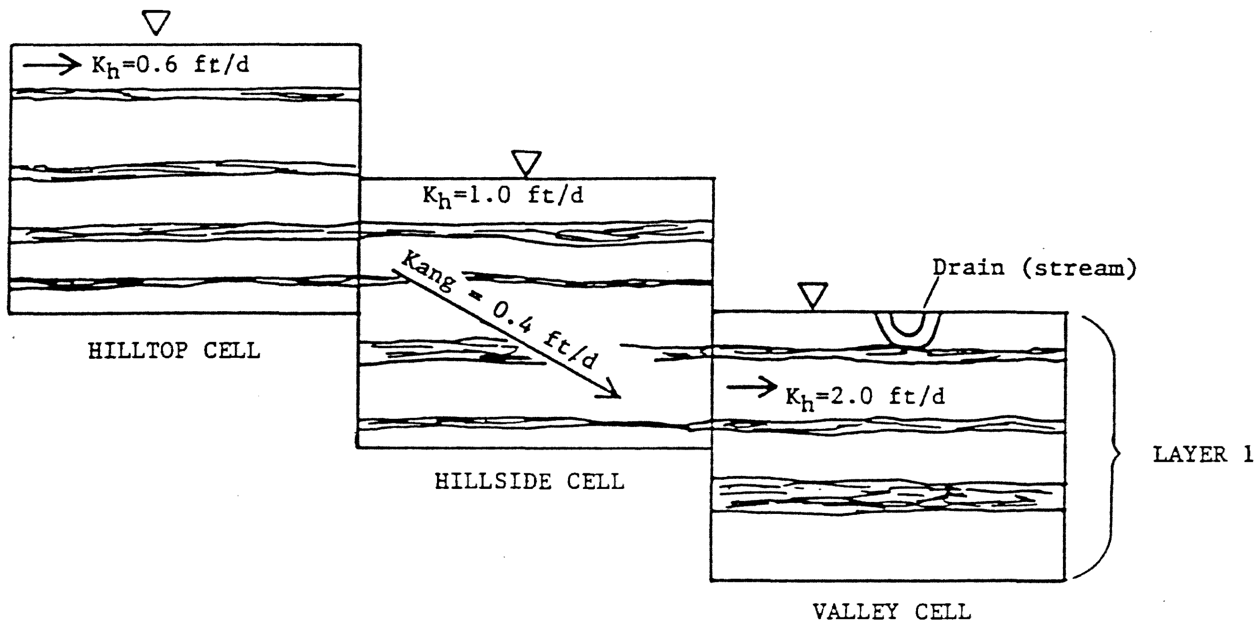
[1]The DRAIN subroutine, not the RIVER subroutine, was used in the model of McDonald and Harbaugh, 1984.



EXPLANATION

K_h HORIZONTAL HYDRAULIC CONDUCTIVITY

Kang HYDRAULIC CONDUCTIVITY AT AN ANGLE ALONG FLOW PATH, FOR HILLSIDE CELLS

▽ WATER LEVEL IN THE CELL

Figure A7.--Variation in hydraulic conductivity with topography and direction of flow for hillside cells.

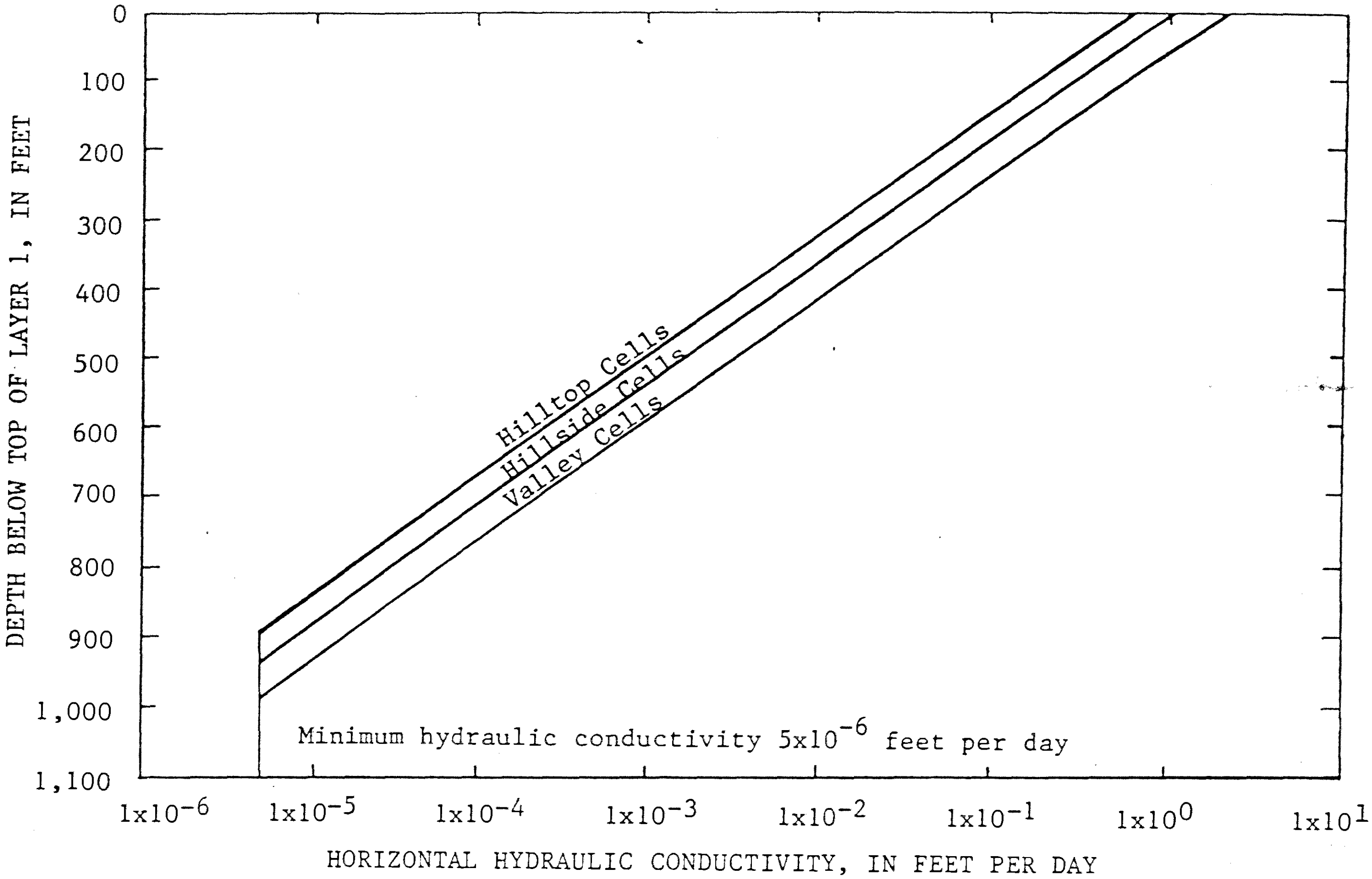


Figure A8.--Curves used to determine horizontal hydraulic conductivity of cells in layers 2, 3, and 4 of the unmined-basin model, on the basis of depth from the top of layer 1 and the cell location (under hilltop, hillside, valley).

The depth from land surface to the center of the cell and the relation between depth and K (fig. A8) was used to determine the horizontal hydraulic conductivity. Each cell represents a multiaquifer system with decreasing horizontal hydraulic conductivity with depth. For modeling purposes, this system can be replaced by a single aquifer with an equivalent horizontal hydraulic conductivity. This equivalent hydraulic conductivity is approximately equal to the hydraulic conductivity calculated for the center of the cell.

The transmissivity for the confined aquifers represented in layers 2, 3, and 4 was calculated by multiplying horizontal hydraulic conductivity by thickness of the cell. The altitude of the top of layer 2 is variable according to topography, but its bottom follows geologic structure. Therefore, thickness of layer 2 depends on topography and structure, as can be seen in figures A2 and A3. The thickness of layer 3 is a constant 50 ft, and the thickness of layer 4 is 600 ft.

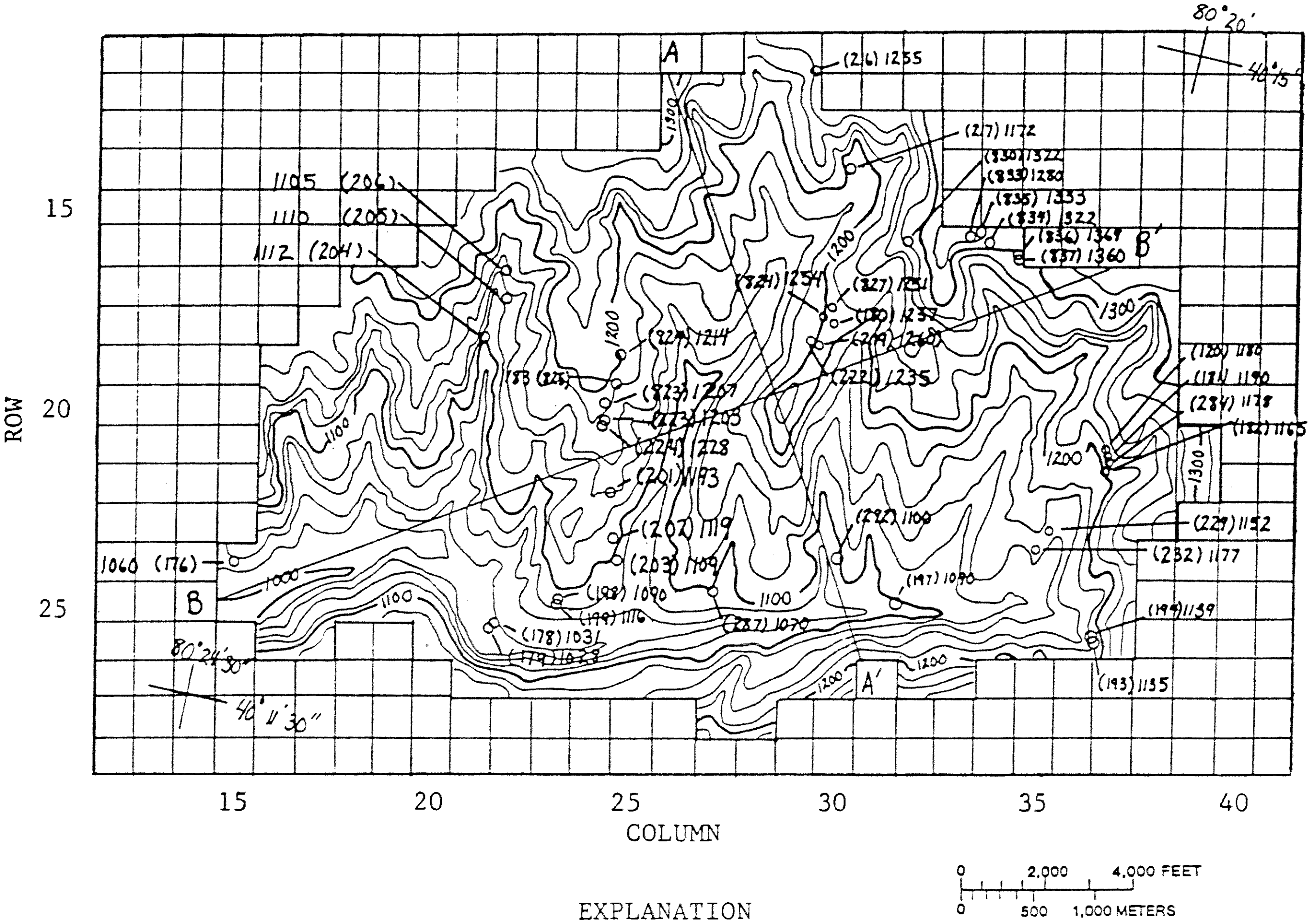
Vertical anisotropy

The anisotropy in the vertical direction, which is defined as the ratio of the horizontal hydraulic conductivity (K_h) to vertical hydraulic conductivity (K_v), increases with depth. The magnitude of the anisotropy depends on the number of vertical fractures, interconnection between fractures, lithology, and stratigraphy. The anisotropies that gave the best overall model fit were 40 for layer 1, 125 for layer 2, 150 for layer 3, and 200 for layer 4. The anisotropy for layer 1 is low because of the great number of vertical fractures found in near-surface rocks, as evidenced by rises in water levels in shallow wells after a recharge event. The anisotropy for layers 2 and 4 is related to a thick sequence of interbedded sedimentary rocks. The anisotropy of layer 3 is controlled mainly by the thick underclay found under the Pittsburgh coal bed.

Model results

All measured water levels were within 70 ft of the computer-generated heads, and the model was able to match measured heads within 40 ft for 32 of the 40 wells measured in the basin (fig. A9). In some places, measured heads were higher than computer-generated heads because the grid size used in the model was too large to depict all the hilltops. This discretization problem caused some of the basins' steep topography to be overly subdued in the model. In other places, measured head may reflect recent pumpage and not actual water-table conditions, or measured head may reflect perched aquifers on hilltops, which the model was not designed to simulate.

Heads in the lower layers of the model were similar to the heads shown in table A1. When the measured head of well WS-825 was corrected for a depth equal to that of layer 2 using a vertical gradient of 0.3 ft/ft, the difference between the computer-generated head and calculated head was less than 15 ft. Computer-generated heads of layers 3 and 4 were similar to the heads reported by Piper (1933) as shown in table A1.



EXPLANATION

A——A' B——B' TRACE OF GEOLOGIC SECTIONS

o(198)1098 MEASURED WATER-LEVEL ALTITUDE IN FEET ABOVE SEA LEVEL. NUMBER IN PARENTHESIS IS WELL NUMBER. CONTOUR INTERVAL 20 FEET

—1000— LINE OF EQUAL HYDRAULIC HEAD GENERATED BY COMPUTER MODEL

Figure A9.--Contoured surface of computer-generated head and measured water-level altitude of wells in the Brush Run basin in layer 1.

Vertical gradients of the model fell within the range of gradients determined from well inventory. Vertical gradients, determined from well inventory pairs, are reported in the section on known hydrologic variables. Model-simulated vertical gradients between layers 1 and 2 were within the range of gradients measured in the county.

Computer-generated discharges were within 10 percent of the measured discharges of the seepage run of April 23, 1985, except in the main valley. Alluvial deposits in the main valley of the basin can modify stream discharge by storing and releasing ground water. The model was not designed to simulate the storage and release of water in these alluvial deposits, which may explain why the modeled discharges for the main valley differ from measured discharges by more than 10 percent.

A ground-water budget of the model was done to quantify ground-water flow (fig. A10). Recharge to layer 1 of the model was 100 percent of the ground water entering the basin. In layer 1, 100 percent of the total ground water was discharged to the streams. Ground-water flow into layer 2 from layer 1 was 3.9 percent of the total ground-water budget flow, and the same amount returned to layer 1. Only 0.1 percent of the ground water entered layer 3 from layer 2 and 0.1 percent returned to layer 2. In layer 3, less than 0.1 percent of the ground water left the basin across the head-dependent flux boundaries and discharged to the east at the outcrops of the Pittsburgh Formation and Conemaugh Group and to the west at the Ohio River Valley. Ground-water flow in layer 4 accounted for less than 0.1 percent of the water budget.

The budget shows that 96 percent of recharge to the ground-water system in the basin remains in the shallow aquifers of the basin, and the regional ground-water flow system has little or no effect on the shallow ground-water system. Less than 0.1 percent of ground-water recharge leaves the basin through the regional aquifer system.

Figures A11 to A14 show a three-dimensional portrayal of the computer-generated head of each layer of the model. Also shown beneath the three-dimensional surface is a contour map of the head.

The relief of the head in each layer of the model generally decreases with increasing depth and follows a subdued topography (except in layer 4, which follows the structural dip to the west). The greatest relief of head is seen in layer 1 (fig. A11).

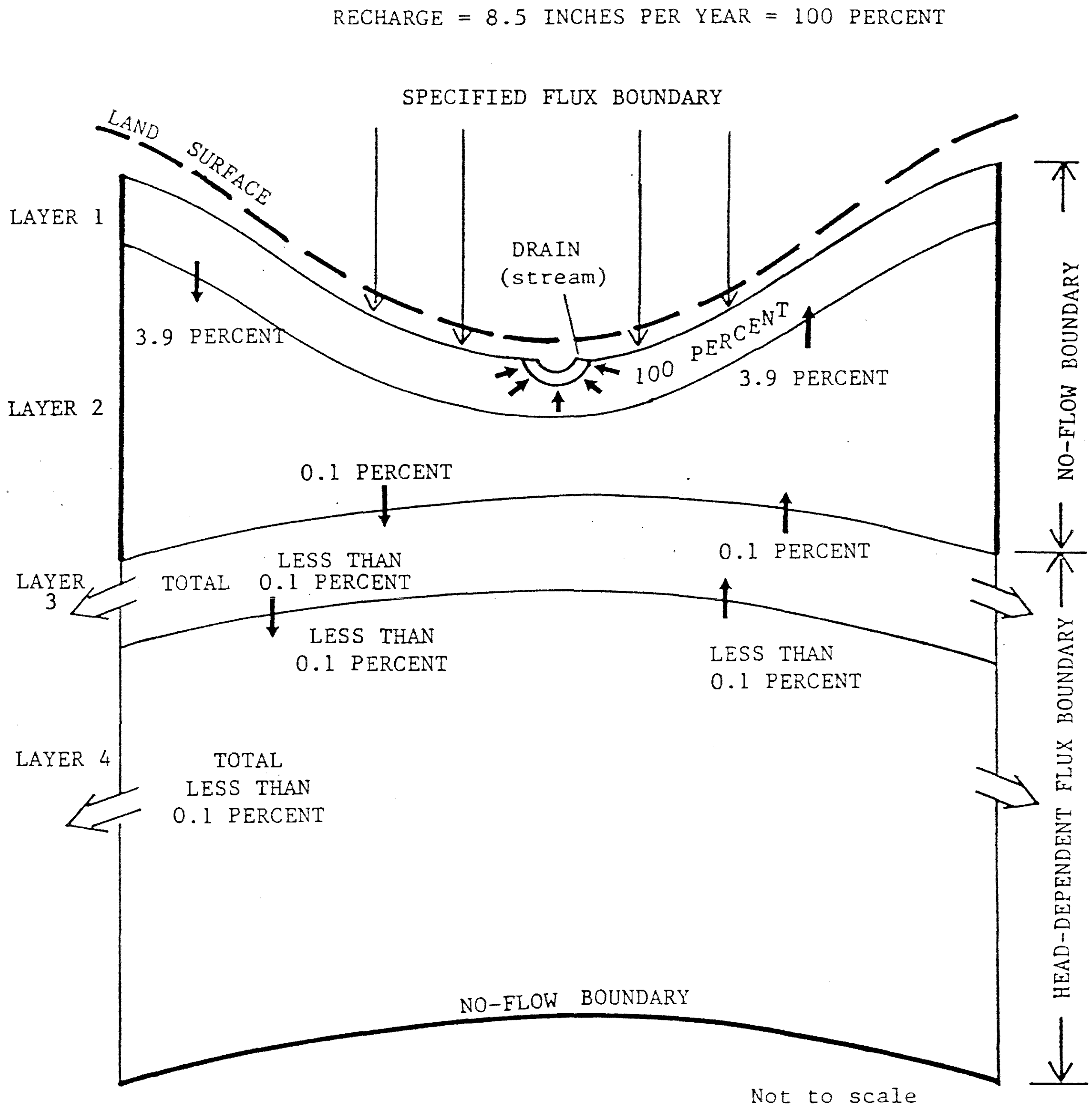
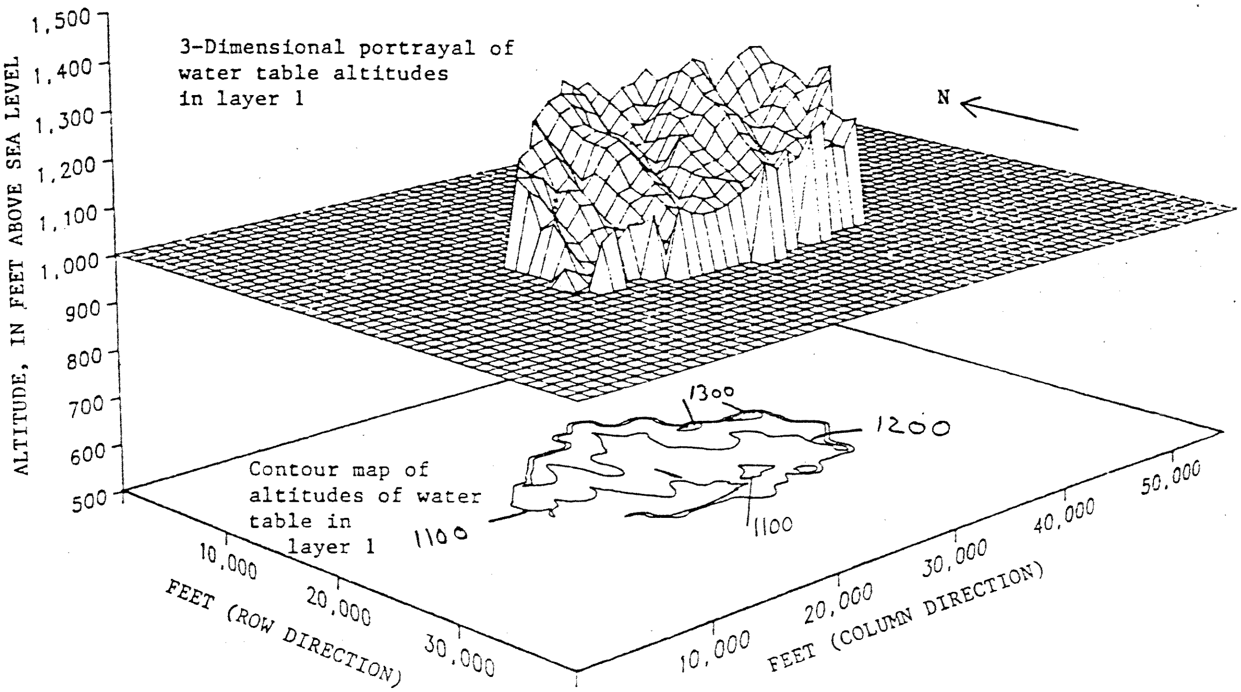


Figure A10.--Budget analysis of ground-water flow in unmined-basin model.

WATER TABLE, LAYER 1

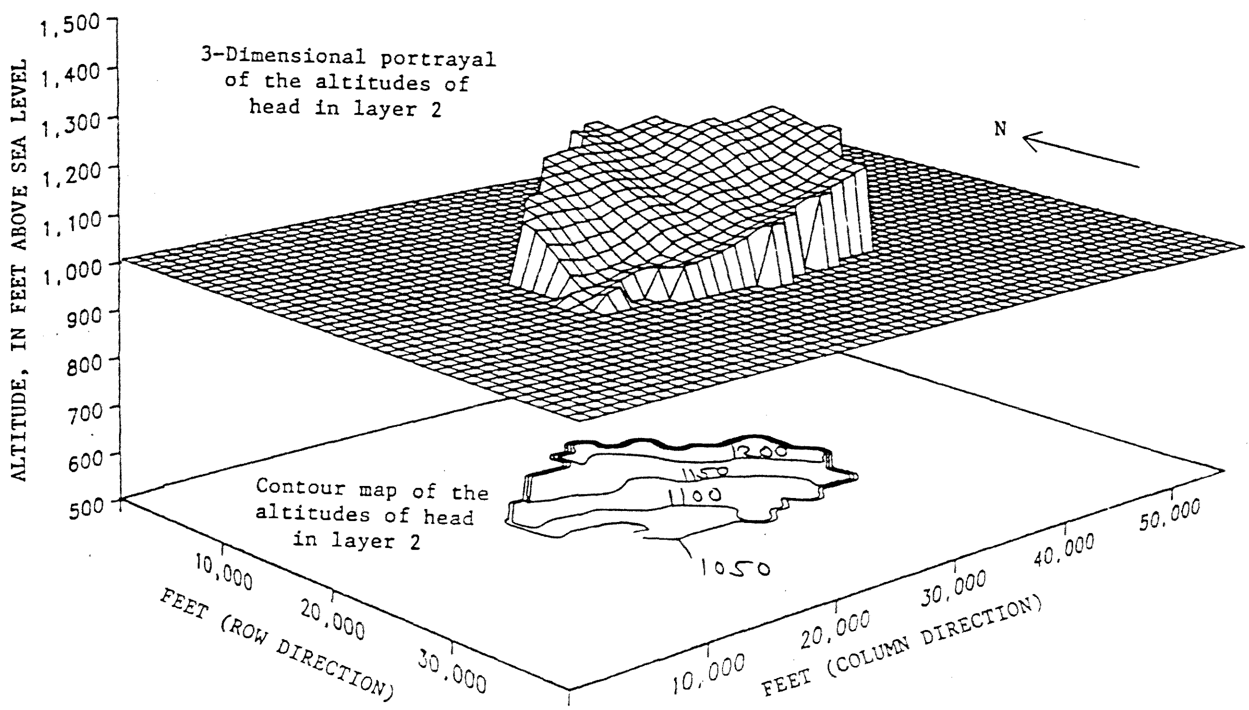
UNMINED-BASIN MODEL
BRUSH RUN BASIN



Contour interval 100 feet

Figure A11.--Computer-generated water table of the unconfined aquifer of layer 1 of the unmined-basin model.

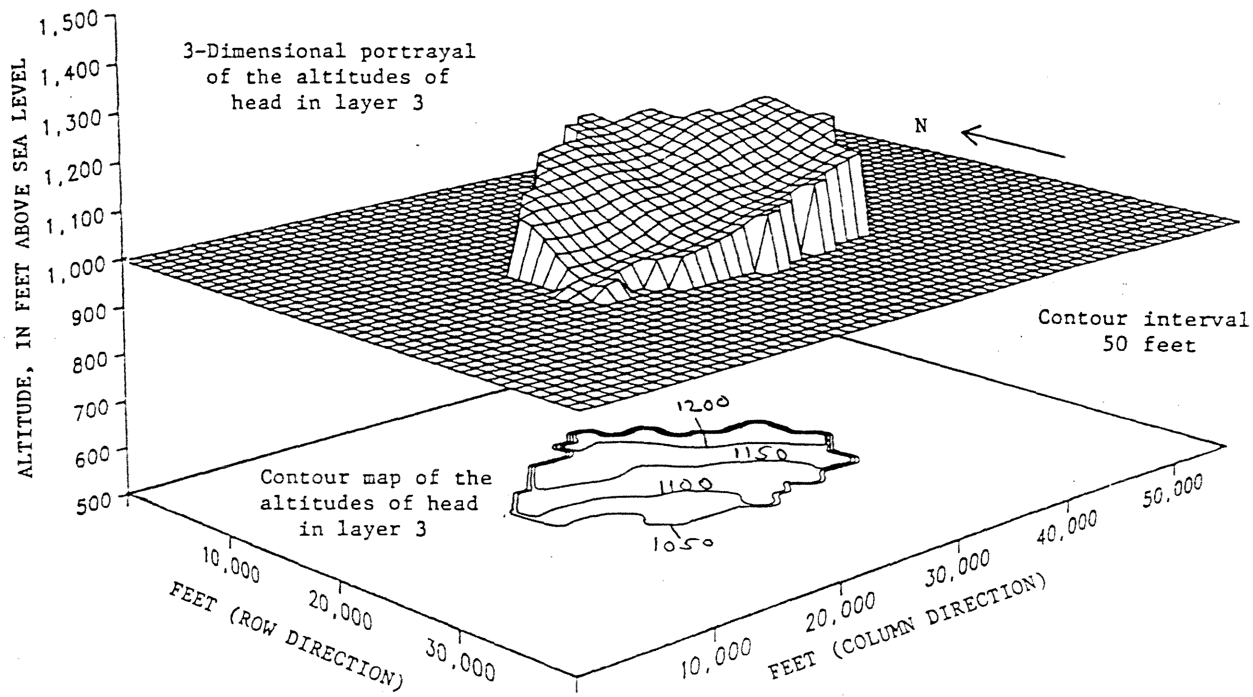
POTENTIOMETRIC SURFACE, LAYER 2
UNMINED-BASIN MODEL
BRUSH RUN BASIN



Contour interval 50 feet

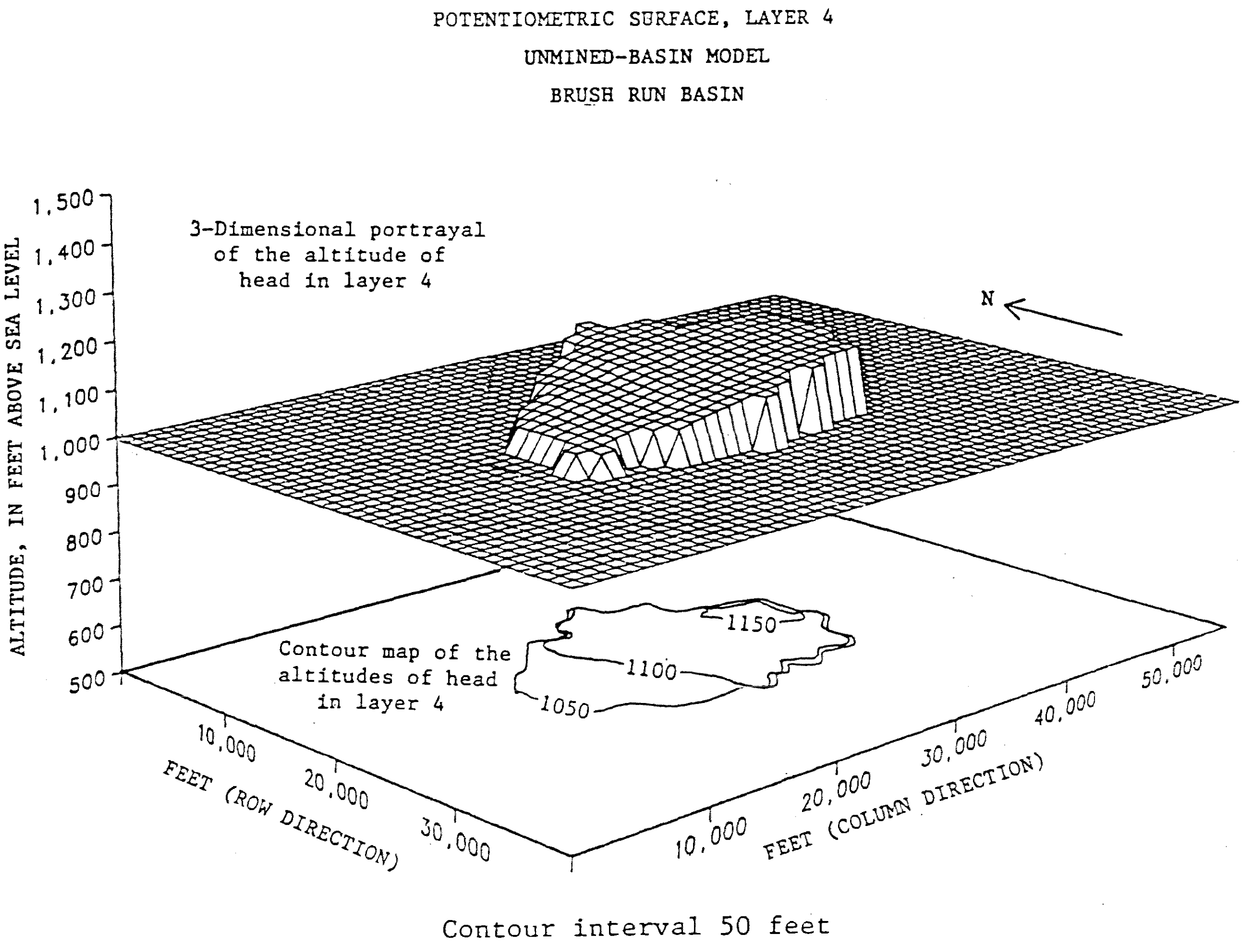
Figure A12.--Computer-generated potentiometric surface of the confined aquifer of layer 2 of the unmined-basin model.

POTENTIOMETRIC SURFACE, LAYER 3
UNMINED-BASIN MODEL
BRUSH RUN BASIN



Contour interval 50 feet

Figure A13.--Computer-generated potentiometric surface of the confined aquifer of layer 3 of the unmined-basin model.



Contour interval 50 feet

Figure A14.--Computer-generated potentiometric surface of the confined aquifer of layer 4 of the unmined-basin model.

Sensitivity analysis

Input values of some aquifer characteristics were varied, one at a time, within a reasonable range, to determine their effect on model output. Values for recharge, drain-aquifer interface horizontal hydraulic conductivity, head-dependent flux boundaries, vertical anisotropy aquifer, and hydraulic conductivity were increased and decreased from the values used in the unmined-basin model.

Recharge to the ground-water system of the basin was varied by intervals of 2.5 in/yr. When the recharge was reduced to 6 in/yr, the head in layer 1 dropped an average of 10 ft per cell. When recharge was increased to 11 in/yr, head in layer 1 increased an average of 6 ft per cell. Only about 4 percent more ground water reached layer 2 when recharge was increased, and the flow leaving layers 3 and 4 was unaffected. Vertical gradients between layers 1 and 2 remained about the same when recharge was varied.

The hydraulic conductivity of the stream-aquifer interface was increased and decreased by a factor of three from the postulated value of 0.05 ft/d. When the hydraulic conductivity was decreased, the average head in layer 1 of the model increased by about 35 ft per cell. When the hydraulic conductivity was increased, the head in layer 1 dropped by an average of 10 ft per cell. In both cases, the amount of ground water flowing between the layers of the model was changed by less than 1 percent of the total ground-water recharge.

When hydraulic conductivity for head-dependent flux boundaries in layers 3 and 4 was increased and decreased by one order of magnitude, the effect on the model was minimal. Head in layer 1 and vertical gradients between layers 1 and 2 were unaffected. When the hydraulic conductivity of the head-dependent boundaries was increased, only an additional 0.1 percent of the total ground-water recharge entered layer 3, and ground water flowing out of the regional system was still less than 0.1 percent of total ground-water recharge. When the hydraulic conductivity was decreased, the ground-water flow budget remained essentially unchanged from the model results.

The anisotropy in the vertical direction (K_h/K_v) for all layers of the model was increased and decreased by a factor of two from the postulated values of 40 for layer 1, 125 for layer 2, 150 for layer 3, and 200 for layer 4. The average head in layer 1 was unaffected by the changes made in the anisotropy. When the anisotropy was reduced, the downward and upward vertical gradients between layers 1 and 2 were lower. An additional 2 percent of the ground-water recharge entered layer 2, but ground-water flow into layers 3 and 4 changed by less than 0.5 percent. When the anisotropy was increased, the gradients were steepened. Ground-water flow into layer 2 changed by about 1 percent of the total recharge, and flow into layers 3 and 4 changed by less than 0.5 percent.

The rate at which the horizontal hydraulic conductivity decreases with depth was varied for the sensitivity analysis. The value assigned to the hydraulic conductivity of the cells in layers 2, 3, and 4 depends on the topographic setting of the cell and on the depth from the top of layer 1 to the center of the cell. In the unmined-basin model, the value for horizontal hydraulic conductivity was assumed to decrease at a rate of one order of magnitude per 175 ft of depth (fig. A8). For the sensitivity analysis, the slope of the lines, shown in figure A8, was changed so that hydraulic conductivity decreased with depth at the rate of one order of magnitude per 100 ft and then per 250 ft. The vertical hydraulic conductivity also has to change to maintain the value of anisotropy (K_h/K_v) for each layer.

When the rate at which the horizontal hydraulic conductivity decreases with depth was increased and decreased, head in layer 1 usually changed by less than 5 ft, but vertical gradients and ground-water flow budget were changed. Changing hydraulic conductivity of layers 2, 3, and 4 produced minimal change in the head of layer 1. When the hydraulic conductivity of cells in layers 2, 3, and 4 was decreased, the downward vertical gradient increased. Conversely, when the hydraulic conductivity of cells in the lower layers was increased, the downward vertical gradient decreased. If recharge is constant, vertical gradients are indicative of the aquifer's vertical hydraulic conductivity. A steep downward gradient is indicative of a low vertical hydraulic conductivity, and a gentle gradient is indicative of a high vertical hydraulic conductivity.

Hydrologic flow budget showed an additional 8.0 percent of the total recharge entered layer 2 of the model when hydraulic conductivity was increased. When hydraulic conductivity of the lower layer was reduced, only 0.6 percent of total recharge entered layer 2, and less than 0.1 percent entered layer 3. When hydraulic conductivity was increased, 8.6 percent of the recharge entered layer 2, 2.0 percent entered layer 3, and less than 0.1 percent entered layer 4.

In conclusion, sensitivity analysis showed that head in layer 1 is most sensitive to recharge and hydraulic conductivity of the stream-aquifer interface. Varying drain hydraulic conductivity by a factor of 3 caused head in layer 1 to change by -10 and +30 ft per cell. Varying recharge by 30 percent resulted in a change in head of -10 and +6 ft.

Figure A15 shows the maximum range of ground-water flow determined by the sensitivity analysis. Ground-water flow shown in figure A15 is described as percentages of the total ground-water recharge. The greatest range of ground-water flow resulted from increasing and decreasing the rate at which the horizontal hydraulic conductivities decreased with depth. Ground-water flow into layer 4 and the ground water leaving the basin by the head-dependent flux boundaries always remained less than 0.1 percent of the total recharge for all model runs in the sensitivity analysis.

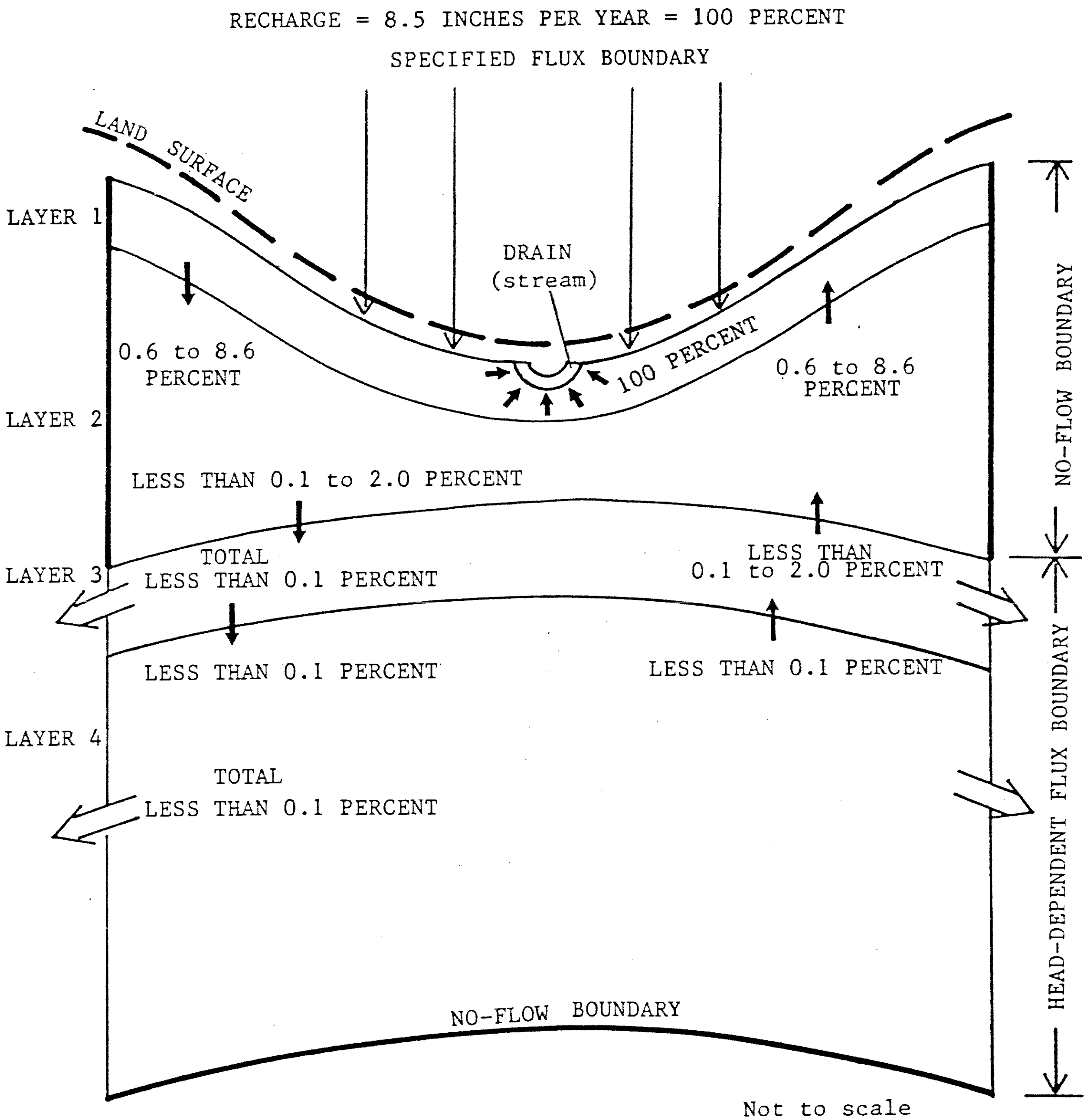


Figure A15.--Range of ground-water flow components used in the sensitivity analysis of the unmined-basin model.

Flow in a vertical fracture zone

The unmined-basin model was changed to simulate the effects of a vertical fracture system. Mine-inflow problems caused by flow to the mine through major fracture zones and lineaments have been well documented (Stoner, 1983). The angulate stream patterns that characterize the study area indicate the presence of fractures and the fracture control of some stream valleys.

Two different fracture systems were simulated to understand the nature and effect of vertical fracture zones on ground-water flow. The locations of the fracture systems in a section of the main Brush Run valley and part of a tributary are shown in figure A16. The fracture system extends vertically throughout the entire thickness of the model and affects 23 cells in each layer of the model. The horizontal and vertical hydraulic conductivities were increased one order of magnitude in every cell that contained the fracture system.

The first fracture simulation resulted in vertical gradients in the fracture zone being almost zero, and in the fracture zone of layer 1, the horizontal gradients were flatter than prefracture conditions. Several heads in layer 1 in the valley cells, within the fracture system, increased as much as 13 ft, and other heads decreased as much as 20 ft. The head in the one hillside cell decreased 60 ft. Vertical gradients are upward in all cells within the fracture zone except in a few valley cells located farthest from the Brush Run Valley. Vertical upward gradients were reduced by as much as an order of magnitude to a minimum of -0.004 ft/ft.

The ground-water flow budget of the basin showed only small additional amounts of ground water entering the lower layers because of the fractures. Only an additional 1 percent of the total ground-water recharge entered layer 2 and then returned to layer 1. Ground-water flow to layers 3 and 4 was unaffected by the fracture system, and no additional water left through the head-dependent flux boundaries of layers 3 and 4.

In the second vertical-fracture simulation, the vertical hydraulic conductivity of only layers 1 and 2 of the model was increased one order of magnitude. The locations of the vertical fracture systems and the increases in horizontal hydraulic conductivity remained unchanged from the first simulation.

Results of model simulations of long-term steady state conditions in the second simulation were the same as results of the first simulation. Vertical gradients between layers 1 and 2 were essentially the same as those for the model of the previous fracture system. Head in layer 4 of the model in some cells varied by only 10 ft between the two simulations.

In summary, model results show that heads in valleys that are underlain by fractures differ from unfractured valleys. Water levels in small tributary valleys underlain by fractures may be deeper than those normally seen in a similar unfractured topographic setting, but water levels in major valleys underlain by fractures may be higher than those normally seen in similar unfractured topographic settings. Vertical upward gradients in the valley cells within the fracture zone generally are less than in unfractured areas.

It would seem that slight upward gradients seen in some valley wells of Washington County may be explained by the presence of vertical fracture zones. The model results indicate that the presence of a few deep fractures within a basin does not change the water budget significantly from that of a basin with no deep fractures.

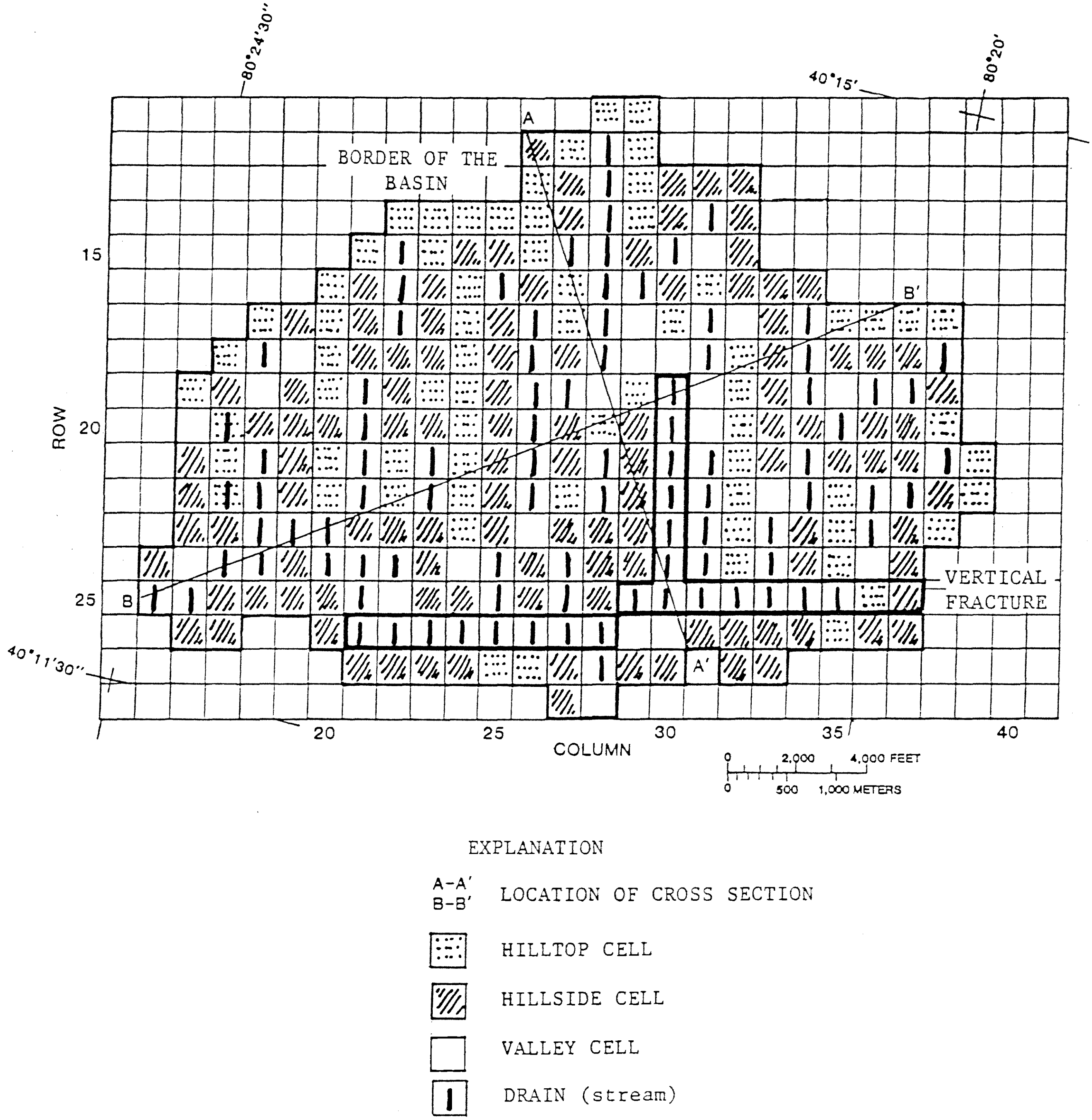


Figure A16.--Locations of two vertical fracture systems in layer 1 of the unmined-basin model.

APPENDIX B.--DETAILS OF MINED-BASIN MODEL

Introduction

The unmined-basin model was altered to include an active underground coal mine. Coal mines in the county have employed two mining methods: room and pillar, and longwall. In the digital model, these two mining techniques were simulated differently according to the condition of the roof rock as a result of the mining methods. The standard room and pillar mining method necessitates that large blocks or pillars of coal remain for support and therefore, the roof rock is unfractured. The pillar recovery operations (of the room and pillar method) and the longwall panel extraction operation result in almost total removal of the coal. Coal removal allows the roof rock to collapse into the mined area.

The calibrated model can be used to simulate possible hydrologic effects of an underground coal mine on the aquifer systems. However, the hydraulic and geologic characteristics of the bedrock between the coal mine and the surface aquifers, which supply most potable ground water, largely determine the effects of the coal mine on the ground-water flow in the shallow aquifers. This bedrock information is lacking in the Brush Run basin. Also, changes in hydraulic conductivity of aquifers caused by roof collapse are not well understood and differ from area to area. Therefore, model results should not be used to predict the effects of underground coal mining in the Brush Run basin because much of the input data had to be estimated. Model results must be analyzed in light of the assumptions made, and because data for model calibration are sparse, the model is referred to as "the hypothetical mined-basin model."

In the mined-basin model, ground water entering the underground coal mine is assumed to be removed from the ground-water-flow system of the basin. The ground-water recharge rate to the mined basin also is assumed not to increase as a result of underground mining.

Steady-state runs were used in the mine simulation because of the lack and variability of transient data (changes of hydraulic head with time) with mining activity in the study area. Data necessary for transient runs are reported by Stoner (1983), Moebs and Barton (1985), Pennington and others (1984), and Booth (1986), but data differ with the situation and are site specific.

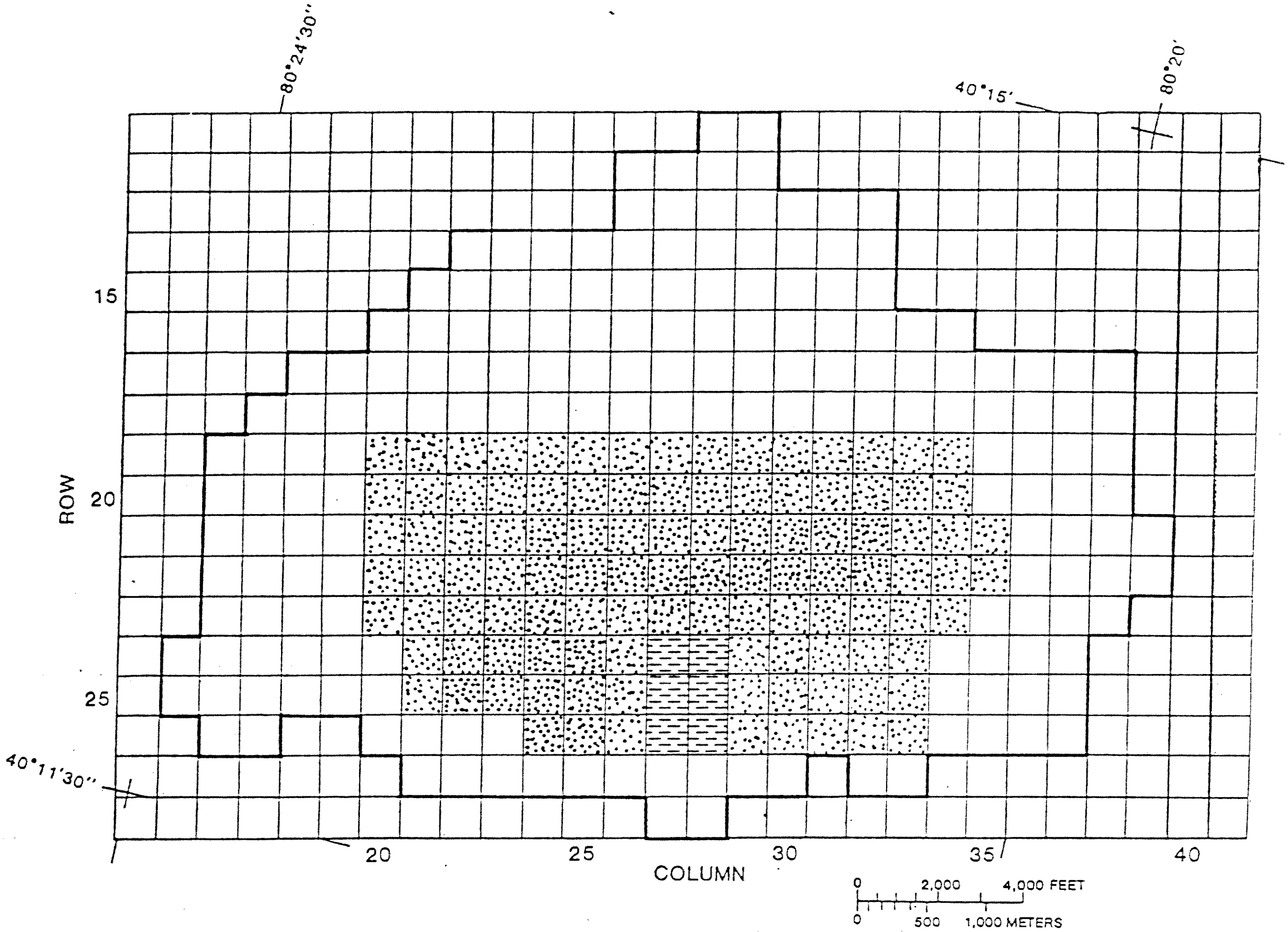
In some places, immediately after the mine collapses, water levels in wells over the mine will decline and then after a period of time (weeks to perhaps a few years) water levels may recover as the mine-subsidence fractures close by strata settlement; flow of plastic strata, such as fire clay; or deposition of clay and other sediment in the fractures. The model simulates steady-state water levels and is based on data collected in Daniels Run basin about 1 year after the roof collapsed.

The Brush Run and Daniels Run stream hydrographs were separated into the base flow and runoff components (using a modified computer program published by Pettyjohn and Henning, 1979) for the water years 1983-85, to determine and then to compare the amount of ground-water-recharge rates for each basin. The recharge computed for each basin varied somewhat with the method of hydrograph separation, but for water years 1983 and 1984, the annual recharge rates for the two basins were within 1/2 in. of each other. However, in 1985, the recharge in Brush Run basin was about 2 in. more than in the Daniels Run basin, even though both basins had the same total precipitation for the water year. The cause of this difference in the ground-water-recharge rates is unknown; seepage runs in the Daniels Run basin did not show loss of stream discharge to the mine in quantities large enough to explain the reduced recharge rate, and surface activities in either basin did not significantly change. Therefore, because the hydrograph separation showed the ground-water-recharge rates for water years 1983-84 in each basin to be about the same, the recharge in the mined basin is assumed to be the same as the recharge in the unmined basin. The validity and effect of this and some of the other assumptions were tested in the sensitivity analysis of the mined model.

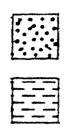
Mine Simulation

About 4 mi^2 of underground coal mines were simulated in layer 3 of the model (fig. B1). Layer 3 of the model contains the Pittsburgh coal bed, and the depth to coal in the mined-basin model is unchanged from that in the unmined-basin model. A mine was simulated by increasing the transmissivity of the mined cells by two orders of magnitude to about 125 ft^2/d. The hydraulic head in an active underground mine is maintained at the altitude of the mine floor. This was simulated in the model by placing constant head nodes in the mined cells of layer 3 at the altitude of the base of the Pittsburgh coal bed.

The horizontal and vertical hydraulic conductivities were increased in cells above the collapsed mine area (fig. B1). The vertical hydraulic conductivity between layers 2 and 3 of the model, in the area over the collapsed mine, was increased by one order of magnitude from the values used in the unmined-basin model. The horizontal hydraulic conductivity for cells over the collapsed mine area was increased by one order of magnitude in layer 2 and increased by a factor of five in layer 1.



EXPLANATION



UNCOLLAPSED MINE

COLLAPSED MINE

Total mined area = 113 cells = 4 square miles

Figure B1.--Location of the mine in layer 3 of the mined-basin model.

Results of Hypothetical Mined-Basin Model Simulation

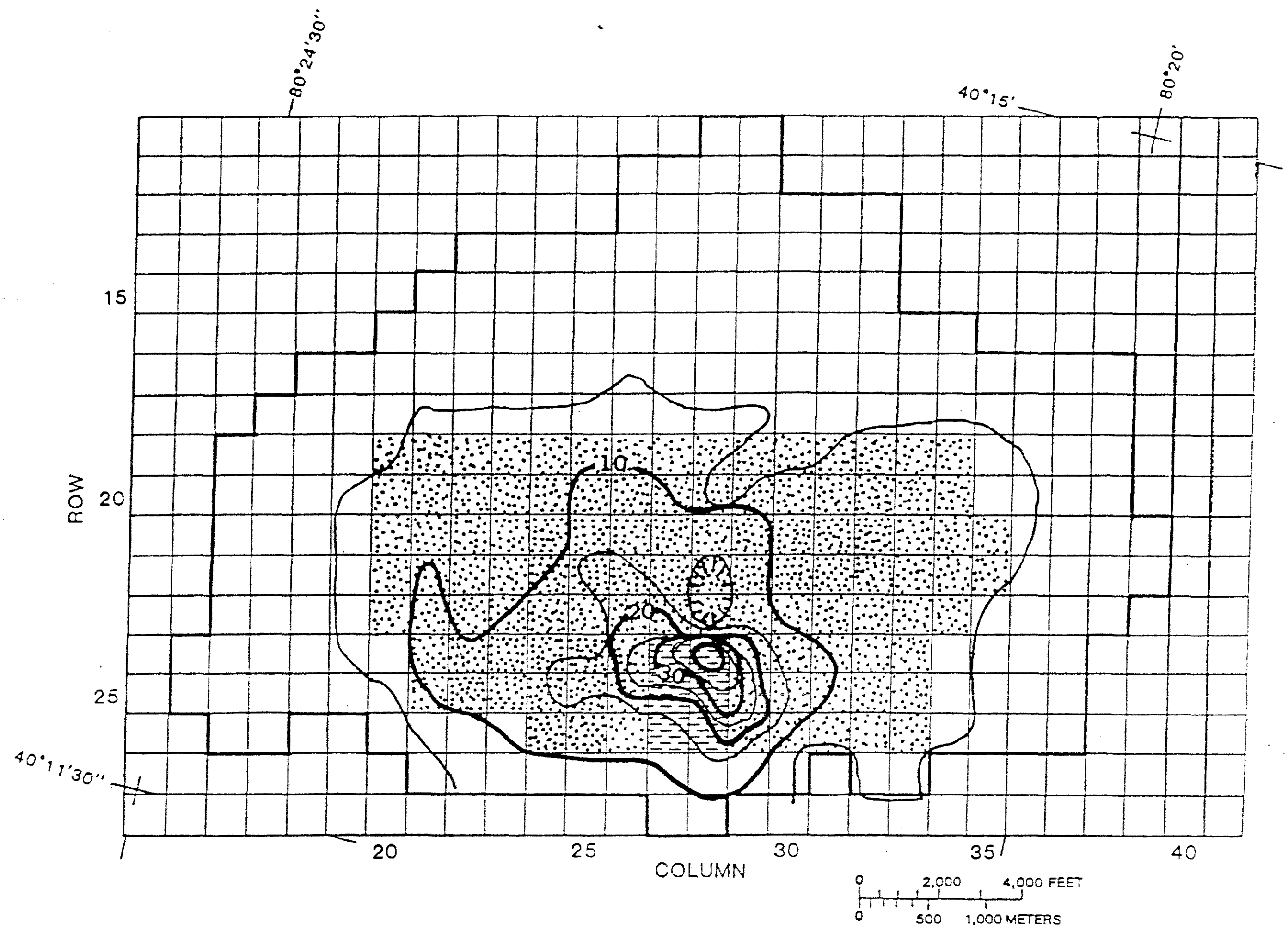
On the basis of the previously outlined assumptions and model alterations, a new head for each layer was generated by the model under the hydrologic stress of a coal mine. Figure B2 shows the drawdown (difference) between the premining head and the head after mining in layer 1. Drawdown of head caused by mining averaged 6 ft for layer 1, but the drawdown for each cell differs with the distance to the mine. Drawdowns in those areas not lying directly over the mine are less than 5 ft, but drawdowns in areas directly over the mine range from 4 to 40 ft and average about 10 ft. In the uncollapsed area, topographic setting has a minimal effect on drawdowns, but drawdowns in hillside cells may be a few feet more than drawdowns in hilltop and valley cells. The largest drawdown is associated with the collapsed-mine area. Drawdowns for cells directly over the collapsed-mine area were as much as 40 ft on a hillside and as little as 12 ft in a valley. A three-dimensional portrayal of the head in layer 1 of the mined-basin model is shown in figure B3, but because of the scale, there is little difference from the premining portrayal in figure A11.

The greatest drawdown is in the lower layers of the model. Figure B4 shows the head in layer 2 of the model. The greatest drawdown (about 200 ft) is in the collapsed-mine area. Drawdowns over the uncollapsed mine range from 100 to 200 ft and decrease with increasing distance from the collapsed-mine area. The drawdowns are smallest at the edge of the basin farthest from the mining.

The computer-generated heads in layers 3 and 4 of the model show considerable drawdown because of mining (figs. B5 and B6). The lowest head in layer 3 (fig. B5) is associated with the mine itself, and drawdowns are large within 3,000 ft of the mine. The head in layer 4 of the model (fig. B6) is depressed because of the mine, and the head over the entire layer is depressed about 150 ft compared with the premining head.

Vertical gradients between layers 1 and 2 that were upward in the unmined-basin model (in the valleys or upland draws) are downward in the mined-basin model if they are within 4,000 to 5,000 ft of the mined area.

The ground-water-flow budget for the postulated mined model shows that 26.7 percent of the total ground-water recharge enters the mine in layer 3 (fig. B7). The total ground water leaving layer 1 of the model amounts to 27.0 percent of the total recharge, and only 0.3 percent of the total recharge returns to layer 1. The mined model also shows that stream base flow in the basin is about 27 percent less than premining base flow (fig. A15). The mine inflow is 0.44 $(ft^3/s)/mi^2$ of area mined, which is common for mines in Washington County. Less than 0.1 percent of the recharge returns to layer 2 from layer 3, and less than 0.1 percent leaves layer 3 by the head-dependent boundaries. Less than 0.1 percent of the recharge enters layer 4 and returns to layer 3.



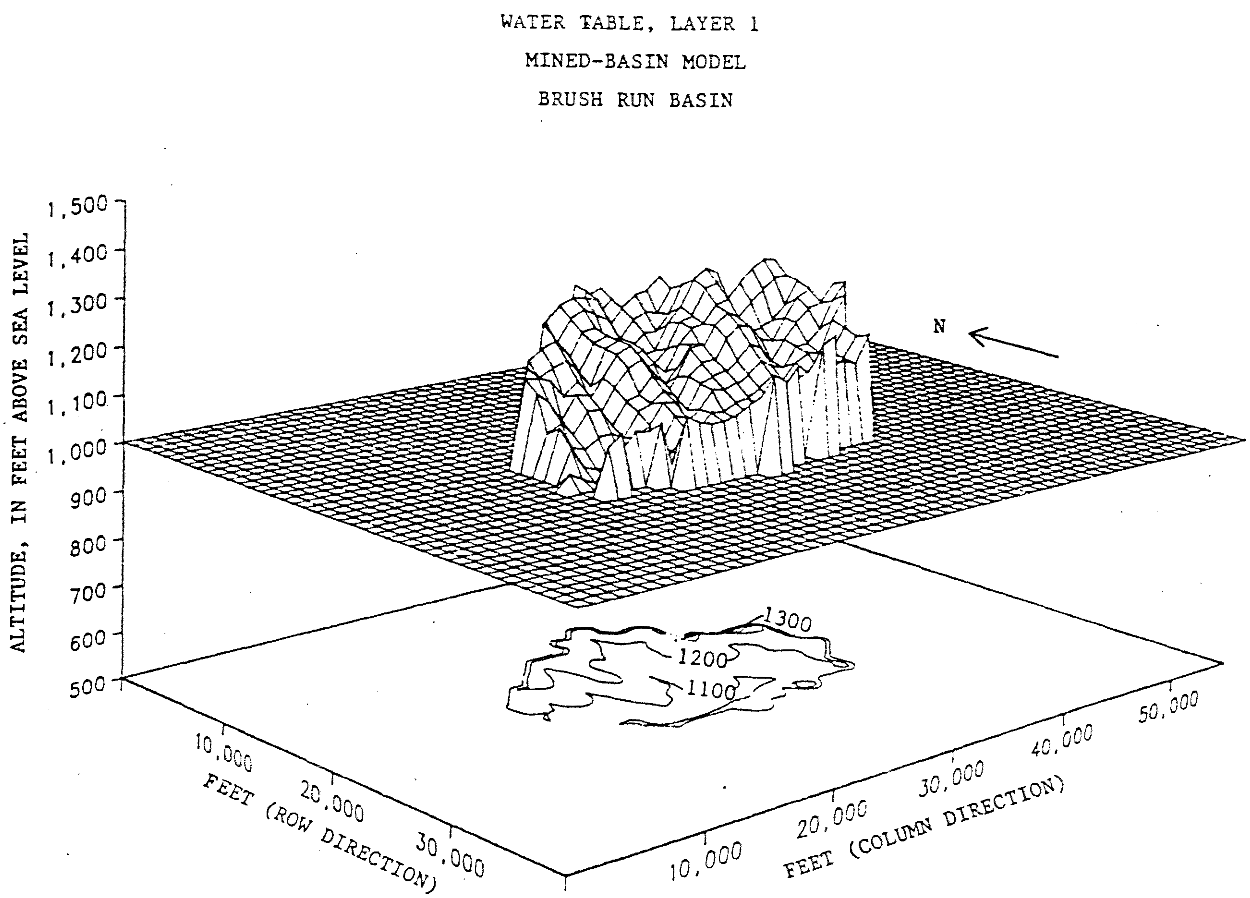
EXPLANATION

AREA OVER UNCOLLAPSED MINE

AREA OVER COLLAPSED MINE

—20— LINE OF EQUAL WATER-LEVEL DRAWDOWN-interval 5 feet

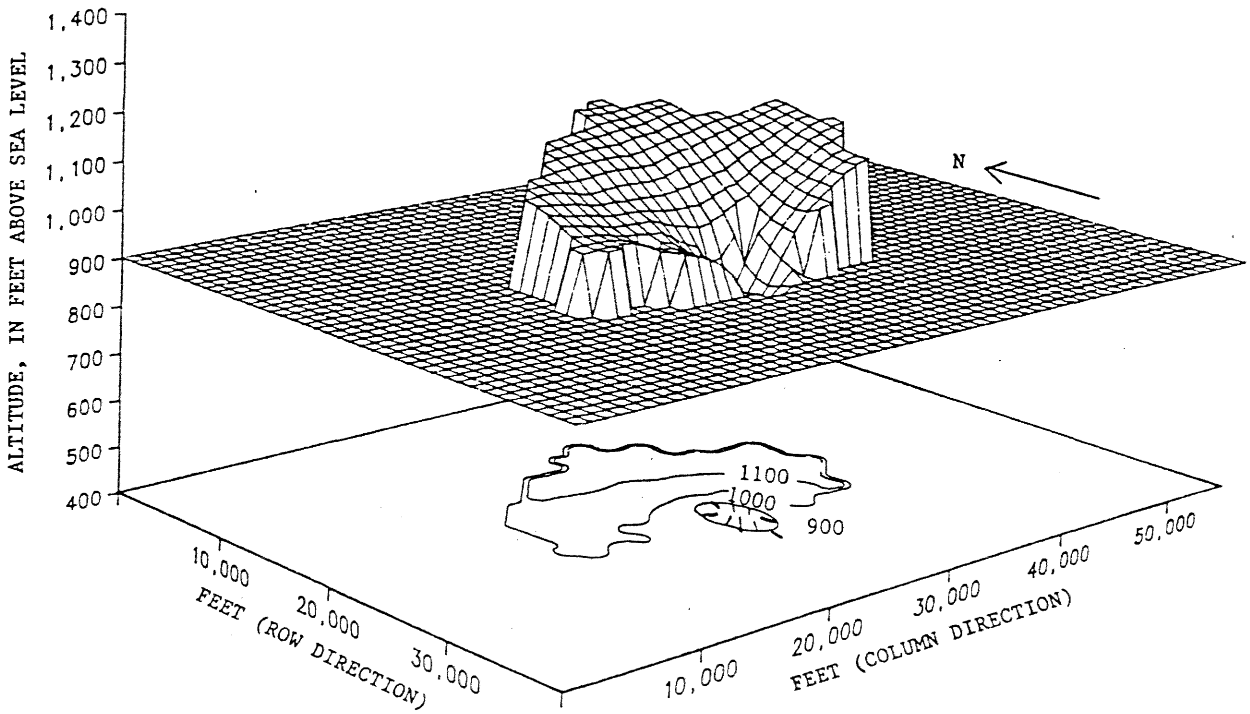
Figure B2.--Drawdown configuration of water levels in layer 1 of the mined-basin model.



Contour interval 100 feet

Figure B3.--Computer-generated water table of the unconfined aquifer represented by layer 1 of the mined-basin model.

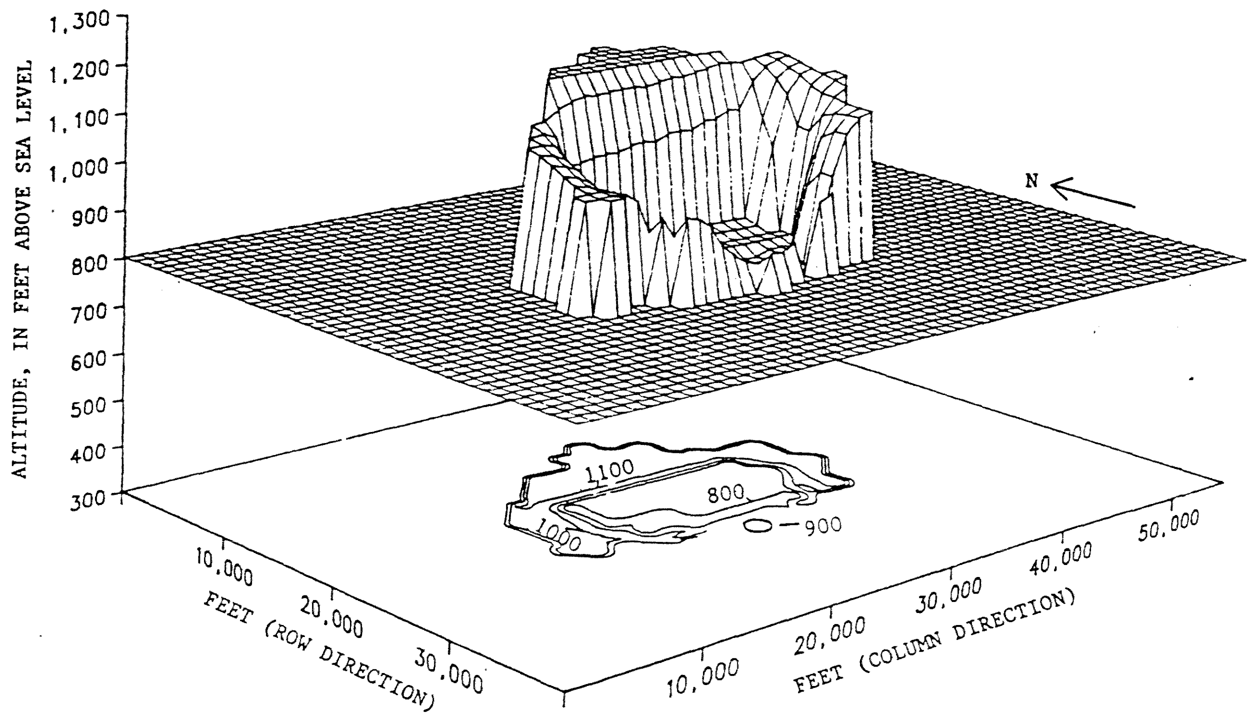
POTENTIOMETRIC SURFACE, LAYER 2
MINED-BASIN MODEL
BRUSH RUN BASIN



Contour interval 100 feet

Figure B4.--Computer-generated potentiometric surface of the confined aquifer represented by layer 2 of the mined-basin model.

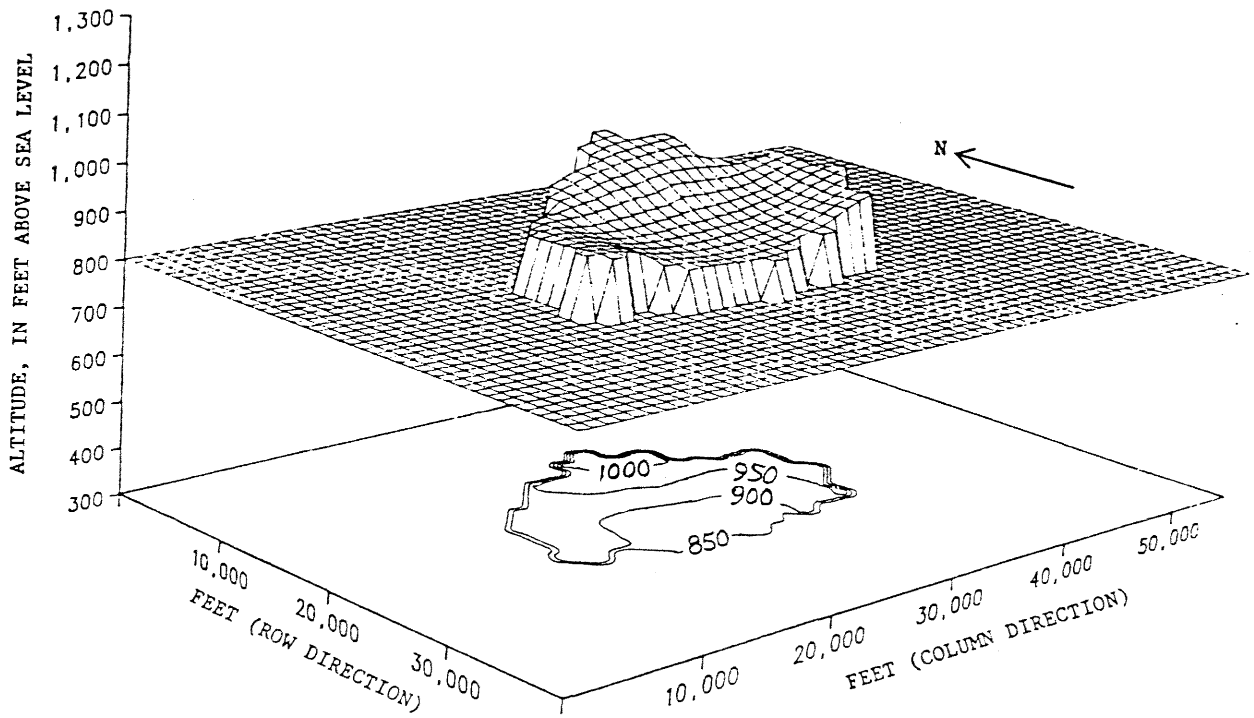
POTENTIOMETRIC SURFACE, LAYER 3
MINED-BASIN MODEL
BRUSH RUN BASIN



Contour interval 100 feet

Figure B5.--Computer-generated potentiometric surface of the confined aquifer represented by layer 3 of the mined-basin model.

POTENTIOMETRIC SURFACE, LAYER 4
MINED-BASIN MODEL
BRUSH RUN BASIN



Contour interval 50 feet

Figure B6.--Computer-generated potentiometric surface of the confined aquifer represented by layer 4 of the mined-basin model.

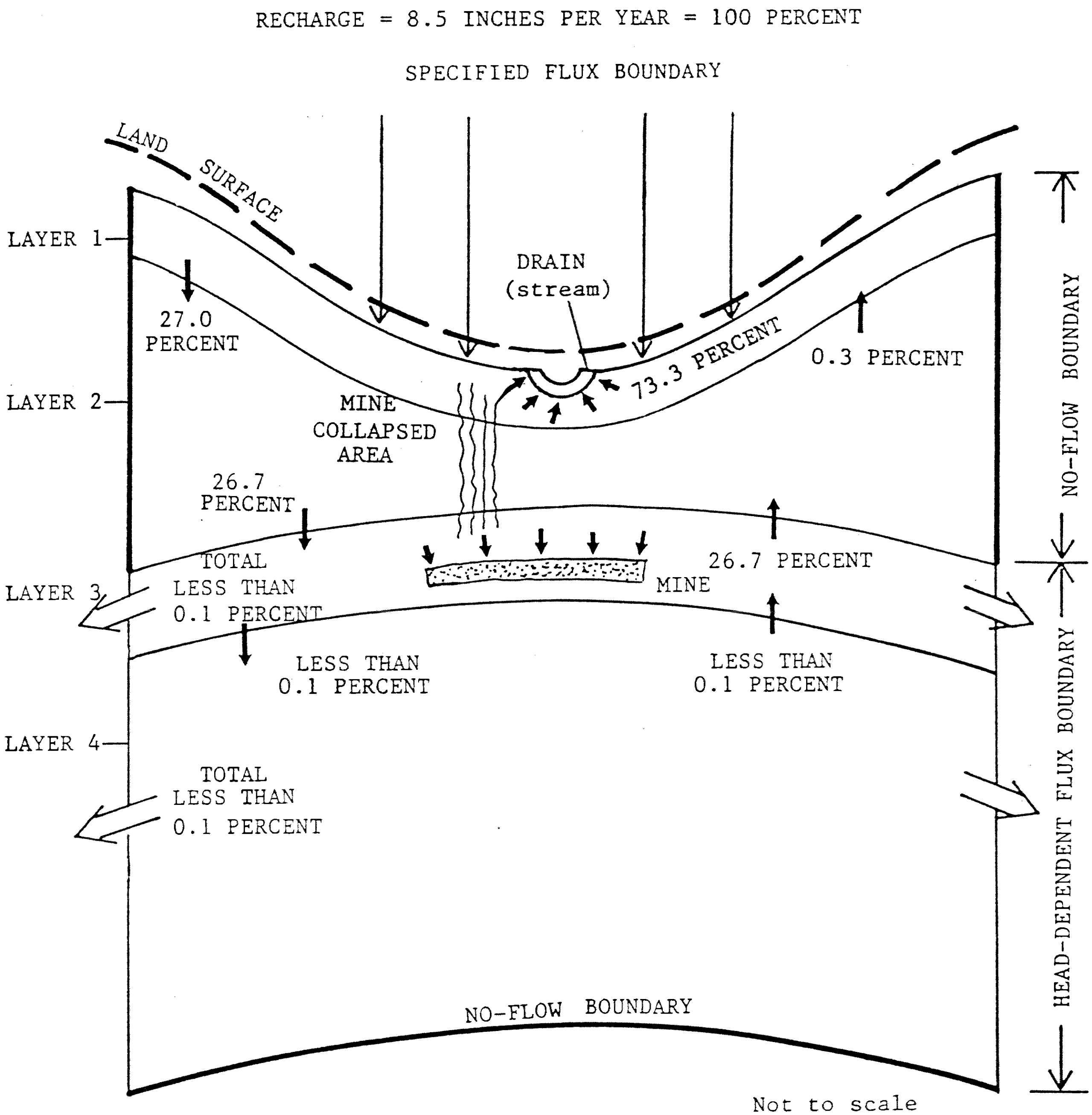


Figure B7.--Ground-water-flow budget of the mined-basin model.

When the depth to the mine was increased by increasing the thickness of layer 2 by 200 ft to simulate conditions in the Daniels Run basin more closely, the model produced a hydrologic system similar to the one measured in the mined Daniels Run basin. The model showed only a small decrease from the premining basin discharge [0.64 to 0.62 $(ft^3/s)/mi^2$ of basin] after mining. The decreased basin discharge is similar to that measured in the Daniels Run basin. The head in layer 1 remained unchanged except for the area within 1,000 ft of the collapsed mine area, where the head dropped by as much as 6 ft per cell. The drawdown is greatest directly over the collapsed area where drawdowns were as large as 23 ft on hillsides and 9 ft in valleys. In some valley cells, the head actually increased by 6 ft. These model-produced heads were compatible with data collected in the Daniels Run basin. Mine inflow in Daniels Run basin is about 0.15 $(ft^3/s)/mi^2$ of area mined, and the model showed mine inflow of 0.05 $(ft^3/s)/mi^2$.

In summary, the mined-basin model showed that if the defined hydrologic criteria and assumptions are true, the largest drawdowns of head would be over the collapsed-mine areas and stream base flow would be reduced 27 percent below premining base flow. Water levels in wells located over a collapsed-mine area may drop 12 to 40 ft, and declines in hillside wells probably would be the greatest. Water levels in wells located over an uncollapsed mine may decline about 10 ft. Drawdowns in wells not directly over the mine probably would be less than 5 ft. When the depth to the mine was increased by 200 ft to simulate conditions in the Daniels Run basin, the model showed that basin discharge [in cubic feet per second per square mile of basin], decline of head caused by mining, and mine inflow are similar to those measured in the Daniels Run basin. This simulated deep coal mine reduced stream base flow of the basin by only 3 percent, and the head in hillside domestic water wells over the collapsed mine may drop 13 to 23 ft.

Sensitivity Analysis

The values of some of the hydrologic characteristics within the mined basin and some of the boundary conditions were varied to determine how the changes would affect the ground-water system and the quantity of mine inflow. Variations in ground-water flow in mined areas may be caused by mine collapse, variation in depth to mining, natural hydrogeologic variation, type of land use, and drainage and recharge efficiency. The relative importance or sensitivity of each hydrologic characteristic can be determined by how greatly changing the values of each characteristic affects the ground-water-flow system.

The values for the hydrologic characteristics used in the mined-basin model were used as a standard in the sensitivity analysis, except that the horizontal and vertical hydraulic conductivity in layers 1 and 2 of the model were not increased to reflect a collapsed mine. Transmissivity was increased to about 125 ft^3/d in mined cells of layer 3 (fig. B5), and in those same cells, constant-head nodes were placed at the altitude of the base of the Pittsburgh coal bed.

When the increase in the hydraulic conductivity from mine collapse was not simulated (fig. B8), the ground-water-flow budget for the basin varied by up to 4 percent of the total ground-water recharge from the mined-basin model, and the average drawdown of head in layer 1 was changed by less than 1 ft. Analysis of the ground-water-flow budget showed that 23.1 percent of the total recharge enters layer 2 from layer 1; 0.3 percent of this is returned to layer 1 (fig. B8). Ground water being discharged into the stream is 77.2 percent of the total recharge. The ground water flowing into the mine is 22.8 percent of the recharge, which is most of the water entering layer 3. Mine inflow is 0.37 $(ft^3/s)/mi^2$ of area mined. Head-dependent boundaries in layer 3 removed less than 0.1 percent of recharge. Less than 0.1 percent of the recharge left head-dependent boundaries in layer 4 and less than 0.1 percent of the recharge enters layer 4 to return to layer 3. The head in layer 1 dropped by an average of about 5 ft per cell over the entire layer and the average drawdown for cells located over the mine was 9 ft. The large drawdowns in layer 1, which were associated with the mine collapse, were not seen in this simulation.

Recharge to layer 1 of the model was increased and decreased by 2.5 in/yr from the value of 8.5 in/yr. The change in recharge had only a small effect on the quantity of mine inflow, but a large effect on stream base flow. When the recharge was reduced, mine inflow was 0.36 $(ft^3/s)/mi^2$ of mined area, and, when recharge was increased, mine inflow was increased only to 0.37 $(ft^3/s)/mi^2$. When recharge was decreased, the average head in layer 1 dropped an additional 11 ft per cell, and when recharge was increased, the average head in layer 1 increased 6 ft per cell. The model shows that seasonal fluctuations of recharge would affect the head in domestic wells, but mostly would change the mine inflow. Furthermore, in some cases, mine-subsidence fractures in the unsaturated zone increase recharge rates to the surface aquifer (Hobba, 1981, p. 46); the additional recharge would explain the reduction in stream base flow and offset the drawdown of head in the surface aquifers.

The hydraulic conductivity of the stream bed was increased and decreased by a factor of three from the value of 0.05 ft/d used in the model. Stream bed hydraulic conductivity in the model is controlled by the anisotropy (K_h/K_v) of layer 1, converging flow to the stream, and the vertical and horizontal hydraulic conductivities of stream alluvium. The previous sensitivity analysis of the unmined-basin model determined that the value of the stream (drain) hydraulic conductivity has a big effect on the head in layer 1; therefore, only changes in mine inflow are reported. When the stream bed (drain) hydraulic conductivity was increased, mine inflow was 0.36 $ft^3/s)/mi^2$ of area mined, and when the hydraulic conductivity was decreased, mine inflow increased to 0.41 $(ft^3/s)/mi^2$. Therefore, variation of hydraulic conductivity in the shallow aquifers would affect the head in that system but would not drastically affect mine inflow.

The anisotropy in the vertical direction (K_h/K_v) for all layers of the postulated mined model was varied by a factor of two from the postulated values of 40 for layer 1, 125 for layer 2, 150 for layer 3, and 200 for layer 4. When the vertical anisotropy was changed, the horizontal hydraulic conductivity (K_h) is unchanged, and the vertical hydraulic conductivity (K_v) of the aquifers is varied by a factor of two. The increase in vertical

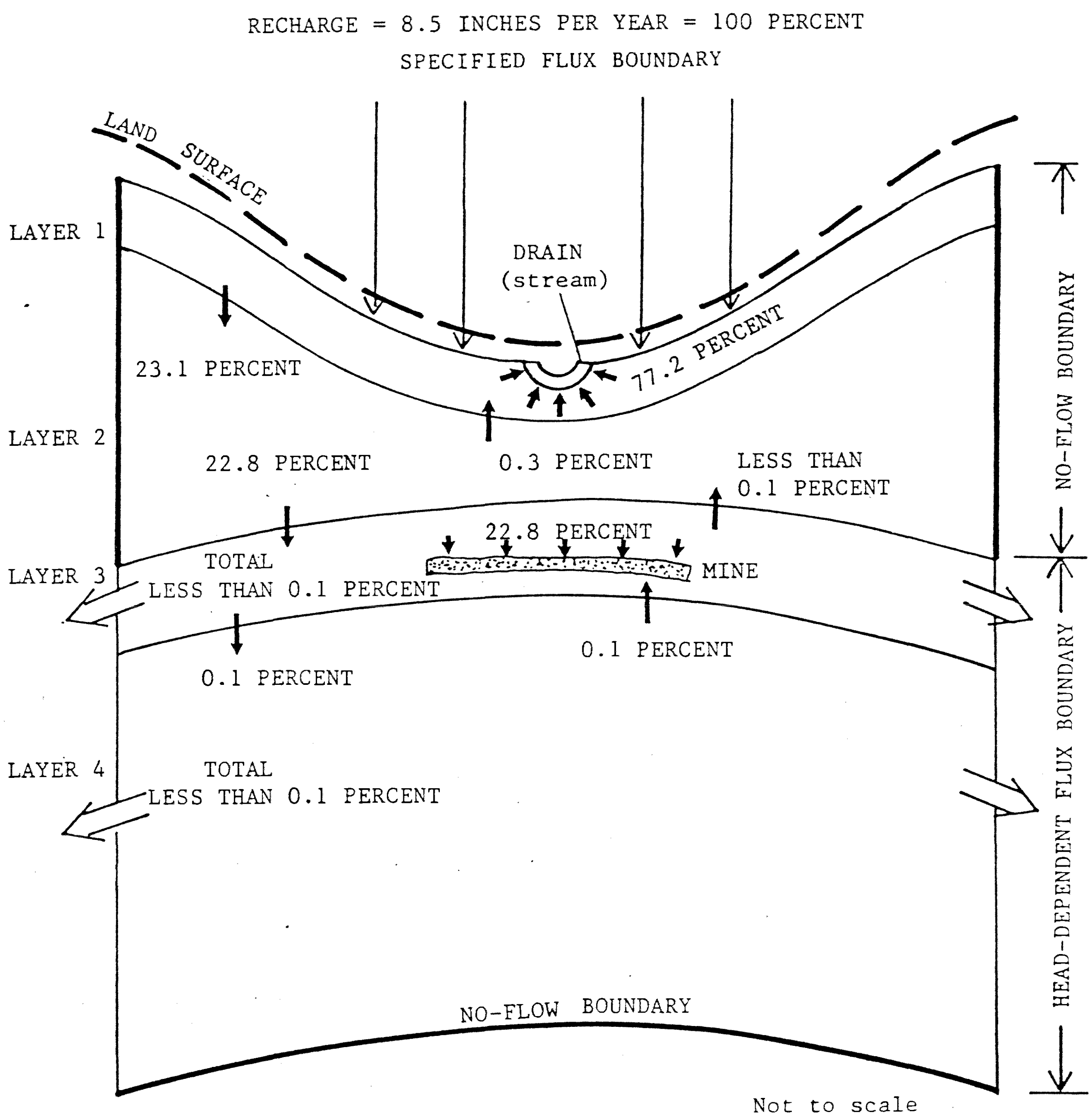


Figure B8.--Ground-water-flow budget of mined model used as a standard for the sensitivity analysis (no callapsed-mine area).

hydraulic conductivity caused the mine inflow to increase to 0.69 $(ft^3/s)/mi^2$ of mined area and the head in layer 1 to drop by an average of 11 ft per cell. The decrease in vertical hydraulic conductivity caused the mine inflow to decrease to 0.20 $(ft^3/s)/mi^2$ of mined area and the head in layer 1 to drop an average of 2 ft per cell. Therefore, increasing the vertical hydraulic conductivity by a factor of four (from the low to high values) caused mine inflow to increase by almost a factor of four also.

The changes made in vertical anisotropy had a large effect on the ground-water-flow budget. When anisotropy was decreased, 42 percent of the ground-water recharge entered the mine and only 58 percent of the recharge was removed by the streams (drains). When anisotropy was increased, 12 percent of the recharge entered the mine and 88 percent was removed by the streams.

The horizontal hydraulic conductivity of layers 2, 3, and 4 was decreased and then increased for the sensitivity analysis. For the mined-basin model the horizontal hydraulic conductivity was assumed to decrease at a rate of one order of magnitude per 175 ft of depth. In the sensitivity analysis, the rate was changed to one order of magnitude per 100 and 250 ft of depth. The vertical hydraulic conductivity also had to be changed so that the vertical anisotropy (K_h/K_v) would remain unchanged. With constant anisotropy, the sensitivity of horizontal conductivity is related to the sensitivity of vertical conductivity. The vertical hydraulic conductivity values of the aquifers between the mine and the shallow aquifers determine how the shallow aquifers will respond to mining.

When the horizontal and vertical hydraulic conductivities of layers 2, 3, and 4 was decreased, the effects of the mine on the ground-water system were very small. The mine inflow was only 0.04 $(ft^3/s)/mi^2$ of area mined, and the mine caused the head in layer 1 to drop by an average of less than 1 ft. The ground-water-flow budget showed 97.4 percent of the recharge left by the streams and only 2.6 percent of the recharge entered the mine in layer 3 of the model.

When the horizontal and vertical hydraulic conductivities of layers 2, 3, and 4 were increased, the effects of the mine on the ground-water system were substantial. Mine inflow became 0.8 $(ft^3/s)/mi^2$. The average head in layer 1 of the model dropped by an average of 14 ft per cell. The head in three cells in layer 1 of the model dropped below the bottom of layer 1, which caused the cells to go dry and altered model results. The ground-water-flow budget showed 50 percent of the recharge entering the mine and the remaining ground water being removed by the streams.

The lateral no-flow boundary in layer 2 of the model was changed to a constant-head boundary to simulate the possibility of ground water moving from the surrounding basins into the mined basin. Under the hydrologic stress of the underground coal mine, the lateral no-flow boundary for layer 1 is assumed to still be an adequate representation of the real system. However, ground water is now allowed to enter layer 2 from the lateral constant-head boundaries to simulate ground water moving in from surrounding basins. This constant-head boundary was placed at the altitude of premining heads. Ground water entering the mined basin from the constant-head boundaries amounted to

3.2 percent of the total ground-water recharge. The ground-water-flow budget did not change substantially. A little more of the total recharge (2.0 percent) stayed in layer 1. The sensitivity analysis showed that in this mine simulation, ground water moving from the surrounding basins into mined basins because of mining would be small and would not significantly change mine inflow. Mine inflow increased only from 0.37 to 0.38 $(ft^3/s)/mi^2$ of area mined, and the head in layer 1 was changed only by an average of 1 ft per cell.

The horizontal hydraulic conductivity for the head-dependent boundaries in layers 3 and 4 was increased and then decreased by one order of magnitude. When these changes were made, mine inflow remained unchanged. Head in layer 1 differed by less than 1 ft, and the ground-water-flow budget differed by less than 0.1 percent of the total recharge. The model shows that regional ground-water-flow system has little effect on the ground water of the mined basin.

The depth to mining was tested in the sensitivity analysis. The thickness of layer 2 was increased by 200 ft to simulate the depth to mining in the Daniels Run basin. Changes had to be made in the vertical and horizontal hydraulic conductivities of layers 2, 3, and 4 to account for the increased depth. Mine inflow decreased from 0.37 to 0.05 $(ft^3/s)/mi^2$ of area mined, which is only 2.5 percent of the total ground-water recharge. The mine inflow at Daniels Run is about 0.15 $(ft^3/s)/mi^2$ of area mined, but this mine inflow includes areas of mine collapse. The head in layer 1 is reduced only by about 1 ft per cell, and the streams still remove almost 98 percent of the recharge to the system. Therefore, according to the sensitivity analysis, depth to mining is a very sensitive hydrogeologic criterion, and the greater the vertical distance between the mine and the surface aquifers, the smaller will be the effects of mining.

In summary, changes of values for some hydrologic characteristics of the shallow aquifers (such as recharge, stream drainage, and ground-water flow entering from neighboring basins) have little effect on the amount of mine inflow, but may affect the head in the shallow aquifers represented by layer 1 of the model.

Vertical hydraulic conductivity of the bedrock between the mine and shallow aquifers is a major factor influencing the amount of ground water entering the mine and the effects of the mine on the shallow ground-water system. Increasing the vertical hydraulic conductivity by a factor of four increased mine inflow by almost the same amount. A high vertical hydraulic conductivity may be caused by mine collapse or vertical fracture zones. Figure B9 shows the range of the ground-water flow budget determined in the sensitivity analysis. The greatest range of flow was produced when vertical anisotropy was varied by a factor of two from the assumed values and when the vertical and horizontal hydraulic conductivities were changed in layers 2, 3, and 4.

Changing the hydraulic conductivity of the regional flow system had almost no effect on mine inflow and the ground-water-flow budget of the basin.

The depth to a mine is a sensitive hydrologic variable. Increasing the depth to a mine by 200 ft decreased mine inflow by an order of magnitude.

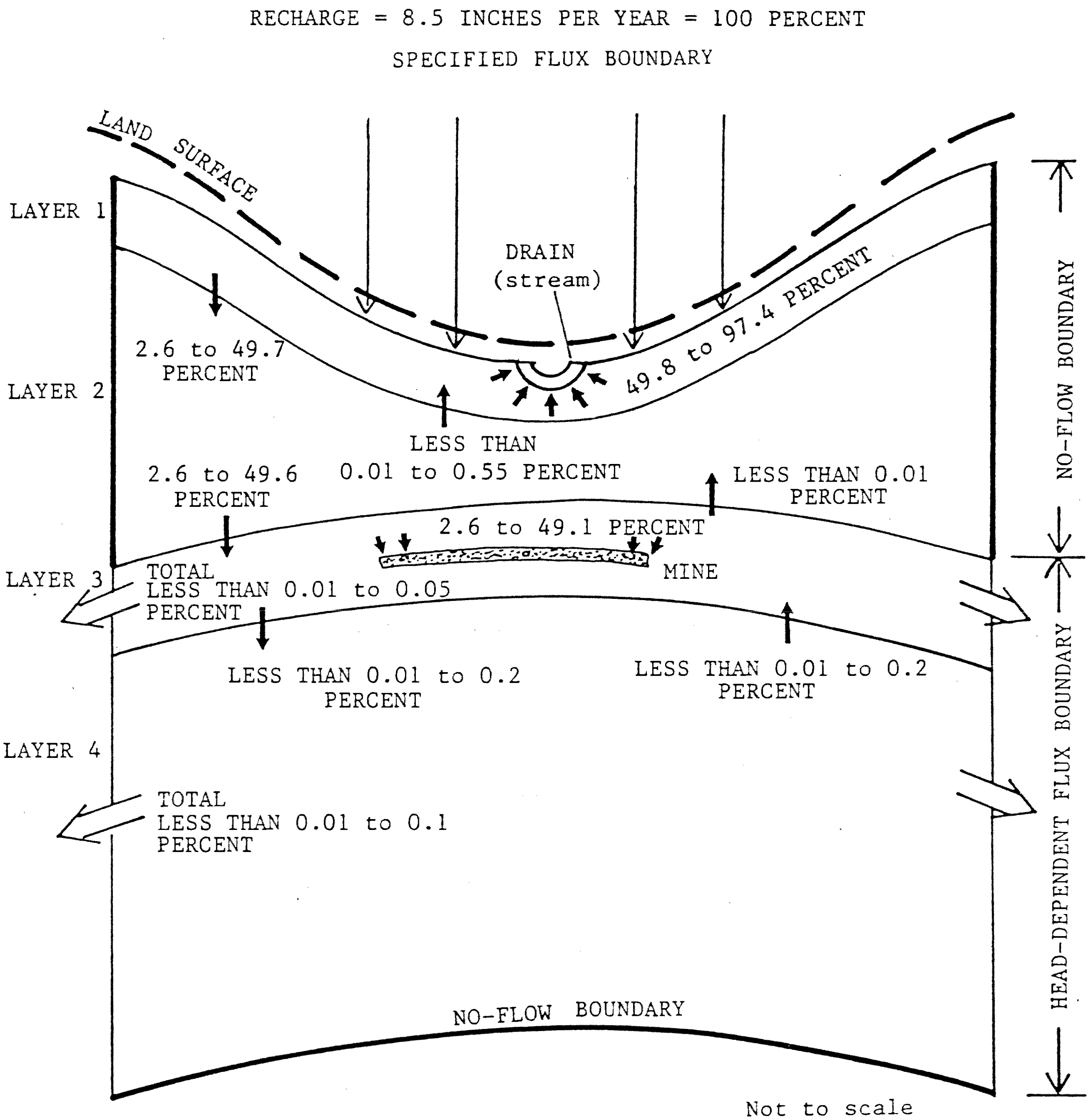


Figure B9.--Range of ground-water-flow components used in the sensitivity analysis of the mined-basin model.

Effects of a Vertical Fracture Zone

The fracture simulations discussed in the section "Flow in a Vertical Fracture Zone" were tested in conjunction with an underground coal mine. Depth to coal and all hydrologic factors discussed in the previous section on flow in a fracture system also were used for this simulation. The initial stage of mining (room development, no pillar extraction) was simulated by placing constant head nodes in layer 3 at an altitude equal to the base of the Pittsburgh coal bed in cells delineated in figure B1. Transmissivity in these same cells also was increased two orders of magnitude (average transmissivity about 125 ft^2/d).

The effect of vertical fractures on underground coal mining depends largely on the vertical hydraulic conductivity of the fracture system. When the horizontal and vertical hydraulic conductivities of cells in the vertical fracture system were increased 10 times, the effect of underground coal mining on heads in layer 1 was significant. Most of the cells in layer 1 within the fracture system went dry; this means the head in these cells fell below the bottom of layer 1.

When the vertical hydraulic conductivity between layers 2, 3, and 4 was not changed by the vertical fracture system, the effects of underground coal mining were not as great. The horizontal hydraulic conductivity of all cells in the fracture zone and only the vertical hydraulic conductivity from layer 1 to layer 2 for cells within the fracture system were increased 10 times. Fractured cells in layer 1 generally had drawdown of 10 to 15 ft from premining heads. Hilltop cells were the least affected (10 ft or less drawdown); hillside and valley cells generally had drawdown of 15 ft as far away as 4,000 ft from the fracture system. These vertical fractures caused mine inflow to increase from 0.37 to 0.41 $(ft^3/s)/mi^2$ of area mined.

In summary, the effects of the fracture system on the local ground-water system depend on the vertical conductivity of the fracture system. If the vertical conductivity in a fracture zone is low, the limited effects of mining on the local ground-water system would be minimal, and the converse also would be true.

Appendix C.--Record of wells

Local well number: The number that is assigned to identify the well. The prefix WS before the well number signifies that the well is located in Washington County.

Location map name: U.S. Geological Survey 7-1/2-minute topographic map.

Use of water: C, commercial; D, dewatering; H, domestic; I, irrigation; N, industrial; P, public supply; R, recreation; S, stock; T, institutional; U, unused; Z, other.

Topographic setting: C, stream channel; D, depression; F, flat; G, flood plain; H, hilltop; S, hillside; T, terrace; V, valley flat; W, upland draw.

Hydrologeologic unit: 111ALVM, Quaternary alluvium; 112ALVM, Quaternary alluvium; 317GREN, Greene Formation; 317TNML, Ten Mile Coal; 317WSNG, Washington Formation; 317WSNGU, Washington Formation, upper member; 317WSNGM, Washington Formation, middle member; 317WSNGL, Washington Formation, lower member; 317WBRG, Waynesburg Formation; 317WBRGU, Waynesburg Formation, upper member; 317WBRGM, Waynesburg Formation, middle member; 317WBRGL, Waynesburg Formation, lower member; 321MNGL, Monongahela Group; 321UNNN, Uniontown Formation; 321PBRG, Pittsburgh Formation; 321PBRGU, Pittsburgh Formation, upper member; 321SCKL, Sewickley Member of Pittsburgh Formation; 321FSPT, Fishpot Member of Pittsburgh Formation; 321RDSN, Redstone Member of Pittsburgh Formation; 321PBRGL, Pittsburgh Formation, lower member; 321PBRGC, Pittsburgh Coal; 321CNMG, Conemaugh Formation; 321CSLM, Casselman Formation; 321MRGN, Morgantown Sandstone Member of Conemaugh Formation; 321GLNS, Glenshaw Formation; 321PBRGR, Pittsburgh Redbed.

Lithology: CLSD, clay with some sand; COAL, coal; LMSN, limestone; SAND, sand; SDSL, sandstone and shale; SHLE, shale; SNDS, sandstone.

Discharge: gal/min, gallons per minute.

Specific capacity: [(gal/min)/ft], gallons per minute per foot of drawdown.

Temperature: deg C, degrees Celsius.

Specific conductance: µS/cm, microsiemens per centimeter at 25 degrees Celsius.

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws- 1	400220	0801219	Amwell	King, Floyd	--	H	S	317WSNG	--	36
2	401042	0801539	Canton	Albert Packing Company	--	N	V	321MNGL	--	200
3	401048	0801554	Canton	O'Brien Steel Construction	1913	U	V	321MNGL	--	160
4	401043	0801612	Canton	Tygart Valley Glass	1935	N	V	321MNGL	--	135
5	401032	0801637	Canton	Findlay Clay Product	1920	N	V	321MNGL	--	80
6	400445	0795124	Long Branch	Moose Brewing Company	1900	N	V	321CNMG	--	145
7	400831	0795349	Charleroi	Corning Glass Company	1944	U	V	111ALVM	SAND	63
8	401144	0795221	Carroll	France Slag Company	1942	N	V	321CNMG	--	200
9	401311	0795759	Union	West Penn Power Company	1947	U	V	321CNMG	--	255
10	401546	0800017	Union	Finleyville Borough	1946	U	V	321CNMG	--	125
11	401547	0800022	Union	Finleyville Borough	1935	U	V	321CNMG	--	105
12	401944	0801104	Cecil	Village of Cecil	1940	P	S	321CNMG	--	250
13	400427	0801020	Amwell	Carnegie Natural Gas	1926	H	V	321MNGL	--	85
14	401023	0801512	Washington	Washington Ice Company	1905	U	V	321MNGL	--	135
15	401625	0801610	Chartiers	Johnson Engr. & Mgmt. Co.	1930	P	V	321CNMG	--	90
16	400910	0801245	South Strabane	Red Schoolhouse	1926	H	S	317WSNG	LMSN	75
17	400757	0800920	South Strabane	Tanneyhill	1926	C	S	317GREN	SHLE	32
18	400732	0800816	Amwell	Hootman, William	1926	R	C	321MNGL	SNDS	182
19	400428	0801018	Amwell	Carnegie Natural Gas	1926	N	C	321MNGL	LMSN	90
20	400423	0801026	Amwell	McCrory, G.E.	--	H	S	321MNGL	--	75
21	400435	0801025	Amwell	Clements, A.B.	--	H	--	321MNGL	LMSN	75
22	400438	0801021	Amwell	Lewis, Clinton	1925	H	V	321MNGL	--	85
23	400419	0801218	Amwell	Keeney, Ralph H.	1925	H	H	317GREN	--	64
24	400325	0801233	Amwell	Wiley, Neal	--	H	S	317WSNG	SHLE	40
25	400221	0801217	Amwell	--	--	H	S	317WSNG	--	90
26	400357	0800143	Deemston	Hill, W.B.	1925	C	S	317WSNG	SNDS	70
27	400707	0800014	Bentleyville	Hertzog, Herbert	--	H	S	321MNGL	LMSN	105
28	400701	0800003	Bentleyville	Hopkins, Mrs. Nettie	--	H	S	321MNGL	LMSN	125
29	401150	0800004	Nottingham	Nottingham Township	--	H	H	321MNGL	--	134
30	401141	0795954	Fallowfield	National Mining Company	--	U	S	321MNGL	LMSN	400
31	401805	0800932	Cecil	Deblasoi, Sam	1916	H	C	111ALVM	SAND	28
32	401742	0800941	Cecil	McConnell, Logan	1916	H	S	317WSNG	--	92
33	401742	0800941	Cecil	McConnell, Logan	1916	H	S	317WSNG	--	82
34	401813	0800702	Cecil	Ofsay, Sam	1916	H	T	321MNGL	--	80
35	401815	0800722	Cecil	Quarturi, Joe	--	H	S	321MNGL	--	73
36	401806	0800655	Cecil	Simpson, A.F.	1916	H	V	321MNGL	LMSN	85
37	400329	0800118	Deemston	Nemacolin Country Club	1925	H	H	317WSNG	--	95
38	400218	0795558	Centerville	Grimes and Bakewell	1925	H	S	321MNGL	--	100
39	400220	0795435	Centerville	Butler, Charles	1925	H	S	321MNGL	--	100
40	400836	0795357	Charleroi	McBeth-Evans Glass Company	1925	N	V	111ALVM	SAND	--
41	401512	0801805	Chartiers	Gretna Oil and Gas Company	1926	N	H	321MNGL	--	107
42	401551	0801433	Chartiers	McCloy and Campbell	1926	N	V	321CNMG	--	123
43	401230	0801730	Canton	Wallace, J.H.	--	U	S	321CNMG	--	2,560
44	400710	0802548	Donegal	--	--	H	S	317WSNG	--	75
45	400703	0802548	Donegal	Williams	1924	H	S	317WSNG	--	100
46	400604	0800353	Cokeburg	Bethlehem Mines Corp.	1922	P	S	321MNGL	--	175
47	401945	0802434	Cross Creek	--	--	H	H	317WSNG	LMSN	50
48	401820	0802300	Cross Creek	Kelly Brothers and Cooper	1909	H	S	321MNGL	--	157
49	401723	0802217	Cross Creek	Nosio Hall School	1921	T	S	321MNGL	--	67

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min)/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
4	40	--	34.00	08-17-36	--	1.0	3	--	--	--	--	1-Ws
--	--	--	25.00	06-15-37	32	--	--	--	--	--	13.0	2
--	--	--	100.00	06-15-37	--	--	--	--	--	--	--	3
--	--	--	100.00	00-00-35	50	--	--	--	--	--	--	4
--	--	--	60.00	01-01-20	8	--	--	--	--	--	--	5
--	--	--	5.00	01-01-00	35	--	--	--	--	--	--	6
52	8	--	14.00	03-01-44	--	5.1	200	--	--	--	--	7
--	--	--	75.00	01-01-42	--	--	--	--	--	--	--	8
70	0	--	30.00	01-01-47	--	9.7	160	--	--	--	--	9
78	0	--	84.00	09-01-49	--	22	43	--	--	--	--	10
--	--	--	30.00	05-01-50	50	--	--	--	--	--	--	11
--	--	--	--	--	--	--	--	--	--	--	--	12
--	--	--	7.00	07-01-50	--	--	--	--	--	--	--	13
--	--	--	20.00	09-01-49	25	--	--	--	--	--	--	14
--	--	--	--	--	--	.73	22	--	--	--	11.0	15
46	6	--	9.00	01-01-26	--	--	--	--	--	--	--	16
--	--	--	--	--	--	--	--	--	--	--	--	17
16	6	--	13.00	00-00-26	--	.4	30	--	--	--	--	18
--	--	--	7.00	00-00-26	--	--	--	--	--	--	11.0	19
40	--	--	40.00	00-00-26	--	--	--	--	--	--	--	20
--	--	--	--	--	--	--	--	--	--	--	--	21
74	6	--	--	--	--	--	--	--	--	--	--	22
--	--	--	50.00	00-00-25	--	--	--	09-28-26	370	--	11.0	23
--	--	--	--	--	--	--	--	--	--	--	--	24
--	--	--	--	--	--	--	--	--	--	--	--	25
22	6	--	5.00	01-01-25	--	--	--	--	--	--	--	26
56	6	--	85.00	09-25-26	--	--	--	--	--	--	--	27
50	6	--	--	--	--	--	--	--	--	--	--	28
--	--	--	--	--	--	--	--	--	--	--	--	29
400	1	--	--	--	--	--	--	--	--	--	--	30
--	--	--	--	--	--	--	--	09-16-26	368	--	11.0	31
--	--	32/ 40/ 55	--	--	1	--	--	--	--	--	--	32
--	--	35/ 36/ 56	--	--	10	--	--	--	--	--	--	33
--	--	--	30.00	09-16-26	<1	--	--	--	--	--	--	34
--	--	--	50.00	09-16-26	--	--	--	--	--	--	--	35
--	--	--	--	--	--	--	--	--	--	--	--	36
26	6	--	80.00	00-00-25	--	--	--	--	--	--	--	37
24	6	--	80.00	01-01-25	--	--	--	--	--	--	--	38
28	6	--	85.00	01-01-25	--	--	--	--	--	--	--	39
--	--	--	--	--	350	--	--	--	--	--	--	40
20	6	--	45.00	00-00-26	3	--	--	09-30-26	280	--	11.0	41
14	8	--	30.00	01-01-26	2	--	--	--	--	--	--	42
--	--	--	--	--	--	--	--	--	--	--	--	43
--	--	--	--	--	--	--	--	--	--	--	--	44
40	6	--	40.00	01-01-24	--	--	--	--	--	--	--	45
40	6	--	145.00	01-01-22	--	--	--	--	--	--	--	46
50	6	--	--	--	--	--	--	--	--	--	--	47
--	--	--	--	--	--	--	--	--	--	--	--	48
20	6	--	--	--	--	--	--	--	--	--	--	49

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws- 50	401643	0802146	Cross Creek	Shaffer, Henry	1926	H	H	317WSNG	--	98
51	401900	0802530	Cross Creek	Dunbar, G.C.	1910	U	F	317WSNGL	--	2,160
52	400655	0802410	Donegal	Claysville Borough	--	P	V	321MNGL	--	140
53	400437	0802132	East Finley	Pleasant Grove School	--	T	S	317WSNG	LMSN	148
54	400046	0802222	East Finley	Marshall School	--	T	V	317GREN	--	--
55	395926	0802416	East Finley	Newland School	--	T	S	317GREN	SNDS	75
56	400225	0795356	Centerville	Elliot, Thomas	1923	S	H	321MNGL	--	114
57	400143	0795435	Centerville	Nixon, A.J.	1923	H	S	317WBRGM	--	69
58	400200	0795250	Centerville	Forsythe Coal Company	1922	C	V	321CNMG	--	122
59	400745	0795716	Fallowfield	Haynan, Harrison	1918	H	T	321MNGL	LMSN	70
60	400744	0795716	Fallowfield	Cole, J.S.	1918	H	T	317WSNG	--	40
61	402745	0802931	Hanover	Manufacturers Light	--	N	V	321CNMG	SNDS	100
62	402708	0802625	Hanover	Fullerton, E.O.	--	H	F	321CNMG	--	60
63	402721	0802812	Hanover	Purdy School	--	T	H	321CNMG	SNDS	140
64	402810	0802633	Hanover	Fullerton, H.	1902	U	V	321CNMG	SNDS	--
65	402545	0802645	Hanover	Bell, James	--	H	H	321MNGL	--	95
66	402552	0802733	Hanover	Steele, James F.	--	U	V	321CNMG	--	1,290
67	402450	0802830	Hanover	Thompson, R.A.	1918	--	S	321CNMG	--	1,790
69	402615	0802205	Hanover	McConnell Heirs	1925	--	S	321CNMG	--	1,000
70	401645	0802800	Independence	Schoolhouse of Avella	1924	H	V	321CNMG	--	100
71	402110	0802852	Jefferson	Dimit, Jacob	1909	H	S	321MNGL	LMSN	92
72	402115	0802825	Jefferson	Boles, McClellan J.	1925	H	S	321MNGL	LMSN	127
73	402035	0802032	Jefferson	Walker, Alexander	1919	U	V	321BNWD	--	2,300
74	401802	0801833	Mount Pleasant	Hickory Grade School	1914	I	S	321UNNN	--	126
75	401758	0801830	Mount Pleasant	Farmers National Bank	1926	C	F	321MNGL	LMSN	165
76	401705	0802124	Mount Pleasant	Stewart, Jim	--	H	V	321MNGL	LMSN	75
77	401714	0801649	Mount Pleasant	Adams Brothers	1925	H	V	321CNMG	LMSN	150
78	401745	0801920	Mount Pleasant	Donaldson	--	U	S	321UNNN	--	700
79	401240	0800345	Nottingham	McClure, Dr. & Margaret	1900	--	S	317WBRG	--	2,340
80	401115	0800320	Nottingham	Barr, J.	1921	--	H	321UNNN	--	2,820
81	401705	0800650	Peters	Strange, William	1916	H	T	317WSNG	SNDS	90
82	401655	0800630	Peters	Philips, A.C.	1916	H	S	317WSNG	--	61
83	401700	0800555	Peters	Brown, William F. Rev.	1915	H	G	--	--	78
84	401800	0800550	Peters	Denniston, Thomas	1916	H	S	321MNGL	--	150
85	401650	0800425	Peters	Schnuth, George	--	H	S	321MNGL	--	85
86	401450	0800317	Peters	Venetia Schoolhouse	--	T	V	321CNMG	--	199
87	401640	0800210	Peters	Phillips, E.B.	--	U	V	321MNGL	--	2,730
90	401445	0800317	Peters	Bryant, Mary E. And M.M.	1921	--	V	321CNMG	--	3,630
91	402603	0802118	Hanover	West Penn Water Company	--	P	V	321CNMG	SNDS	90
92	402228	0802215	Smith	Beabout, S.G.	1926	H	V	321CNMG	LMSN	60
93	402218	0801700	Robinson	Carnegie Coal Company	1919	P	V	321CNMG	SNDS	48
94	402645	0802035	Robinson	Moody	1925	U	F	321CNMG	--	1,000
95	402615	0802100	Robinson	Bigger	1925	U	S	321CNMG	SHLE	1,100
100	402251	0802347	Smith	Burgettstown Coal Company	1917	P	S	321CNMG	--	90
101	402330	0802315	Smith	Chastulik, Ciril	1920	H	T	321CNMG	--	110
102	402155	0802420	Smith	Ptrucci, D.	1917	H	S	321CNMG	--	114
103	402255	0802433	Smith	Grnsbrg-Cnlsvlle C&C Co.	--	H	S	321CNMG	--	70
104	402252	0802430	Smith	Grnsbrg-Cnlsvlle C&C Co.	--	H	V	321CNMG	--	145

Appendix C.--Record of wells--Continued

Casing		Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield			Field water quality				USGS well number
Depth (feet)	Diameter (inches)				Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	
--	--	--	90.00	01-01-26	--	--	--	--	--	--	--	50
--	--	50/200	--	--	--	--	--	--	--	--	--	51
--	--	--	--	--	--	--	--	--	--	--	--	52
--	--	--	119.00	09-30-26	--	--	--	--	--	--	--	53
--	--	--	--	--	--	--	--	--	--	--	--	54
--	--	--	--	--	--	--	--	--	--	--	--	55
45	6	--	95.00	09-26-26	--	--	--	--	--	--	--	56
30	6	--	55.00	09-26-26	--	--	--	--	--	--	--	57
80	8	--	100.00	09-17-26	--	--	--	--	--	--	--	58
--	--	--	57.00	09-23-26	--	--	--	--	--	--	--	59
--	--	--	25.00	09-23-26	--	2.5	20	--	--	--	--	60
--	--	--	5.00	09-22-26	110	--	--	09-22-26	280	--	10.0	61
--	--	--	30.00	09-22-26	--	--	--	--	--	--	--	62
--	--	--	--	--	--	--	--	--	--	--	--	63
--	--	--	--	--	--	--	--	--	--	--	--	64
--	--	--	--	--	--	--	--	--	--	--	--	65
43	8	35	--	--	--	--	--	--	--	--	--	66
1,305	7	55	--	--	--	--	--	--	--	--	--	67
--	--	--	--	--	10	--	--	--	--	--	--	69
--	--	--	--	--	--	--	--	--	--	--	--	70
25	6	--	--	--	--	--	--	--	--	--	--	71
41	8	--	75.00	09-21-26	--	--	--	--	--	--	--	72
--	--	80	--	--	--	--	--	--	--	--	--	73
126	6	--	43.90	06-14-83	--	--	--	06-14-83	875	6.8	29	74
					--	--	--	08-11-83	880	7.1		
48	6	--	75.00	01-01-26	--	--	--	--	--	--	--	75
--	--	--	30.00	09-30-26	--	--	--	--	--	--	--	76
--	--	--	--	--	--	--	--	--	--	--	--	77
--	--	--	--	--	--	--	--	--	--	--	--	78
--	--	30/ 80/967/146	--	--	--	--	--	--	--	--	--	79
1,570	7	150/150	--	--	--	--	--	--	--	--	--	80
--	--	--	30.00	01-01-16	--	--	--	--	--	--	--	81
--	--	--	--	--	1	--	--	--	--	--	--	82
--	--	--	--	--	2	--	--	--	--	--	--	83
--	--	37/ 57	--	--	1	--	--	--	--	--	--	84
45	6	32/ 45/ 51/ 75	--	--	3	--	--	--	--	--	--	85
100	6	--	140.00	09-23-26	--	--	--	--	--	--	--	86
104	0	80/203/183	--	--	--	--	--	--	--	--	--	87
1,360	7	80/620/700	--	--	--	--	--	--	--	--	--	90
14	0	--	7.00	00-00-00	120	--	--	--	--	--	--	91
38	6	--	36.00	09-00-26	--	--	--	09-22-26	880	--	10.0	92
40	6	--	--	--	22	--	--	09-22-26	330	--	10.0	93
--	--	--	--	--	--	--	--	--	--	--	--	94
--	--	--	--	--	--	--	--	--	--	--	--	95
--	--	--	--	--	--	--	--	09-21-26	1,800	--	11.0	100
30	6	--	--	--	--	--	--	--	--	--	--	101
27	6	--	--	--	--	--	--	--	--	--	--	102
--	--	--	--	--	10	--	--	--	--	--	--	103
--	--	--	--	--	--	--	--	--	--	--	--	104

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-105	401945	0802330	Cross Creek	Adams, Mrs.	--	H	V	321CNMG	--	101
106	402320	0802140	Smith	Racoon Schoolhouse	1913	T	S	321CNMG	SHLE	85
107	402332	0802202	Smith	P.C.C. and St.L. Railroad	1918	U	V	321CNMG	--	125
108	402302	0802449	Smith	Grnsbrg-Cnlsvlle C&C Co.	--	Z	S	321CNMG	--	220
109	402250	0802150	Smith	Shean Coal Company	--	D	S	321CNMG	SNDS	110
110	402300	0802140	Smith	--	--	H	V	321CNMG	SNDS	50
111	402246	0802135	Smith	Elias, Charles	1926	H	S	321CNMG	--	60
112	402232	0802305	Smith	Laverick, Anton	1915	U	H	321CNMG	SNDS	259
113	402230	0802330	Smith	Tennyson, Henry	--	C	S	321CNMG	--	87
114	402341	0802331	Smith	Burgettstown High School	1925	T	S	321CNMG	--	83
115	402230	0802305	Smith	Vajantic, Dominick	1915	H	H	321MNGL	--	119
116	402214	0801942	Smith	Bulger Schoolhouse	1916	H	S	321MNGL	--	82
117	402212	0801907	Smith	Lewis, Ben	1926	H	F	321MNGL	LMSN	106
118	402146	0802400	Smith	American Zinc and Company	1914	H	F	321MNGL	--	112
119	402146	0802400	Smith	American Zinc and Company	1914	U	S	321MNGL	LMSN	174
120	402130	0802325	Smith	Horovitz, Adolph	1913	H	V	321MNGL	--	58
121	402140	0802415	Smith	American Zinc and Company	1914	N	S	321MNGL	LMSN	89
122	402130	0802325	Smith	Krzeczowski, M.J.	1916	H	V	321MNGL	--	76
123	402205	0802325	Smith	Fullam	1925	H	S	321MNGL	LMSN	60
124	402105	0802050	Smith	--	--	H	V	321CNMG	LMSN	150
127	401053	0800802	Somerset	Grange Hall	1925	H	V	317WSNG	SNDS	52
128	400720	0801445	South Franklin	Vankirk, Warren F.	1925	H	S	317GREN	--	90
129	400720	0801440	South Franklin	Vankirk Schoolhouse	1925	H	S	317GREN	LMSN	120
130	400920	0801250	South Strabane	--	--	H	H	317GREN	--	100
131	400910	0801245	South Strabane	Lockwood, Hugh	1926	H	S	317GREN	LMSN	103
132	400715	0795230	Fallowfield	Kittle	--	S	S	321CNMG	--	175
134	401507	0795507	Union	Equitable Gas Company	--	N	V	111ALVM	SAND	--
135	401614	0800117	Union	Mineral Beach	1925	R	V	321CNMG	--	438
136	401614	0800117	Union	Mineral Beach	1925	R	S	321CNMG	--	790
137	401510	0800015	Union	H.D. Benn Garage	--	C	V	321CNMG	--	44
138	401507	0795525	Union	Equitable Gas Company	--	P	T	321CNMG	--	98
139	401507	0795507	Union	Equitable Gas Company	--	N	V	321CNMG	SHLE	94
140	401356	0795821	Union	Diamond Coal Company	--	N	V	321MNGL	--	153
141	401230	0795905	Union	Colson, A.K.	--	H	V	321CNMG	--	97
142	401030	0801610	Washington	Washington Ice Company	--	N	V	321MNGL	SNDS	200
143	401020	0801505	Washington	Washington Baking Company	1921	C	V	321MNGL	--	100
144	401010	0801510	Washington	--	--	U	V	321MNGL	--	365
145	400935	0801407	North Franklin	Casto, Earl	1925	H	S	317WSNG	--	105
146	400350	0800750	West Bethlehem	Schrontz, Geaman	--	H	C	317WSNG	--	140
147	400120	0800749	West Bethlehem	Franklin Schoolhouse	--	H	S	317WSNG	--	95
148	400105	0800615	West Bethlehem	Manaokoff, Angeline	1923	H	T	317WSNG	SNDS	87
149	400105	0800615	New Bethlehem	Fenosniff, Mrs. Annie	1923	H	T	317WBRGM	--	126
150	400315	0795600	West Pike Run	Vesta Coal Company	--	H	V	111ALVM	--	30
151	400300	0800005	Centerville	Koches, Mike	1925	H	F	321MNGL	LMSN	95
152	400315	0795600	West Pike Run	Vesta Coal Company	1925	P	V	321CNMG	SNDS	141
153	400250	0795635	West Pike Run	Pepper, Taylor C.	1923	H	S	321CNMG	LMSN	156
155	400233	0802613	West Finley	U.S. Geological Survey	1971	U	V	317WSNG	SNDS	140
156	401735	0800507	Peters	Williams, W.H.	--	H	S	317WSNG	--	55

Casing					Measured yield			Field water quality				
Depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	USGS well number
40	6	--	--	--	--	--	--	--	--	--	--	105
--	--	--	25.00	01-01-13	--	--	--	--	--	--	--	106
13	8	--	--	--	--	--	--	--	--	--	--	107
50	6	--	--	--	--	--	--	--	--	--	--	108
--	--	--	--	--	--	--	--	--	--	--	--	109
--	--	--	--	--	--	--	--	--	--	--	--	110
--	--	--	30.00	01-01-26	--	--	--	--	--	--	--	111
83	6	--	--	--	--	--	--	--	--	--	--	112
--	--	--	--	--	2	--	--	09-21-26	1,840	--	12.0	113
37	8	--	--	--	--	--	--	--	--	--	--	114
57	6	--	--	--	--	--	--	--	--	--	--	115
20	8	--	--	--	--	--	--	--	--	--	--	116
--	--	--	--	--	--	--	--	--	--	--	--	117
--	--	--	--	--	--	--	--	--	--	--	--	118
--	--	--	--	--	--	--	--	--	--	--	--	119
--	--	--	--	--	--	--	--	--	--	--	--	120
--	--	--	--	--	--	--	--	--	--	--	--	121
24	6	--	--	--	--	--	--	--	--	--	--	122
--	--	--	20.00	01-01-25	--	--	--	--	--	--	--	123
--	--	--	--	--	--	--	--	--	--	--	--	124
20	6	--	35.00	01-01-25	--	--	--	--	--	--	--	127
--	--	--	60.00	01-01-25	--	--	--	--	--	--	--	128
94	6	--	75.00	01-01-25	--	--	--	--	--	--	--	129
--	--	--	--	--	--	--	--	09-25-26	330	--	11.0	130
25	6	--	41.00	01-01-26	--	--	--	--	--	--	--	131
--	--	--	140.00	09-23-26	--	--	--	--	--	--	--	132
--	--	--	10.00	09-17-26	125	--	--	--	--	--	--	134
100	8	--	--	--	65	--	--	--	--	--	--	135
300	8	--	--	--	35	--	--	--	--	--	--	136
--	--	--	--	--	2	--	--	09-23-26	360	--	13.0	137
--	--	--	50.00	09-17-26	--	--	--	--	--	--	--	138
55	6	--	--	--	--	--	--	--	--	--	--	139
--	--	--	--	--	--	--	--	--	--	--	--	140
35	6	--	--	--	--	--	--	--	--	--	--	141
30	6	--	60.00	09-29-26	25	--	--	10-29-26	360	--	12.0	142
28	6	--	25.00	01-01-21	--	--	--	--	--	--	--	143
20	--	--	4.00	09-29-26	--	--	--	--	--	--	--	144
--	--	--	--	--	--	--	--	--	--	--	--	145
--	--	--	--	--	--	--	--	--	--	--	--	146
--	--	--	25.00	09-28-26	--	--	--	--	--	--	--	147
27	6	--	45.00	01-01-23	--	--	--	--	--	--	--	148
--	--	--	--	--	--	--	--	--	--	--	--	149
10	6	--	--	--	--	--	--	--	--	--	--	150
22	6	--	80.00	01-01-25	--	--	--	--	--	--	--	151
40	6	--	100.00	01-01-25	--	--	--	--	--	--	--	152
127	5	--	75.00	01-01-23	--	--	--	--	--	--	--	153
19	6	--	38.00	06-01-71	--	.12	2	07-01-71	518	8.2	12	155
					--	--	--	08-23-83	490	7.9		
--	--	--	--	--	--	--	--	11-12-67	347	8.3	--	156

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-176	401204	0802427	Hopewell	Kraft, Kenneth	--	U	S	317WBRGL	--	34
178	401203	0802259	Hopewell	Boni, Dino	--	U	S	321UNNN	--	33
179	401202	0802301	Hopewell	Boni, Dino	--	H	S	321UNNN	--	20
180	401335	0802134	Hopewell	Denning, Homer	1967	H	S	317WSNGM	SHLE	70
181	401315	0801958	Hopewell	Amos, James	1979	U	S	317WBRGL	--	92
182	401312	0801958	Hopewell	Calvert, William	1979	U	S	--	--	74
183	400655	0800724	North Bethlehem	Wonsettler, John	1980	U	S	317WBRGU	--	35
184	400654	0800726	North Bethlehem	Wonsettler, John	1966	H	S	317WBRGU	--	62
185	400627	0800629	North Bethlehem	Wright, Bill	1924	H	S	317GREN	--	51
186	400639	0800632	North Bethlehem	Cowden, Mildred	1950	U	S	317WSNGM	--	95
187	400640	0800632	North Bethlehem	Brady, Donald	--	U	H	317WSNGM	--	55
188	400434	0800558	North Bethlehem	Thearston, Norman	--	U	H	317WBRGU	--	16
189	400410	0800552	North Bethlehem	Hoffman, George	1960	U	H	317WBRGU	--	32
190	400543	0800655	North Bethlehem	Bonczek, John	--	U	H	317WBRGU	--	25
193	401230	0801949	Canton	Armstrong, William	1973	H	S	317WBRGL	--	60
194	401231	0801951	Canton	Valduga, Donald	1970	H	S	317WBRGL	--	80
195	401232	0802018	Buffalo	Morrison, Robert	1972	D	S	321UNNN	--	100
196	401239	0802043	Hopewell	Bailey, Charles	1969	D	S	321PBRGU	--	120
197	401230	0802055	Hopewell	--	--	--	V	321UNNN	--	100
198	401212	0802240	Hopewell	Richmond, Bruce	1957	H	S	317WBRG	--	90
199	401211	0802241	Hopewell	Richmond, Bruce	1957	U	S	317WBRGL	--	38
200	401213	0802240	Hopewell	Richmond, Bruce	--	U	S	317WBRG	--	22
201	401245	0802232	Hopewell	Williams, Roger	--	U	H	--	--	40
202	401231	0802228	Hopewell	Voytek, Joseph	1956	D	S	317WBRGL	--	74
203	401228	0802225	Hopewell	Miller, Donald	1952	H	S	317WBRGL	--	60
204	401313	0802323	Hopewell	Smith, Thelma	--	U	S	317WBRG	--	90
205	401323	0802319	Hopewell	Smith, David	1979	U	W	317WBRGL	--	91
206	401330	0802321	Hopewell	Smith, David	1966	U	W	321UNNN	--	97
208	400548	0800523	North Bethlehem	--	--	U	H	317WSNGM	--	130
209	400613	0800635	North Bethlehem	Symdo, Andrew J.	1975	H	S	317WBRGU	--	110
210	400524	0800639	North Bethlehem	Gogoroncy, George	1968	U	V	317WBRGL	--	30
212	400517	0800427	North Bethlehem	Crumrine, Clark	--	U	S	317GREN	--	68
214	400553	0800622	North Bethlehem	Kusch, Charles	1970	U	S	317WBRGU	--	18
216	401436	0802158	Hopewell	Taggart, Diane	1977	H	H	317WSNGM	--	130
217	401414	0802140	Hopewell	Johnson, Ray	1948	H	S	317WBRGL	--	56
218	401332	0802140	Hopewell	Waychoff, L.A.	1942	H	H	317WSNGL	--	78
219	401328	0802138	Hopewell	Upper Buffalo Church	1979	P	H	317WSNGM	--	100

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
--	--	--	25.00	10-22-82	--	--	--	--	--	--	--	176
--	--	--	13.60	10-22-82	--	--	--	--	--	--	--	178
--	--	--	11.90	10-22-82	--	--	--	--	--	--	--	179
--	--	16/ 27	43.00	10-22-82	15	--	--	--	--	--	--	180
--	--	--	38.10	10-22-82	--	--	--	08-19-83	520	6.5	13	181
15	8	--	26.20	10-22-82	--	.38	3	08-26-83	540	7.4	15	182
--	--	--	13.00	10-25-82	--	--	--	--	--	--	--	183
62	6	--	20.00	00-00-66	--	--	--	--	--	--	--	184
--	--	--	44.70	10-25-82	--	--	--	--	--	--	--	185
20	6	--	--	10-25-82	--	--	--	--	--	--	--	186
55	48	--	52.00	10-25-82	--	--	--	--	--	--	--	187
--	--	--	--	10-25-82	--	--	--	--	--	--	--	188
--	--	--	30.50	10-25-82	--	--	--	08-30-84	555	7.4	13.5	189
					--	--	--	11-23-84	580	6.8	11	
					--	--	--	09-27-85	480	7.5	17	
--	--	--	12.80	10-27-82	--	--	--	--	--	--	--	190
--	--	--	50.20	11-01-82	--	--	--	--	--	--	--	193
--	--	--	48.20	11-01-82	--	--	--	--	--	--	--	194
--	--	75	--	--	--	--	--	--	--	--	--	195
--	--	--	--	--	25	--	--	--	--	--	--	196
--	--	--	--	--	--	--	--	08-22-84	640	7.5	--	197
--	--	--	68.00	11-01-82	--	--	--	09-26-85	580	7.3	13.5	198
--	--	--	24.40	11-01-82	--	--	--	--	--	--	--	199
19	24	--	18.30	11-01-82	--	--	--	--	--	--	--	200
40	30	--	21.60	11-01-82	--	--	--	--	--	--	--	201
--	--	--	60.60	11-01-82	--	--	--	10-30-84	635	7.0	17.5	202
					--	--	--	04-23-85	660	7.2	18.0	
					--	--	--	09-26-85	655	7.3	19.0	
--	--	--	27.00	11-01-82	--	--	--	04-23-85	685	7.2	14.0	203
					--	--	--	09-26-85	615	7.3	14.5	
--	--	--	33.20	11-01-82	--	--	--	--	--	--	--	204
14	6	--	6.36	11-02-82	--	.18	2	08-24-83	580	7.2	15	205
--	--	--	29.60	11-02-82	--	--	--	--	--	--	--	206
--	--	--	60.50	11-02-82	--	--	--	--	--	--	--	208
--	--	--	29.30	11-03-82	--	--	--	09-07-83	600	6.9	17.5	209
					--	--	--	11-23-84	640	7.0	16.0	
					--	--	--	04-30-85	600	7.0	14.5	
					--	--	--	09-27-85	650	7.3	17.5	
--	--	--	--	--	--	--	--	--	--	--	--	210
--	--	--	57.80	11-02-82	--	--	--	--	--	--	--	212
--	--	--	14.00	11-03-82	--	--	--	--	--	--	--	214
26	8	45/ 80	45.00	03-20-77	--	.05	4	06-06-83	710	7.1	22.0	216
--	--	--	18.20	06-06-83	--	--	--	06-06-83	510	6.9	21.0	217
					--	--	--	10-26-84	555	7.1	20.0	
					--	--	--	04-30-85	560	7.4	15.0	
					--	--	--	09-26-85	562	7.3	16.0	
20	10	--	--	--	--	--	--	06-06-83	850	6.8	26.5	218
26	8	40	47.00	06-06-83	--	.1	6	09-04-85	605	7.7	19	219
					--	.1	6	--	--	--		

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topographic setting	Hydrogeologic unit	Lithology	Depth of well (feet)
Ws-221	401329	0802141	Hopewell	Jones, Wray M.	--	H	H	317WBRGM	--	63
222	401329	0802140	Hopewell	Vorhes, Ed	1975	H	H	317WSNGL	--	88
223	401300	0802241	Hopewell	Sinclair, William	1982	H	H	317WSNGL	--	120
224	401259	0802242	Hopewell	Miller, Juanita	1947	H	S	317WSNGL	--	100
225	401257	0802240	Hopewell	Merideth, William	1973	H	H	317WSNGL	--	55
226	401258	0802241	Hopewell	Richmand, William	1963	H	S	317WSNGL	--	40
227	401257	0802014	Hopewell	Minor, Charles	--	H	S	317WBRGL	--	110
228	401256	0802012	Hopewell	Pallett, Alvin	1960	H	S	321UNNN	--	143
229	401255	0802011	Hopewell	--	--	H	S	317WBRGL	--	100
230	401253	0802011	Hopewell	Karpen, Paul	1946	H	S	317WBRGL	--	86
231	401251	0802015	Hopewell	Riggs, William	1967	H	H	317WBRGU	--	75
232	401250	0802014	Hopewell	Ward, Henry S.	1959	H	H	317WBRGL	--	93
233	401847	0801457	Mount Pleasant	Smith, Richard	1970	H	H	321UNNN	--	100
234	401846	0801756	Mount Pleasant	Slates, Dorothy	1961	H	H	321UNNN	--	120
235	401919	0801616	Mount Pleasant	Banro, Edward	1983	H	S	321SCKL	--	130
236	401916	0802351	Mount Pleasant	Osbourne, Alvan	1982	H	S	321UNNN	--	100
237	401704	0802123	Mount Pleasant	Zimmerman, Andrew	--	--	S	321SCKL	--	50
239	401706	0802131	Mount Pleasant	Carter, W.F.	--	U	S	321SCKL	--	40
240	401707	0802137	Cross Creek	Cowden, Andrew T.	--	H	V	321PBRGU	--	48
241	401705	0802148	Cross Creek	Rosko, David	1976	H	V	321SCKL	--	80
242	401705	0802146	Cross Creek	Malanosky, Frank	1976	P	V	321SCKL	--	110
243	401705	0802147	Cross Creek	Malanosky, Frank	1976	P	V	321SCKL	--	110
244	401710	0802152	Cross Creek	Hobbs, Robert L.	--	H	S	321SCKL	--	200
245	401712	0802155	Cross Creek	Conn, Wedron A.	1981	--	S	321SCKL	--	180
246	401713	0802155	Cross Creek	Conn, Jr., Wedron	1981	H	S	321SCKL	--	120
248	401712	0802152	Cross Creek	Malanosky, Frank	1977	--	S	321UNNN	--	120
249	401712	0802152	Cross Creek	Malanosky, Frank	--	H	S	321UNNN	--	--
250	401710	0802154	Cross Creek	Malanosky, Frank	1977	H	S	321PBRGU	--	160
251	401709	0802153	Cross Creek	Kearney, Edward	1977	H	S	321SCKL	--	110
252	401713	0802153	Cross Creek	Smith, David	1977	H	S	321UNNN	--	110
253	401709	0802151	Cross Creek	Conn, Jack	--	H	S	321SCKL	--	--
254	401702	0802155	Cross Creek	Miller, Elva	1922	--	V	321SCKL	--	28
255	401704	0802154	Cross Creek	Schafer, James	1950	H	V	321SCKL	--	50
257	401705	0802152	Cross Creek	Ragan, James	1962	H	V	321SCKL	--	18
258	401701	0802157	Cross Creek	Wilson, Joseph	1903	H	V	321SCKL	--	35
259	401702	0802200	Cross Creek	Fekula, Julia	1960	H	S	321SCKL	--	60
260	401658	0802209	Cross Creek	Marcott, Henry	1951	--	S	321SCKL	--	42

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
--	--	46	--	--	--	--	--	06-06-83	800	7.0	22	221
--	--	--	65.00	06-06-83	--	--	--	06-06-83	690	6.8	25	222
					--	--	--	09-02-83	825	7.4		
--	--	--	21.40	06-06-83	--	--	--	06-06-83	795	7.1	17	223
--	--	--	12.00	06-06-83	--	--	--	06-06-83	585	6.7	27	224
--	--	--	--	--	--	--	--	06-06-83	590	6.6	20.5	225
--	--	--	--	--	--	--	--	06-06-83	615	6.6	21.0	226
--	--	--	--	--	--	--	--	06-08-83	560	7.5	20	227
--	--	--	--	--	--	--	--	06-08-83	580	7.1	20.5	228
--	--	--	47.70	06-08-83	--	--	--	06-08-83	505	7.3	21	229
--	--	--	--	--	4	--	--	06-08-83	595	7.1	21	230
--	--	--	--	--	--	--	--	06-08-83	625	6.8	20.5	231
22	6	23	23.00	04-00-59	--	--	--	06-08-83	680	7.0	17.5	232
--	--	--	35.50	06-14-83	--	--	--	06-14-83	550	7.5	15.5	233
--	--	--	--	--	--	--	--	06-14-83	440	7.0	15.5	234
130	6	45/120	69.70	06-14-83	--	--	--	06-14-83	525	7.7	19	235
--	--	--	70.60	06-14-83	12	--	--	06-14-83	555	7.6	16.5	236
--	--	--	--	--	--	--	--	06-15-83	630	7.3	19.5	237
--	--	--	29.90	06-15-83	--	--	--	--	--	--	--	239
--	--	--	--	--	--	--	--	06-15-83	4,500	7.7	18	240
					--	--	--	08-11-83	4,400	8.0	16.5	
--	--	--	21.90	06-15-83	--	--	--	06-15-83	800	7	20.5	241
					--	--	--	08-22-84	800	6.8	26	
110	8	--	25.20	06-15-83	22	--	--	--	--	--	--	242
110	8	--	26.90	06-15-83	50	--	--	--	--	--	--	243
--	--	--	--	--	5	--	--	06-15-83	825	7.1	18	244
					--	--	--	08-07-84	1,180	7.7	16.0	
					--	--	--	09-17-84	1,240	7.5	17.0	
					--	--	--	04-17-85	730	6.9	13	
					--	--	--	09-12-85	1,500	7.5	14.0	
--	--	--	--	--	--	--	--	--	--	--	--	245
--	--	--	39.70	06-15-83	--	--	--	06-15-83	510	7.7	18	246
					--	--	--	08-23-85	520	7.4	24	
					--	--	--	09-12-85	460	7.5	23	
--	--	--	50.20	06-15-83	6	--	--	--	--	--	--	248
--	--	--	46.80	06-15-83	--	--	--	--	--	--	--	249
--	--	--	50.90	06-15-83	2	--	--	--	--	--	--	250
--	--	--	52.10	06-15-83	--	--	--	06-15-83	610	6.8	16.5	251
					--	--	--	09-17-84	825	7.6	19	
--	--	--	--	--	3	--	--	--	--	--	--	252
--	--	--	49.30	06-16-83	--	--	--	06-16-83	640	6.8	20.0	253
--	--	--	2.99	06-16-83	--	--	--	06-16-83	690	7.3	19	254
--	--	--	--	--	--	--	--	06-16-83	720	7.0	15.5	255
17	48	--	7.95	06-16-83	--	--	--	06-16-83	650	6.7	15.5	257
					--	--	--	08-23-84	750	6.7	22	
					--	--	--	09-12-85	550	7.1	22	
--	--	--	4.99	06-16-83	--	--	--	06-16-83	700	7.3	19.0	258
--	--	--	--	--	--	--	--	06-16-83	715	7.1	18.0	259
16	8	--	10.40	06-16-83	6	--	--	06-16-83	675	7.2	22	260

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-260									
261	401658 0802209	Cross Creek	Marcott, Henry	1965	H	S	--	--	65
262	401716 0802152	Cross Creek	Vorhes, James	1962	H	S	321PBRGU	--	130
263	401719 0802152	Cross Creek	Eckles, Robert	1970	H	S	321UNNN	--	200
264	401736 0802210	Cross Creek	Rouse, Jeaine	1979	H	H	317WBRGU	--	140
265	401744 0801850	Mount Pleasant	Mount Pleasant Township	--	U	W	321UNNN	--	99
266	401745 0801855	Mount Pleasant	--	--	U	S	321UNNN	--	37
267	401740 0801856	Mount Pleasant	--	--	U	S	321UNNN	--	21
268	401658 0802207	Cross Creek	Marcott, Henry	1959	U	V	321SCKL	--	60
269	401656 0802214	Cross Creek	Monticello, Julian	1980	H	V	321UNNN	--	40
270	401754 0801842	Mount Pleasant	--	--	U	S	317WBRG	--	54
271	401849 0801945	Mount Pleasant	Pritts, John R.	1978	U	S	317WSNGL	--	176
272	401926 0801911	Mount Pleasant	Antoazeski, Richard	1980	H	S	321SCKL	--	100
274	395824 0802520	East Finley	Studt, Richard A.	1976	H	V	317WSNG	--	52
276	401759 0801824	Mount Pleasant	Zimmerman, Alan	1966	H	H	321PBRG	--	200
277	401806 0801810	Mount Pleasant	Brown, Margret	1944	U	S	321PBRGU	--	125
278	400621 0801730	South Franklin	Beeghly, Blaine	--	U	S	317WBRGU	--	152
279	400619 0801730	South Franklin	Beeghly, Blaine	1976	P	S	321UNNN	--	285
280	400617 0801729	South Franklin	Beeghly, Blaine	1977	P	V	317WBRGU	--	125
281	400635 0801713	South Franklin	Beeghly, Blaine	1977	P	S	317WBRGU	--	250
282	400647 0801704	South Franklin	Beeghly, Blaine	1979	P	H	317WBRGU	--	310
283	400646 0801713	South Franklin	Beeghly, Blaine	--	P	H	317WSNGM	--	165
284	401257 0802009	Hopewell	Roup, Charles	1950	H	S	321UNNN	--	123
285	401314 0801955	Hopewell	Amos, James	1971	H	S	321UNNN	--	108
286	401315 0801957	Hopewell	Amos, James	1979	H	S	317WBRGL	--	95
287	401223 0802153	Hopewell	Bredniak, Robert	1979	H	S	321UNNN	--	140
288	401214 0802203	Hopewell	Bragor, Mary	1960	H	S	321PBRGU	--	65
289	401209 0802221	Hopewell	Hixenbaugh, Vaughn	--	H	V	321PBRGU	--	80
290	401208 0802224	Hopewell	Miller, John	1971	H	V	321PBRGU	--	85
291	401211 0802222	Hopewell	Rothwell, Charles	1974	H	T	321PBRGU	--	77
292	401238 0802116	Hopewell	Wilkenson, Jerry	1975	H	H	321PBRGU	--	90
294	401213 0802208	Hopewell	--	--	H	V	321PBRGU	--	100
295	401232 0802304	Hopewell	West, Ronald	1965	H	S	317WBRGL	--	100
297	400527 0800502	North Bethlehem	Clark, John	1962	H	H	317WSNGU	--	125

Appendix C.--Record of wells--Continued

Casing					Measured yield			Field water quality				
Depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	USGS well number
					--	--	--	09-12-83	480	--	22	
					--	--	--	09-12-85	--	7		
19	8	--	20.90	06-16-83	--	--	--	06-16-83	505	6.9	21	261
--	--	--	--	--	--	--	--	06-16-83	590	6.8	21.0	262
--	--	100	--	--	--	--	--	06-16-83	625	6.7	22.0	263
--	--	--	38.70	06-16-83	--	--	--	06-16-83	695	7.1	16.5	264
21	6	--	7.67	06-17-83	--	.08	4	06-17-83	830	7	14	265
					--	--	--	08-16-83	850	7.4		
--	--	--	20.70	06-16-83	--	--	--	06-17-83	287	6.5	15	266
--	--	--	19.10	06-17-83	--	--	--	06-17-83	1,750	6.2	13	267
--	--	--	--	--	10	--	--	--	--	--	--	268
--	--	--	11.70	06-17-83	--	--	--	06-17-83	805	7	19.5	269
					--	--	--	08-07-84	780	7.6	19	
					--	--	--	08-23-84	600	7.0	20	
					--	--	--	09-12-85	800	7.3	22	
--	--	--	36.90	06-27-83	--	--	--	--	--	--	--	270
24	6	--	42.50	06-20-83	--	3.3	9	08-18-83	520	6.8	12	271
--	--	--	46.70	06-20-83	--	--	--	06-20-83	590	7.3	16.5	272
					--	--	--	08-22-84	625	6.9	21	
					--	--	--	09-12-85	600	7.3	15.5	
16	8	--	16.60	10-03-79	10	--	--	--	--	--	--	274
--	--	--	--	--	1	--	--	07-12-83	860	7.1	19	276
24	5	--	86.30	07-13-83	--	.07	2	08-19-83	2,750	5.9	18.5	277
25	0	72/ 11	--	--	2	--	--	--	--	--	--	278
22	10	158/216/225/250	170.00	06-02-76	12	--	--	--	--	--	--	279
20	10	65	18.00	06-01-77	25	--	--	--	--	--	--	280
20	10	165/185	142.00	10-12-77	4	--	--	--	--	--	--	281
20	10	55/275	170.00	08-00-79	3	--	--	--	--	--	--	282
--	--	--	157.00	07-29-83	--	--	--	--	--	--	--	283
--	--	80	--	--	--	--	--	08-04-83	380	7.1	22.5	284
--	--	--	--	--	2	--	--	08-04-83	550	7.4	18.0	285
--	--	--	47.00	08-04-83	--	--	--	04-23-85	545	7.1	14.5	286
					--	--	--	09-26-85	540	7.2	17.0	
--	--	--	40.10	08-04-83	5	--	--	08-04-83	--	7.4	23	287
--	--	--	--	--	--	--	--	08-04-83	770	8.4	17.5	288
--	--	--	--	--	--	--	--	08-04-83	1,600	8.6	20.5	289
--	--	--	--	--	--	--	--	08-04-83	1,320	8.4	27	290
					--	--	--	09-02-83	1,380	8.6		
--	--	--	--	--	4	--	--	08-04-83	405	7.4	22.5	291
					--	--	--	09-02-83	410	7.8		
14	8	--	18.80	08-05-83	--	--	--	08-05-83	505	6.8	22.5	292
					--	--	--	08-23-84	565	7.2	21	
					--	--	--	10-26-84	55	7	18	
					--	--	--	04-23-85	580	7.1	14.5	
					--	--	--	09-26-85	560	7.3	16	
--	--	--	--	--	--	--	--	--	--	--	--	294
--	--	--	--	--	--	--	--	08-05-83	545	7.4	17.5	295
22	6	--	85.50	08-10-83	5	--	--	08-10-83	1,650	6.7	20	297
					--	--	--	09-07-83	1,850	7	15	

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-297										
298	400520	0800514	North Bethlehem	Sandrovich, Philomen A.	1944	H	S	317WSNGM	--	140
299	400526	0800456	North Bethlehem	Hohns, Joe	1959	H	H	317WSNGM	--	135
300	400526	0800455	Ellsworth	Martina, Charles	1951	H	H	317WSNGU	--	135
300	400526	0800455	Ellsworth	Martina, Charles	1951	H	H	317WSNGU	--	135
301	400604	0800652	North Bethlehem	Foertsch, Arthur	--	H	S	317WBRGL	--	120
302	400348	0800559	West Bethlehem	--	--	U	S	317WBRGM	--	55
303	400348	0800559	West Bethlehem	Barnhart, Ralph	1958	U	S	317WBRGM	--	64
304	400442	0800600	North Bethlehem	Barnhart, Ralph	--	--	T	317WBRGL	--	110
305	400448	0800403	North Bethlehem	Baker, Alvin	1923	H	S	317WSNG	--	65
306	400420	0800412	North Bethlehem	Kinder, Ernest	1978	H	H	317WSNGM	--	140
307	400404	0800547	North Bethlehem	Beck, Ronald	1977	H	S	317WBRGL	--	150
308	401158	0800120	Nottingham	Mingo Creek Park	1973	P	S	321RDSN	--	100
309	401157	0800116	Nottingham	Mingo Creek Park	1973	P	S	321PBRGL	SHLE	117
310	401203	0800110	Nottingham	Mingo Creek Park	1973	P	T	321PBRGR	SHLE	108
311	401205	0800111	Nottingham	Mingo Creek Park	--	U	S	321FSPT	--	25
312	401132	0800231	Nottingham	Mingo Creek Park	1973	P	V	321PBRGR	--	78
313	401133	0800222	Nottingham	Mingo Creek Park	1973	P	V	321RDSN	--	78
314	401133	0800232	Nottingham	Mingo Creek Park	1973	P	V	321PBRGR	--	78
315	401132	0800243	Nottingham	Mingo Creek Park	1973	P	V	321PBRGL	SHLE	78
316	401128	0800251	Nottingham	Mingo Creek Park	1973	P	V	321PBRGR	SHLE	78
320	400515	0800425	North Bethlehem	--	--	H	H	317GREN	--	127
321	400627	0801752	South Franklin	Maloy, Jason	--	H	T	317WSNGM	--	--
322	400627	0801752	South Franklin	Maloy, Jason	--	U	T	317WSNGM	--	127
324	402419	0802503	Hanover	U.S. Geological Survey	1984	U	W	321MRGN	SNDS	301
401	401457	0801910	Mount Pleasant	Clayton, Lee	1982	P	S	321PBRGU	--	180
402	401512	0801852	Mount Pleasant	Salvini, Ronald	1979	H	S	321UNNN	SDSL	90
403	401707	0801955	Mount Pleasant	Phillips, James	1976	H	S	317WBRGL	SHLE	165
404	401717	0801945	Mount Pleasant	Brezinski, Robert	1972	H	S	321PBRGU	--	60
405	401736	0801855	Mount Pleasant	Tustin, William	1973	H	S	321PBRG	LMSN	118
406	400508	0800420	North Bethlehem	Thomas, Robert W.	1943	H	S	317WSNGU	--	85
407	400506	0800426	North Bethlehem	Berdine, Harold	1917	--	S	317GREN	--	15
408	400503	0800428	North Bethlehem	Miller, Joe H.	1930	H	S	317GREN	--	21
409	400505	0800410	North Bethlehem	--	1973	H	S	317WSNGM	--	120
410	400453	0800401	North Bethlehem	McCracken, Donald	1970	H	H	317WSNGU	--	42

Appendix C.--Record of wells--Continued

Casing		Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield			Field water quality				USGS well number
Depth (feet)	Diameter (inches)				Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	
					--	--	--	11-23-84	1,700	6.7	22	
					--	--	--	04-24-85	1,550	6.8	21	
					--	--	--	09-27-85	1,760	6.8		
--	--	--	--	--	4	--	--	08-05-83	1,100	7.0	23.5	298
--	--	--	--	--	--	--	--	08-05-83	1,370	6.8	20	299
--	--	--	--	--	--	--	--	08-05-83	1,550	6.9	17.5	300
--	--	--	--	--	--	--	--	09-07-83	1,550	7.2		300
--	--	--	--	--	--	--	--	08-05-83	610	7.3	20	301
					--	--	--	09-07-83	640	7.3	18	
--	--	--	28.40	08-05-83	--	--	--	--	--	--	--	302
16	8	--	28.40	08-05-83	--	.93	2	08-17-83	425	6.7	12	303
--	--	--	--	--	--	--	--	08-05-83	880	8.1	22.5	304
					--	--	--	09-07-83	900	8.4	15	
--	--	--	--	--	--	--	--	08-10-83	640	6.9	23.5	305
--	--	100	--	--	--	--	--	08-10-83	690	7.2	14	306
--	--	140	--	--	3	--	--	--	--	--	--	307
21	6	29	--	--	2	--	--	08-17-83	520	7.5	13	308
26	6	18	--	--	1	--	--	--	--	--	--	309
23	6	38	--	--	1	--	--	--	--	--	--	310
--	--	--	11.70	08-17-83	--	--	--	08-17-83	770	7	13.5	311
25	6	18	53.20	08-17-83	1	--	--	--	--	--	--	312
25	6	--	--	--	1	--	--	08-17-83	745	7.3	14	313
21	6	--	--	--	<1	--	--	08-17-83	675	7.4	13.5	314
26	6	17	--	--	<1	--	--	--	--	--	--	315
25	6	17	--	--	--	--	--	--	--	--	--	316
--	--	--	--	--	--	--	--	09-07-83	680	7.4	21	320
--	--	--	78.50	05-03-84	--	--	--	--	--	--	--	321
--	--	--	20.80	05-01-84	--	.03	3	09-05-84	690	7.3	12	322
350	2	130/240	30.30	11-27-84	--	--	--	08-29-85	1,500	7.4	12.5	324
170	8	--	70.90	06-08-83	--	--	--	--	--	--	--	401
26	8	40	--	--	--	1.7	75	06-08-83	645	7.2	14.5	402
24	8	35	89.50	06-15-83	--	.00	<1	06-15-83	875	7.2	26.0	403
					--	--	--	08-07-84	840	7.6	21	
					--	--	--	04-23-85	860	7.2	23	
					--	--	--	09-11-85	860	6.9	24	
21	8	--	12.50	06-08-83	--	--	--	06-08-83	365	6.0	13.0	404
22	8	42/ 92	--	--	10	--	--	06-08-83	425	6.7	22.5	405
--	--	--	--	--	--	--	--	06-09-83	800	7.2	21.0	406
--	--	--	6.70	06-09-83	--	--	--	06-09-83	460	6.4	15.0	407
					--	--	--	04-30-85	365	6.9	28.5	
14	48	--	15.80	06-09-83	--	--	--	06-09-83	860	6.8	16.5	408
					--	--	--	08-31-84	875	7.1	14	
					--	--	--	11-21-84	850	6.7	11.5	
					--	--	--	04-24-85	810	7	13.5	
					--	--	--	09-27-85	825	7.3	18.5	
--	--	--	--	--	2	--	--	09-07-83	1,100	7.1	19.5	409
--	--	--	29.30	06-09-83	--	--	--	06-09-83	350	5.8	16.0	410
					--	--	--	04-24-85	470	6.3	15	
					--	--	--	09-27-85	378	6.3	20.5	

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-411	400455	0800402	North Bethlehem	McCracken, Donald	--	U	H	317WSNGU	--	65
412	400405	0800511	North Bethlehem	Golick, Ralph J.	1982	H	S	317WBRGU	--	150
413	401759	0801620	Mount Pleasant	Hursh, Paul	1980	H	S	321PBRG	--	250
413	401759	0801620	Mount Pleasant	Hursh, Paul	1980	H	S	321PBRG	--	250
414	401758	0801610	Mount Pleasant	Houze, John	1980	H	S	321PBRGU	SHLE	150
416	401809	0801807	Mount Pleasant	Nagy, Alex	1977	H	S	321PBRGU	--	100
417	401811	0801805	Mount Pleasant	Corwin, Chester W.	1979	H	S	321PBRGU	--	100
418	401900	0801955	Mount Pleasant	Willkens, Dave	1981	--	S	317WBRGU	SHLE	130
419	401924	0801958	Mount Pleasant	Schwab, Nada	1975	H	H	317WSNGL	--	105
420	401926	0802001	Mount Pleasant	Brothers, Jim	1976	H	S	317WSNGL	--	125
421	401819	0801851	Mount Pleasant	Phillips, Jeanne	1981	H	W	321PBRGU	--	35
422	401802	0801840	Mount Pleasant	Dagnana, Ralph	1960	H	S	321UNNN	--	80
423	401801	0801843	Mount Pleasant	Sarchet, Dennis	1977	H	S	321PBRGU	LMSN	110
424	402053	0801659	Mount Pleasant	Toth, Casper	1967	H	S	321UNNN	LMSN	187
426	401742	0801912	Mount Pleasant	Crowley, Robert	1963	H	H	321UNNN	--	96
427	401732	0801907	Mount Pleasant	Paluso, Betty	1974	H	H	321PBRG	--	200
429	401734	0801906	Mount Pleasant	Lofsterd, Clarence	1978	H	H	321PBRGU	--	160
430	401733	0801908	Mount Pleasant	Smiley, Ray	1978	H	H	321PBRGU	--	150
433	401654	0801944	Mount Pleasant	Godwin, George	1971	H	H	317WBRGL	--	120
434	401646	0801938	Mount Pleasant	Godwin, George	1969	H	W	321UNNN	--	100
435	401738	0801908	Mount Pleasant	Donati, John	1973	H	H	321PBRGU	--	120
436	401740	0801911	Mount Pleasant	Covalesky, Jean	1964	H	H	321PBRG	--	125
437	401738	0801910	Mount Pleasant	Diaz, Milton	1971	H	H	321PBRGU	--	180
438	401756	0801838	Mount Pleasant	--	--	H	S	321PBRG	--	153
440	401803	0801834	Mount Pleasant	Hickory Grade School	1946	I	S	321PBRGU	--	122
442	401758	0801844	Mount Pleasant	Watson, John	1977	H	S	321UNNN	--	125
443	401757	0801843	Mount Pleasant	Keegan, William	--	H	S	321UNNN	--	85
444	401800	0801843	Mount Pleasant	Weber, Robert	1965	H	S	321UNNN	--	80
445	401759	0801842	Mount Pleasant	Dagnana, Julia	1953	H	S	321UNNN	--	60
446	401757	0801834	Mount Pleasant	Goughnour, Robert	1981	H	H	317WBRGL	--	40
447	401833	0801709	Mount Pleasant	Cowden, James C.	1951	H	S	317WBRGL	--	60
448	401832	0801716	Mount Pleasant	Kelley, Walter	1981	H	S	317WBRGL	--	--

Appendix C.--Record of wells--Continued

Casing					Measured yield			Field water quality				
Depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	USGS well number
--	--	--	--	--	--	--	--	--	--	--	--	411
--	--	--	90.10	06-09-83	--	--	--	06-09-83	425	6.9	20.5	412
					--	--	--	08-31-84	545	7.2	16.5	
					--	--	--	11-21-84	540	6.7	12.5	
--	--	--	40.80	06-01-83	--	--	--	06-10-83	458	7.3	18.0	413
					--	--	--	08-22-84	480	7.7	25	
					--	--	--	04-23-85	500	7.9	26	
--	--	--	40.80	06-01-83	--	--	--	09-11-85	380	7.4	24	413
26	6	70	56.90	06-10-83	<1	--	--	06-10-83	800	7.0	20.0	414
--	--	--	48.80	06-10-83	--	--	--	06-10-83	730	6.6	19.5	416
--	--	--	--	--	--	--	--	06-10-83	560	6.5	23.0	417
29	8	62/ 89	34.10	06-10-83	50	--	--	06-10-83	780	6.4	16.0	418
--	--	--	15.00	01-01-75	15	--	--	06-10-83	--	6.3	19.0	419
--	--	--	--	--	5	--	--	06-10-83	800	6.5	16.0	420
--	--	--	--	--	20	--	--	06-10-83	550	7.4	15	421
					--	--	--	08-11-83	525	7.6	12	
--	--	--	--	--	--	--	--	06-10-83	495	6.4	22.0	422
22	8	64	47.40	06-10-83	--	.02	1	06-10-83	535	6.8	17.0	423
					1	--	--	--	--	--		
29	6	49	44.30	06-13-83	--	.01	2	06-13-83	480	7.2	22.0	424
20	6	--	--	--	--	--	--	06-13-83	630	7.1	25.0	426
--	--	--	--	--	--	--	--	06-13-83	590	7.4	23.0	427
--	--	--	92.60	06-13-83	8	--	--	06-13-83	695	7.6	23.0	429
					--	--	--	08-07-84	695	7.6	23	
					--	--	--	04-17-85	710	7.5	14.5	
					--	--	--	09-11-85	675	7.2	23	
--	--	--	98.10	06-12-83	--	--	--	06-13-83	615	7.5	32.0	430
					--	--	--	08-06-84	610	7.6	16.5	
					--	--	--	04-16-85	635	7.3	13	430
					--	--	--	09-11-85	650	7.3	18	
--	--	--	52.50	06-12-83	2	--	--	06-13-83	480	7.0	28.5	433
--	--	--	--	--	35	--	--	06-13-83	545	7.0	25.0	434
--	--	90/105	--	--	30	--	--	06-13-83	725	6.9	24.0	435
--	--	--	--	--	--	--	--	06-13-83	640	7.1	24.0	436
--	--	75	--	--	20	--	--	--	--	--	--	437
--	--	--	--	--	--	--	--	06-13-83	875	7.6	25	438
					--	--	--	08-11-83	450	7.1	18	
--	--	--	117.00	04-19-53	--	--	--	06-14-83	875	6.8	29.0	440
					--	--	--	08-21-84	930	7.2	19.5	
--	--	--	34.40	06-15-83	--	--	--	06-15-83	690	7.1	18.5	442
					--	--	--	08-22-84	660	7.2	23	
					--	--	--	04-16-85	660	6.9	23	
					--	--	--	09-11-85	675	6.8	19	
--	--	--	--	--	--	--	--	06-15-83	780	7.1	19.0	443
--	--	--	--	--	--	--	--	06-15-83	470	7.0	20.0	444
--	--	--	--	--	--	--	--	06-15-83	615	7.2	25.0	445
--	--	--	--	--	--	--	--	06-15-83	1,120	6.7	25	446
--	--	19	20.00	01-01-51	--	--	--	06-15-83	575	6.8	23.0	447
--	--	--	30.70	06-15-83	--	--	--	06-15-83	600	7.3	22	448

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-449	401711	0801956	Mount Pleasant	Phillips, Robert R.	--	H	S	317WBRGL	--	36
450	401745	0801924	Mount Pleasant	Corwin, Juniata	1923	H	S	321PBRG	--	130
452	401820	0801740	Mount Pleasant	Regine, Dr.	1975	H	S	321UNNN	--	100
453	401818	0801744	Mount Pleasant	Dinsmore, J.C.	1982	H	S	321UNNN	--	100
454	401816	0801804	Mount Pleasant	Ware, Lester	1958	H	S	321UNNN	--	90
455	401813	0801808	Mount Pleasant	Pollinger, Henry	1944	H	H	321UNNN	--	95
456	401812	0801809	Mount Pleasant	Bedilion, Eva	1945	H	H	317WBRGL	--	80
457	401811	0801809	Mount Pleasant	Williams, Roy C.	1990	H	H	317WBRGL	--	20
458	401808	0801813	Mount Pleasant	McCalmont, Don	1969	H	S	321UNNN	--	108
459	401809	0801812	Mount Pleasant	Athey, James B.	1966	H	S	321PBRGU	--	126
460	401809	0801812	Mount Pleasant	Athey, James B.	--	U	S	321UNNN	--	45
461	401815	0801802	Mount Pleasant	Sweetie, Jay	--	H	H	321PBRG	--	200
462	401814	0801801	Mount Pleasant	Ward, Martin	1965	H	H	321UNNN	--	110
465	401948	0801741	Mount Pleasant	Bershok, Russel	1976	H	H	317WBRGU	--	170
466	401714	0801932	Mount Pleasant	Narigon, Cora	1983	H	V	321PBRGU	--	100
467	401711	0801935	Mount Pleasant	Shaw, David	1977	H	S	321UNNN	--	155
468	401729	0801959	Mount Pleasant	Kraeer, Thomas O.	1965	H	S	321PBRGU	--	60
469	401730	0801858	Mount Pleasant	Kraeer, Thomas O.	1955	H	S	321PBRG	--	60
470	401720	0801900	Mount Pleasant	Kraeer, Thomas O.	1972	S	V	321PBRG	--	140
471	401731	0801827	Mount Pleasant	Sparks, James	1979	H	H	321PBRG	--	160
472	401733	0801826	Mount Pleasant	Shumaker, Wilbur E.	--	H	H	321PBRGU	--	--
473	401858	0801847	Mount Pleasant	Carter, Denny	1980	H	S	321PBRGU	LMSN	120
474	401800	0801612	Mount Pleasant	Engel, Kenny	1981	H	S	321PBRGU	--	220
475	401759	0801835	Mount Pleasant	Kumer, John	1967	H	S	317WBRGL	CLSD	185
476	401800	0801833	Mount Pleasant	Cowden, Joe A.	--	H	S	321UNNN	--	30
477	401807	0801844	Mount Pleasant	Mason, Ralph	--	H	S	321UNNN	--	92
478	401808	0803042	Mount Pleasant	Krysmalski, Charles	1960	H	S	321PBRG	--	127
479	401806	0803043	Mount Pleasant	Phillips, R.J.	1960	H	S	321PBRGU	--	100
480	401805	0801842	Mount Pleasant	Haught, John	--	H	S	321PBRG	--	140
481	401802	0801708	Mount Pleasant	Cowden, J.C.	--	U	S	321UNNN	--	35
482	401757	0801834	Mount Pleasant	Googhenour, Burl	1988	H	S	317WBRGL	--	22
483	401800	0801836	Mount Pleasant	Reed, Donald	--	H	S	321UNNN	--	112
484	401802	0801837	Mount Pleasant	Jefferys, Janette	1970	H	S	321UNNN	--	100
485	401802	0801837	Mount Pleasant	Marquis, Raymond	--	H	S	321UNNN	--	90
486	401813	0801758	Mount Pleasant	Dallapiazza, Ken	1980	H	H	321UNNN	--	140

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Temperature (deg C)	USGS well number
--	--	--	12.50	06-15-83	--	--	--	06-15-83	1,400	6.9	25.0	449
--	--	--	--	--	--	--	--	06-15-83	630	7.0	22.0	450
--	--	--	33.00	06-16-83	40	--	--	06-15-83	--	7.0	21.0	452
--	--	--	11.00	06-16-83	--	--	--	06-16-83	740	6.9	22.0	453
--	--	--	--	--	--	--	--	06-16-83	805	7.1	17.0	454
--	--	--	--	--	--	--	--	06-16-83	800	7.0	17.0	455
--	--	--	--	--	--	--	--	06-16-83	800	7.0	26.0	456
--	--	--	--	--	--	--	--	06-16-83	605	6.1	18.0	457
--	--	--	--	--	--	--	--	06-16-83	700	6.6	27.0	458
--	--	120	77.40	06-20-83	--	--	--	06-16-83	760	6.7	24.5	459
--	--	--	27.10	06-16-83	--	--	--	--	--	--	--	460
--	--	--	--	--	--	--	--	06-16-83	640	6.6	23.5	461
--	--	--	--	--	--	--	--	06-16-83	810	6.9	22.0	462
20	8	--	62.90	06-16-83	3	--	--	06-16-83	795	6.8	27.0	465
22	8	17/ 35	17.40	06-17-83	25	--	--	06-17-83	690	--	24.0	466
--	--	50	--	--	3	--	--	06-17-83	790	7.7	20.5	467
--	--	16	--	--	--	--	--	06-17-83	550	7.3	24.5	468
--	--	--	--	--	--	--	--	--	--	--	--	469
--	--	--	22.50	06-17-83	--	--	--	06-17-83	690	7.3	18.5	470
					--	--	--	08-21-84	710	7.5	22	470
					--	--	--	04-17-85	700	7.5	14.5	
					--	--	--	09-12-85	590	7.2	21	
17	8	--	97.40	06-17-83	5	--	--	06-17-83	560	7.3		
					--	--	--	08-22-84	540	7.9	25.0	471
					--	--	--	04-17-85	570	7.3	19	
					--	--	--	09-11-85	520	7.1	14	
--	--	--	74.40	06-17-83	--	--	--	06-17-83	535	7.4	24.5	
--	--	60	87.80	06-20-83	2	--	--	--	--	--	23.0	472
--	--	70	38.80	06-22-83	2	--	--	06-22-83	620	7.5	--	473
					--	--	--	08-22-84	630	7.6	18.5	474
					--	--	--	04-23-85	610	7.7	24	
					--	--	--	09-11-85	620	7.5	28	
--	--	31/ 75	--	--	6	--	--	06-24-83	--	7.1	19	
--	--	--	--	--	--	--	--	06-24-83	795	7.1	20.0	475
--	--	--	--	--	--	--	--	06-24-83	575	6.8	19.0	476
--	--	--	--	--	--	--	--	06-24-83	700	7.2	21.0	477
--	--	--	--	--	--	--	--	06-24-83	880	6.9	20.5	478
--	--	--	--	--	--	--	--	06-24-83	860	7.2	25.5	479
--	--	--	7.28	06-24-83	--	--	--	--	--	--	24.0	480
--	--	--	12.30	06-24-83	--	--	--	06-24-83	660	6.7	--	481
--	--	--	58.30	06-24-83	--	--	--	06-24-83	875	7.0	31.0	482
					--	--	--	08-21-84	890	7.3	32.0	483
					--	--	--	04-16-85	835	7	19	
					--	--	--	09-12-85	600	7.3	21	
--	--	--	--	--	--	--	--	06-24-83	--	7.3	17	
--	--	--	--	--	--	--	--	06-24-83	845	7.1	31.0	484
--	--	--	68.80	06-27-83	--	--	--	06-27-83	625	7.2	24.5	485
					--	--	--	08-07-84	590	--	23.0	486
					--	--	--	04-17-85	620	7.6	18	

USGS well number	Location Latitude Longitude (degrees)		Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-486										
487	401739	0801831	Mount Pleasant	Lauderbach, Don	1955	H	H	321PBRG	--	166
488	401737	0801830	Mount Pleasant	Pirih, Mary	1928	H	H	321UNNN	--	100
489	401740	0801828	Mount Pleasant	Ahrns, W.C.	1979	H	H	321PBRGU	--	140
490	401742	0801836	Mount Pleasant	Porter, William	1975	H	H	321UNNN	--	160
490	401742	0801836	Mount Pleasant	Porter, William	1975	H	H	321UNNN	--	160
491	401741	0801836	Mount Pleasant	Porter, William	1977	H	S	321UNNN	--	125
492	401743	0801842	Mount Pleasant	Zimmerman, Donna	1976	H	S	321UNNN	--	85
493	401751	0801841	Mount Pleasant	Ringer, Jim	--	H	S	321PBRGU	--	140
494	401719	0801841	Mount Pleasant	Pirih, Henry	1957	H	S	321UNNN	--	81
495	401747	0801842	Mount Pleasant	Spada, Tony	1952	H	S	321UNNN	--	74
496	401745	0801848	Mount Pleasant	Bernard, John	1963	H	S	321PBRGU	--	110
497	401748	0801803	Mount Pleasant	Cole, Henry	1923	H	H	321UNNN	--	90
498	401746	0801811	Mount Pleasant	Brezinski, Mark	1977	H	W	321UNNN	--	148
499	401748	0801811	Mount Pleasant	Templeton, Lou	1976	H	S	321UNNN	SHLE	150
500	401750	0801807	Mount Pleasant	Palas, Mike	1978	H	S	321UNNN	--	150
501	401751	0801808	Mount Pleasant	Fela, Ronald	1976	H	H	321UNNN	SNDS	115
503	401920	0802022	Mount Pleasant	Kaste, William F.	1977	H	H	317WSNGL	--	165
504	401755	0801845	Mount Pleasant	Faczolari, Donald K.	1949	H	H	321UNNN	--	180
505	401754	0801813	Mount Pleasant	Robison, Larry	1954	H	H	321UNNN	--	75
506	401754	0801812	Mount Pleasant	Cook, Minnie	1956	H	H	321UNNN	--	140
507	401752	0801810	Mount Pleasant	Caldwell, John T.	1952	H	S	317WBRGL	--	90
508	401751	0801808	Mount Pleasant	Defibrugh, Donald	1950	H	H	321UNNN	--	87
509	401751	0801806	Mount Pleasant	Bedillion, John	1952	H	H	317WBRGL	--	60
510	401749	0801806	Mount Pleasant	Brown, Robert	1976	H	H	317WBRGL	--	123
511	401805	0801835	Mount Pleasant	Hickory Up Ch	--	P	S	321UNNN	--	140
512	401740	0801958	Mount Pleasant	Hickory Up Ch	1975	P	H	317WBRGL	--	--
513	401739	0801904	Mount Pleasant	McCracken, Clair	1965	H	H	321PBRGU	--	130
514	401739	0801905	Mount Pleasant	McCracken, Clair	1980	H	S	321PBRG	--	200

Appendix C.--Record of wells--Continued

Casing: Depth (feet)	Casing: Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Temperature (deg C)	USGS well number
					--	--	--	08-07-85	--	7.6	15	
					--	--	--	09-13-85	600	7.2	15	
--	--	--	--	--	--	--	--	06-27-83	620	7.0	26.0	487
--	--	--	--	--	--	--	--	06-27-83	570	7.2	26.0	488
18	8	--	97.00	06-27-83	--	--	--	06-27-83	690	7.5	29.5	489
					--	--	--	08-21-84	700	7.9	22.0	
					--	--	--	04-17-85	690	7.3	14.5	
					--	--	--	09-12-85	710	7.6	17.0	
25	8	--	43.70	06-27-83	3	--	--	07-08-84	690	6.7	20	490
25	8	--	43.70	06-27-83	--	--	--	04-17-85	720	7.2	15	490
					--	--	--	09-12-85	1,220	7.1	18.5	
--	--	80	--	--	--	--	--	06-27-83	690	6.7	25.5	491
--	--	--	--	--	--	--	--	06-27-83	875	7.0	21.5	492
--	--	--	--	--	--	--	--	06-27-83	710	6.6	29	493
					--	--	--	08-16-83	670	7.2	19.5	
--	--	--	39.00	10-30-65	--	--	--	06-27-83	950	6.7	18.5	494
--	--	--	--	--	--	--	--	06-27-83	630	6.8	20.5	495
--	--	--	61.80	06-27-83	--	--	--	06-27-83	745	7.3	23.0	496
--	--	--	--	--	--	--	--	06-27-83	--	7.3	33.5	497
--	--	--	27.90	06-27-83	3	--	--	06-27-83	600	7	30.5	498
					--	--	--	08-11-83	600	7.1	20	
					--	--	--	08-22-84	680	7	20	
					--	--	--	04-17-85	535	7.3	15	
--	--	50	124.00	06-28-83	1	--	--	06-28-83	570	7.4	21.0	499
--	--	--	31.60	06-28-83	5	--	--	06-28-83	690	6.6	17.0	500
					--	--	--	08-22-84	670	7.2	20	
					--	--	--	04-17-85	650	7.4	13.5	
					--	--	--	09-11-85	690	6.9	16	
--	--	50	--	--	7	--	--	06-28-83	900	6.9	18.0	501
--	--	--	133.00	06-28-83	--	--	--	06-28-83	800	6.5	24.0	503
					--	--	--	08-06-84	780	7.2	14	
6	10	--	63.80	06-30-83	--	--	--	06-30-83	900	7.0	22.0	504
					--	--	--	08-22-84	920	7.1	17	
					--	--	--	04-17-85	880	7.1	13	
					--	--	--	09-11-85	910	7.0	17.5	
--	--	--	--	--	--	--	--	06-30-83	--	7.0	24.5	505
--	--	--	--	--	--	--	--	06-30-83	1,050	7.0	25.0	506
--	--	--	--	--	--	--	--	06-30-83	--	7.4	23.5	507
--	--	--	--	--	--	--	--	06-30-83	860	7.0	23.0	508
--	--	--	--	--	--	--	--	06-30-83	590	6.9	25.0	509
--	--	30/ 90	--	--	10	--	--	06-30-83	--	6.9	21.5	510
--	--	--	58.50	06-30-83	3	--	--	06-30-83	590	6.4	22.5	511
					--	--	--	08-21-84	570	6.7	14	
					--	--	--	04-16-85	535	7.0	16	
--	--	--	55.70	06-30-83	--	--	--	06-30-83	1,200	7.0	23.5	512
--	--	--	--	--	--	--	--	--	--	--	--	513
--	--	--	147.00	06-30-83	--	--	--	06-30-83	600	7.1	26.5	514
					--	--	--	08-07-84	570	7.6	19	
					--	--	--	04-17-85	610	7.7	17	

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-515	401748	0801906	Mount Pleasant	Barr, John	1960	H	S	317WBRGL	--	25
517	401748	0801904	Mount Pleasant	Krenn, Josephine	--	H	S	321PBRG	--	150
518	401747	0801903	Mount Pleasant	Bezusko, Charles	1957	H	S	321UNNN	--	65
519	401750	0801909	Mount Pleasant	Wagner, Harry	1910	H	S	317WBRGL	--	60
521	401748	0801900	Mount Pleasant	Richards, Edward	1900	H	S	321PBRG	--	210
522	401748	0801853	Mount Pleasant	Baroni, John	1940	H	H	321PBRG	--	120
523	401751	0801852	Mount Pleasant	Martorana, Frank	1958	H	S	321UNNN	--	100
524	401856	0801801	Mount Pleasant	Dallmeyer, Mildred	1949	H	S	317WBRGL	--	67
525	401834	0801800	Mount Pleasant	Miller, James	1947	H	S	317WBRGL	--	49
526	402011	0801716	Mount Pleasant	Hess, George	1978	H	S	321UNNN	--	120
527	402016	0801720	Mount Pleasant	Herbst, Tom	1976	--	S	321UNNN	--	91
528	402013	0801730	Mount Pleasant	Herbst, Mary	1977	H	S	321UNNN	--	110
529	402005	0801749	Mount Pleasant	Steiminger, Tom	1979	H	S	317WBRGU	--	125
530	401816	0801805	Mount Pleasant	Acheson, Lois	1913	H	S	321UNNN	--	65
533	401859	0801826	Mount Pleasant	Cohenour, Grandville	--	H	H	321UNNN	--	125
534	401749	0801857	Mount Pleasant	Miller, Donald	1940	H	S	321UNNN	--	180
535	401745	0801851	Mount Pleasant	Lugaila, John	1973	H	S	321PBRG	--	142
537	401751	0801846	Mount Pleasant	Allison, Jay	--	H	H	321UNNN	--	105
538	401754	0801838	Mount Pleasant	Cox, Ronald	--	H	S	321PBRG	--	160
540	401756	0801835	Mount Pleasant	White, Robert	1969	H	H	321PBRG	--	158
541	401756	0801833	Mount Pleasant	Wilson, Louise B.	1965	H	H	321PBRG	--	180
542	401758	0801831	Mount Pleasant	Walters, Paul	--	H	S	317WBRGL	--	75
543	401758	0801830	Mount Pleasant	Hickory, P.O.	1976	C	H	321PBRG	--	200
544	401757	0801828	Mount Pleasant	Bell, Martha	1978	H	H	317WBRGL	LMSN	75
545	401757	0801828	Mount Pleasant	Bell, Donald	--	U	S	317WBRGL	--	30
546	401928	0801829	Mount Pleasant	Menzies, Thomas	1977	H	S	321UNNN	--	100
547	401927	0802033	Mount Pleasant	Robinson, Lee	1966	H	H	317WSNGL	--	140
549	401934	0801827	Mount Pleasant	Weagly, Willis	1973	H	S	321UNNN	--	75
550	401758	0801827	Mount Pleasant	Nunn, James	1954	H	S	321UNNN	--	67
551	401756	0801830	Mount Pleasant	Butler, John	--	H	S	321UNNN	--	110
552	401759	0801818	Mount Pleasant	Schilinski, Tom	--	H	H	317WBRGL	--	150
553	401803	0801817	Mount Pleasant	Wallace, Richard	--	H	S	321PBRGU	--	70
554	401801	0801821	Mount Pleasant	Shurr, Marie	--	H	S	317WBRGL	--	30
555	401826	0801718	Mount Pleasant	Crowley, Reggie	1983	H	S	321UNNN	--	76
556	401739	0801908	Mount Pleasant	Briggs, Kay	1970	H	S	321PBRG	--	120
557	401759	0801822	Mount Pleasant	Scott, Dwayne	--	H	H	317WBRGL	--	83
558	401800	0801824	Mount Pleasant	Carpenter, Harry	1930	H	H	317WBRGL	--	95

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
--	--	--	--	--	--	--	--	06-30-83	1,250	6.9	23.0	515
--	--	--	--	--	--	--	--	06-30-83	1,060	6.6	27.5	517
--	--	--	--	--	--	--	--	06-30-83	1,400	6.8	20.0	518
--	--	--	--	--	--	--	--	07-01-83	860	7.0	23.0	519
--	--	--	--	--	--	--	--	07-01-83	960	7.1	23.5	521
--	--	--	--	--	--	--	--	07-01-83	--	7.4	31.0	522
--	--	--	--	--	--	--	--	07-01-83	--	7.2	22.5	523
--	--	--	--	--	--	--	--	07-01-83	710	7.1	23.0	524
--	--	--	23.90	07-01-83	--	--	--	07-01-83	645	7.0	22.0	525
--	--	--	14.40	07-01-83	--	--	--	07-01-83	490	6.8	26.5	526
--	--	--	21.20	07-01-83	75	--	--	07-01-83	710	7.3	22.5	527
--	--	--	28.20	07-01-83	--	--	--	07-01-83	660	6.8	22.5	528
--	--	--	28.30	07-01-83	7	--	--	07-01-83	800	6.5	19.5	529
--	--	--	--	--	--	--	--	07-01-83	1,200	6.6	25.0	530
--	--	--	--	--	--	--	--	07-01-83	--	6.8	23.0	533
					--	--	--	07-05-83	710	--		
--	--	--	--	--	--	--	--	07-05-83	1,010	7.2	22.0	534
--	--	--	--	--	--	--	--	07-05-83	--	6.8	25.0	535
--	--	--	65.00	01-01-77	2	--	--	07-05-83	1,410	6.6	23.5	537
--	--	--	--	--	--	--	--	07-05-83	800	7.0	27.0	538
--	--	--	--	--	--	--	--	07-05-83	810	7.1	24.0	540
--	--	--	--	--	--	--	--	07-05-83	1,000	6.6	28.0	541
--	--	--	--	--	--	--	--	07-05-83	875	6.5	28.5	542
--	--	--	152.00	07-05-83	--	--	--	07-05-83	755	6.7	27.0	543
					--	--	--	08-21-84	770	6.8	23.0	
					--	--	--	09-11-85	610	6.8	21.0	
--	--	40	38.10	07-06-83	6	--	--	07-06-83	740	7.0	18.5	544
					--	--	--	08-08-84	810	7.4	18.5	
					--	--	--	04-16-85	850	7.4	15	
--	--	--	22.30	07-06-83	--	--	--	07-06-83	540	6.5	16.0	545
--	--	30	18.30	07-06-83	5	--	--	07-06-83	740	7.3	22.0	546
--	--	7/ 14/ 90	76.00	07-14-83	40	--	--	07-14-83	--	6.5	18.0	547
--	--	--	56.40	07-06-83	--	--	--	07-06-83	595	7.2	23.0	549
--	--	--	--	--	--	--	--	07-06-83	745	6.8	21.0	550
--	--	--	--	--	--	--	--	07-06-83	910	6.6	22.0	551
--	--	--	68.50	07-06-83	--	--	--	07-06-83	1,120	6.7	19.5	552
--	--	--	--	--	--	--	--	07-06-83	910	7.0	24.0	553
--	--	--	--	--	--	--	--	07-06-83	1,080	6.9	21.0	554
--	--	--	17.90	07-06-83	9	--	--	07-07-83	790	7.6	29.5	555
					--	--	--	08-11-83	640	7.3	15.5	
					--	--	--	09-11-83	750	7.5	16	
					--	--	--	08-07-84	615	--	18	
					--	--	--	04-16-85	670	7.3	13.5	
--	--	--	--	--	2	--	--	07-07-83	680	7.0	15.5	556
--	--	--	--	--	--	--	--	--	--	--	--	557
--	--	--	42.40	07-07-83	--	--	--	07-07-83	1,100	7.0	20.0	558
					--	--	--	08-21-84	980	7.6	19	
					--	--	--	04-16-85	1,230	7.2	18	
					--	--	--	09-13-85	850	7	22.5	

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude	Location Longitude	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-559	401801	0801815	Mount Pleasant	Ivory, Jane	1961	H	S	321UNNN	--	130
560	401802	0801814	Mount Pleasant	Loughry, Robert	1940	H	H	321PBRG	--	220
561	401806	0801810	Mount Pleasant	Brown, Margaret	1973	H	S	321PBRGU	--	--
562	401810	0801808	Mount Pleasant	Kehn, Joe B.	1973	H	S	321PBRG	--	125
563	401807	0801810	Mount Pleasant	Gross, Fred	1989	H	S	317WBRGL	--	15
564	401758	0801817	Mount Pleasant	Donati, William	--	H	H	321UNNN	--	160
565	401751	0801849	Mount Pleasant	Dire, Louis	1970	H	S	321UNNN	--	160
567	401749	0801849	Mount Pleasant	Grimm, Doris	1951	H	H	321PBRG	--	150
568	401740	0801844	Mount Pleasant	Caldwell, James	1950	H	S	317WBRGL	--	60
569	401706	0802010	Mount Pleasant	Caldwell, Doug	1977	H	H	321UNNN	--	130
570	401759	0801822	Mount Pleasant	Young, James D.	--	H	H	317WBRGL	--	75
571	401711	0801953	Mount Pleasant	Kraeer, Tom	1901	H	S	321PBRG	--	156
573	401756	0801816	Mount Pleasant	Donati, John A.	--	H	H	317WBRGL	--	080
575	400723	0801737	South Franklin	Marth	--	H	S	321UNNN	--	160
576	400719	0801738	South Franklin	Mounts, Elma	--	H	S	317WSNGL	--	90
577	400720	0801739	South Franklin	Mounts, Mary C.	1979	H	S	317WBRGU	SHLE	125
578	400730	0801751	South Franklin	Hupp, Leroy	1959	H	V	317WBRGU	--	66
579	400732	0801756	South Franklin	Hart, Tom	1973	H	V	317WSNGL	SNDS	185
580	400732	0801756	South Franklin	Hart, Tom	--	H	V	317WSNGL	--	45
581	400718	0801744	South Franklin	Houston, Richard	1970	H	S	317WSNGM	LMSN	85
582	400715	0801654	South Franklin	Coffield, John R.	1960	H	V	317WBRGU	--	90
583	400717	0801657	South Franklin	Pryor, Duane	1957	H	S	317WBRGU	--	080
584	400715	0801658	South Franklin	Cole, Jack	1970	H	V	317WBRGU	--	90
585	400718	0801706	South Franklin	Houston, Ray	1953	H	S	317WBRGU	--	65
586	400715	0801702	South Franklin	Verner, Jesse J.	1953	H	V	317WBRGU	--	54
587	400716	0801702	South Franklin	Verner, Jesse J.	--	U	V	112ALVM	--	7
588	400717	0801701	South Franklin	Balaban, Tom	1963	H	S	317WBRGU	--	121
589	400722	0801809	South Franklin	Cumer, John	--	U	H	317WSNGM	--	150
590	400718	0801703	South Franklin	Burns, Mike	1980	H	S	317WBRGU	--	--
591	400244	0801726	Morris	Phillips, Clarence	1968	H	S	317WSNGM	SHLE	225
592	400245	0801745	Morris	Dittman, Tom	1973	H	S	317WSNGM	LMSN	175

Appendix C.--Record of wells--Continued

Casing: Depth (feet)	Casing: Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Temperature (deg C)	USGS well number
--	--	--	--	--	--	--	--	07-07-83	1,130	7.3	19.0	559
--	--	--	--	--	--	--	--	07-07-83	1,000	6.8	22.0	560
--	--	--	--	07-07-83	--	--	--	07-07-83	1,250	6.5	19	561
					--	--	--	08-19-83	950	6.9		
--	--	--	--	--	--	--	--	07-07-83	840	7.2	28.0	562
--	--	--	7.46	07-07-83	--	--	--	07-07-83	890	6.9	23.0	563
--	--	--	--	--	--	--	--	07-07-83	1,020	7.0	25.5	564
--	--	--	90.50	07-15-83	--	--	--	07-15-83	910	6.8	22.0	565
					--	--	--	08-21-84	940	7.3	17.5	
					--	--	--	04-17-85	950	7.3	14	
					--	--	--	09-12-85	940	7.2	16	
--	--	--	--	--	--	--	--	07-15-83	860	7.2	28.0	567
--	--	--	--	--	--	--	--	07-15-83	355	6.6	27.0	568
--	--	--	81.00	07-15-83	--	--	--	07-15-83	--	7.5	24.5	569
--	--	--	39.10	07-15-83	--	--	--	07-15-83	1,600	7.0	17.0	570
--	--	--	--	--	--	--	--	07-15-83	650	6.7	34.0	571
--	--	--	--	--	--	--	--	07-15-83	1,180	6.8	30.0	573
--	--	52	61.20	07-20-83	8	--	--	05-08-85	610	8.7	17	575
--	--	--	56.00	07-20-83	--	--	--	07-20-83	435	7.2	29.0	576
					--	--	--	08-09-84	440	7.3	13.5	
					--	--	--	09-17-84	395	--	23	
					--	--	--	05-08-85	410	7.5	19	
					--	--	--	09-17-85	--	7.1	18	
					--	--	--	09-27-85	440	6.9		
--	--	85	73.90	07-20-83	6	--	--	07-20-83	415	7.0	29.0	577
					--	--	--	09-17-84	400	7.3	20	
					--	--	--	05-08-85	380	7.4	19	
--	--	17/ 50	--	--	--	--	--	07-20-83	625	7.6	28.5	578
--	--	30	--	--	<1	--	--	07-20-83	4,500	6.8	25	579
					<1	--	--	08-12-83	3,600	7.3	19	
--	--	30	--	--	--	--	--	07-20-83	505	7.0	24.5	580
--	--	32/ 67	--	--	15	--	--	07-20-83	520	7.0	26.0	581
					15	--	--	--	--	--		
--	--	--	--	--	--	--	--	07-15-83	750	7.2	26.0	582
--	--	--	--	--	--	--	--	07-20-83	530	7.1	32.0	583
--	--	--	--	--	--	--	--	07-20-83	845	7.0	28.5	584
--	--	--	--	--	--	--	--	07-21-83	580	6.4	31.5	585
--	--	--	--	--	--	--	--	07-21-83	990	7.2	23.5	586
					--	--	--	08-12-83	840	7	19	
--	--	--	3.57	07-21-83	--	--	--	--	--	--	--	587
--	--	--	--	--	--	--	--	07-21-83	540	6.4	27.5	588
--	--	--	84.90	07-21-83	--	--	--	--	--	--	--	589
--	--	30	--	--	--	--	--	07-21-83	505	6.5	23.5	590
--	--	90	--	--	<1	--	--	07-22-83	860	7.2	22.0	591
					<1	--	--	--	--	--		
--	--	38/125	56.70	07-22-83	6	--	--	07-22-83	725	8.2	17.0	592
					6	--	--	08-09-84	725	8.6	14.5	
					--	--	--	09-18-84	875	8.8	16	
					--	--	--	04-24-85	750	8.5	20	

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-592										
593	400243	0801740	Morris	Hickman, Reed	1968	H	V	317WSNGM	--	107
594	400244	0801740	Morris	Lindley, Earl	1970	H	S	317WSNGU	--	110
597	400250	0801739	Morris	Lindley, Herbert G.	1980	--	S	317GREN	--	160
598	400245	0801732	Morris	Phillips, James D.	--	U	S	317WSNGL	--	103
599	400246	0801731	Morris	Phillips, Dan	--	H	S	317GREN	--	16
600	400244	0801732	Morris	Phillips, James B.	--	U	S	317GREN	--	22
601	400247	0801737	Morris	Kiger, Ken L.	--	H	S	317GREN	--	21
601	400247	0801737	Morris	Kiger, Ken L.	--	H	S	317GREN	--	21
603	400653	0801639	South Franklin	Dyson, William	1971	H	H	317GREN	--	135
604	400606	0801632	South Franklin	Miller, Tom	1968	H	S	317GREN	--	204
605	400606	0801632	South Franklin	Miller, Tom	1968	U	H	317GREN	--	115
606	400616	0801646	South Franklin	Hackney, Ray	1966	H	S	317GREN	--	198
607	400637	0801646	South Franklin	Johnson, Larry	1977	H	H	317GREN	SHLE	110
608	400545	0801704	South Franklin	Krehel, Richard	1968	H	S	317GREN	--	125
609	400628	0801739	South Franklin	Lone Pine Golf Course	1982	C	V	317WBRGL	--	188
611	400723	0801742	South Franklin	Meighen, Denis	1966	H	S	317WBRGU	--	118
612	400719	0801736	South Franklin	Meighen, Denis	1950	H	S	317WBRGU	--	100
613	400038	0801534	Morris	Wood, Alvin H.	1961	U	S	317GREN	--	47
614	400039	0801531	Morris	Wood, Alvin H.	1972	H	S	317WSNGM	--	130
615	400039	0801529	Morris	Wood, Alvin H.	--	U	S	317GREN	--	30
616	400037	0801528	Morris	Wood, Alvin H.	--	U	S	317GREN	--	55
618	400250	0801746	Morris	Andrew, Nora	1968	H	V	317WSNGM	--	90
619	400252	0801744	Morris	Coen Oil	--	C	S	317WSNGU	--	--
620	401317	0802000	Hopewell	Amos, Gwen	1978	H	S	317WBRGL	--	145

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
					--	--	--	09-26-85	700	8.5	18	
--	--	--	--	--	--	--	--	07-22-83	395	6.7	27.0	593
--	--	35	--	--	--	--	--	07-22-83	2,800	6.9	23.5	594
					--	--	--	08-16-83	2,500	7.2	16.5	
--	--	--	28.80	07-22-83	6	--	--	07-22-83	--	7.4	26.0	597
					--	--	--	04-24-85	750	7.6	20	
					--	--	--	09-26-85	740	7.4	18.5	
--	--	--	33.80	07-22-83	--	--	--	--	--	--	--	598
--	--	--	9.46	07-22-83	--	--	--	07-22-83	195	6.1	17.5	599
					--	--	--	04-24-85	410	6.4	21	
--	--	--	5.42	07-22-83	--	--	--	--	--	--	--	600
--	--	--	10.40	07-22-83	--	--	--	07-22-83	570	7.2	22.0	601
--	--	--	10.40	07-22-83	--	--	--	08-09-84	540	7.3	20	601
					--	--	--	09-20-84	530	7	15.5	
					--	--	--	04-24-85	540	7.4	22	
					--	--	--	09-26-85	445	7.1	18.5	
--	--	78	--	--	2	--	--	07-26-83	655	7.0	29.0	603
--	--	65	--	--	--	--	--	07-26-83	570	7.0	23.0	604
--	--	--	68.30	07-26-83	--	--	--	--	--	--	--	605
--	--	138	--	--	--	--	--	07-26-83	550	7.3	23.0	606
--	--	36/ 90	--	--	25	--	--	07-25-83	--	6.9	24.0	607
					25	--	--	--	--	--		
--	--	--	62.00	07-26-83	--	--	--	09-18-84	655	7.2	20	608
					--	--	--	05-08-85	650	7.2	18	
--	--	86/166	13.40	07-26-83	3	--	--	07-26-83	1,550	8.4	25.5	609
					--	--	--	08-09-84	1,950	8.7	21.5	
					--	--	--	09-17-84	2,500	8.6	18.5	
					--	--	--	05-08-85	1,800	9	14	
					--	--	--	09-27-85	2,000	8.5	16.5	
--	--	75	32.00	09-06-66	--	--	--	--	--	--	--	611
--	--	--	45.00	00-00-50	--	--	--	07-25-83	425	6.3	17.5	612
--	--	47	16.30	07-28-83	--	--	--	07-28-83	560	7.0	22.0	613
					--	--	--	09-20-84	415	7	16.5	
					--	--	--	09-26-85	560	7	22	
--	--	--	--	--	3	--	--	07-28-83	605	7.1	24.0	614
					3	--	--	--	--	--		
--	--	--	27.40	07-28-83	--	--	--	07-28-83	390	6.5	18.5	615
--	--	--	22.90	07-28-83	--	--	--	07-28-83	435	6.5	21.0	616
					--	--	--	09-26-85	585	6.7	12.5	
--	--	--	--	--	--	--	--	07-28-83	2,600	8.6	28	618
					--	--	--	09-02-83	2,900	8.4	18	
--	--	--	17.70	07-24-83	--	--	--	07-28-83	600	7.1	25.0	619
					--	--	--	09-24-84	550	7	19	
					--	--	--	04-24-85	620	7.5	24	
					--	--	--	09-26-85	570	7.2	23	
--	--	--	39.50	08-19-83	--	--	--	08-19-83	495	6.9	21	620
					--	--	--	08-23-84	470	7.4	15	
					--	--	--	04-23-85	410	6.6	14.5	
					--	--	--	09-26-85	505	7	14	

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-621	400212	0801224	Amwell	Miller, Reed	1982	H	H	317WSNGM	--	125
622	400212	0801225	Amwell	Miller, Reed	--	U	H	317WSNG	--	25
624	400206	0801227	Amwell	Farabee, Don F.	1955	H	H	317WSNGM	--	100
625	400207	0801224	Amwell	Lemley, Catherine	--	H	H	317WSNGM	--	--
626	400205	0801225	Amwell	Dille, Harry	1978	H	S	317WSNGM	--	150
627	400203	0801226	Amwell	Tennant, Don	1980	H	H	317WSNGM	--	125
628	400219	0801217	Amwell	Salsberry, Ken	--	H	H	317WSNGM	--	19
630	401432	0802516	West Middletown	Rush, Jane	1965	H	H	317GREN	--	50
631	401432	0802519	West Middletown	Brownlee, Frank	1956	H	H	317GREN	--	50
632	401433	0802520	West Middletown	Flowers	1955	H	H	317GREN	--	85
633	401435	0802522	West Middletown	Farrer, Juanita	1950	H	H	317WSNGU	--	150
634	401434	0802543	West Middletown	McKee, Janet	1965	H	H	317WSNGU	--	125
635	401434	0802540	West Middletown	McMillen, Wilma	1962	H	H	317WSNGM	--	110
636	401434	0802537	West Middletown	Carter, Bob	1980	H	H	317WSNGM	--	250
640	401433	0802533	West Middletown	Brownlee, Sarah	--	H	H	317WSNGU	--	90
641	401434	0802529	West Middletown	Brownlee, Jack	--	H	H	317GREN	--	--
642	401433	0802532	West Middletown	King, Marjorie	1957	H	H	317WSNGU	--	080
643	401434	0802533	West Middletown	Skariot, Pat	--	H	H	317GREN	--	37
644	401435	0802535	West Middletown	Ross, Homer	1974	H	H	317WSNGM	--	135
645	401435	0802536	West Middletown	Keenan, J.	1957	H	H	317WSNGU	--	88
646	401435	0802536	West Middletown	Carter, Robert	--	H	H	317GREN	--	--
647	401435	0802535	West Middletown	Ross, Homer	--	U	H	317TNML	--	36
648	401433	0802530	West Middletown		1974	H	S	317WSNGU	--	90
649	401434	0802530	West Middletown	King, Marjorie	1972	H	H	317WSNGU	--	68
650	401432	0802511	West Middletown		1964	H	H	317WSNGM	--	180
651	401431	0802511	West Middletown	Gilbert, Paul	1969	H	H	317WSNGU	--	125
652	400214	0801224	Amwell	Heckman, Earl	--	H	H	--	--	60
653	400215	0801227	Amwell	Church, Dwain	1978	H	S	317WSNGM	--	100
654	400221	0801216	Amwell	Tennant, Donald F.	1954	H	H	317WSNGM	--	60
655	400218	0801217	Amwell	Wietasch, Otto	--	H	S	317WSNGM	--	22
656	400218	0801217	Amwell	Wietasch, Market	--	C	S	317WSNGM	--	145
657	400213	0801220	Amwell	Briggs, Ted	1980	U	S	317WSNGM	--	125

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
--	--	25/ 45/ 75	17.50	09-01-82	--	--	--	09-30-83	670	7.1	27.0	621
--	--	--	--	--	--	--	--	09-30-83	860	6.0	17.0	622
--	--	--	--	--	--	--	--	09-30-83	800	6.7	27.5	624
--	--	--	--	--	--	--	--	09-30-83	860	6.8	19.5	625
--	--	--	72.80	09-30-83	--	--	--	09-30-83	850	6.8	20.0	626
					--	--	--	08-30-84	760	7.3	20	
					--	--	--	10-19-84	815	--	18.5	
					--	--	--	09-26-85	740	7	25	
					--	--	--	10-19-85	--	7.1		
125	6	50	89.00	09-30-83	--	--	--	09-30-83	900	7.0	20.0	627
					--	--	--	10-19-84	865	7.2	19	
					--	--	--	05-29-85	875	7.3	26	
					--	--	--	09-26-85	920	7.1	20.5	
--	--	--	16.50	09-30-83	--	--	--	09-30-83	900	7.0	19.0	628
					--	--	--	10-19-84	815	7.1	19	
					--	--	--	09-27-85	950	6.8	21	
--	--	--	--	--	--	--	--	10-17-83	850	7.0	15.0	630
--	--	--	--	--	--	--	--	10-17-83	850	7.0	15.0	631
--	--	--	--	--	--	--	--	10-17-83	1,070	7.1	16.5	632
--	--	--	--	--	--	--	--	10-17-83	1,550	7.7	17.0	633
--	--	--	--	--	--	--	--	10-17-83	1,100	7.0	21.0	634
--	--	--	--	--	--	--	--	10-17-83	925	7.2	20.0	635
--	--	--	84.70	10-17-83	12	--	--	10-17-83	930	7.2	18.0	636
					12	--	--	08-08-84	635	7.6	19	
					--	--	--	10-17-84	850	7.3	18.5	
--	--	--	--	--	--	--	--	05-17-84	990	6.9	15.5	640
--	--	--	--	--	--	--	--	05-17-84	945	6.9	11.0	641
--	--	--	--	--	--	--	--	05-17-84	1,300	6.8	19.5	642
--	--	--	--	--	--	--	--	05-17-84	1,420	6.5	21.0	643
--	--	85	--	--	--	--	--	05-17-84	900	7.0	21.0	644
--	--	--	--	--	--	--	--	05-17-84	750	7.0	23.5	645
--	--	--	--	--	--	--	--	05-17-84	345	7	19	646
--	--	--	43.90	07-17-84	--	--	--	--	--	--	--	647
--	--	--	--	--	--	--	--	05-17-84	1,380	6.6	22.5	648
--	--	--	--	--	--	--	--	05-17-84	790	6.7	16.5	649
--	--	--	--	--	--	--	--	05-17-84	860	6.6	18	650
--	--	--	--	--	--	--	--	05-17-84	650	6.7	18.5	651
--	--	--	21.20	05-18-84	--	--	--	05-18-84	770	6.6	16.5	652
					--	--	--	08-30-84	670	7.2	16.5	
					--	--	--	10-19-84	600	7.1	16.0	
					--	--	--	05-29-85	700	7.2	21	
					--	--	--	09-27-85	690	6.8	17	
--	--	--	--	--	3	--	--	05-18-84	700	6.9	17.5	653
--	--	--	--	--	--	--	--	07-18-84	740	6.5	19.5	654
--	--	--	20.10	05-18-84	--	--	--	05-18-84	800	--	15.5	655
					--	--	--	05-18-85	--	6.8	21	
					--	--	--	09-26-85	870	7.3		
--	--	--	--	--	--	--	--	05-18-84	800	6.6	17.5	656
--	--	--	61.00	05-27-84	--	--	--	--	--	--	--	657

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-658	400209	0801224	Amwell	Briggs, Maybell	1974	H	H	317WBRGU	--	200
659	400206	0801225	Amwell	Weitasch, Otto	1970	H	S	317WSNGM	SNDS	126
660	400223	0801220	Amwell	Johnson, Charles	1964	H	S	317WSNGM	--	115
661	400223	0801219	Amwell	Howsdre, Martin	--	H	H	317WSNGM	--	150
662	400225	0801221	Amwell	Frye, Ted	1974	H	H	317WSNGM	--	90
663	400225	0801221	Amwell	Frye, Ted	1964	H	H	317WSNGM	--	90
664	400226	0801218	Amwell	Farabee, William	1963	H	S	317WSNGM	--	150
665	400227	0801222	Amwell		1970	H	S	317WSNGM	--	122
666	400215	0801219	Amwell	Amity Fire Company	1968	P	S	317WSNGM	SHLE	110
667	400225	0801218	Amwell	Watkins, Bill	--	H	S	317GREN	--	23
668	400228	0801222	Amwell	Elliott, Ken	1951	H	S	317WSNGM	--	230
669	400233	0801221	Amwell	Gaus, Margret	1954	H	H	317GREN	--	110
671	400200	0801225	Amwell	Beddon, Clarence	--	H	S	317WSNGM	--	25
672	400157	0801225	Amwell		--	H	T	317WSNGM	--	160
673	400229	0801220	Amwell	Wood, Clyde	1940	H	H	317GREN	--	55
674	400431	0801028	Amwell	Clark	--	H	S	321UNNN	--	57
675	400430	0801027	Amwell	Houston, Ivan	1964	H	S	321PBRGU	--	101
676	400429	0801029	Amwell	Koscho, Joseph	--	H	S	321UNNN	--	93
677	400429	0801029	Amwell	Koscho, Tim	--	H	S	321UNNN	--	080
678	400432	0801034	Amwell	Ballard, Alice	--	H	S	321UNNN	--	100
68	402413	0802924	Hanover	Meise, Charles and Francis	1918	--	S	321CNMG	--	2,460
680	400450	0801042	Amwell		1955	C	V	321UNNN	--	60
681	400459	0801045	Amwell	Stephens, Frank	1959	H	S	321UNNN	--	100
682	400428	0801022	Amwell	Taylor, James	--	U	V	321UNNN	--	15
683	400428	0801020	Amwell		--	H	V	321UNNN	--	20
684	400413	0801025	Amwell	Horne, Monna	1967	H	S	321UNNN	--	100
685	400420	0801022	Amwell	Mitchel, Thomas	1954	H	S	321PBRG	--	150
687	400449	0801051	Amwell	Efaws, Curtis	1934	H	V	321PBRG	--	100
689	400445	0801044	Amwell	Rasel, Frank	1978	H	S	321UNNN	--	120
690	400443	0801043	Amwell	Lightner, Fred R.	1947	H	S	321UNNN	--	108
691	400442	0801040	Amwell	Sanders, Chuck	--	H	S	321UNNN	--	65
692	400412	0801023	Amwell	Smith, George	--	H	S	321UNNN	--	102
693	400413	0801016	Amwell	Smith, Patricia	--	H	S	321UNNN	--	60
694	400420	0801021	Amwell	Hertze, Richard	1966	H	S	321UNNN	--	170
695	400418	0801021	Amwell	Riggle, Earl	--	H	S	321UNNN	--	68
696	400418	0800958	West Bethlehem		1960	H	H	317WBRGL	--	080

Appendix C.--Record of wells--Continued

Casing: Depth (feet)	Casing: Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
--	--	--	--	--	--	--	--	05-22-84	840	6.7	25.5	658
--	--	42	38.00	05-22-84	2	--	--	05-22-84	670	6.5	23.5	659
					--	--	--	09-26-85	580	7.2	27	
--	--	--	35.00	00-00-76	--	--	--	05-22-84	725	6.7	26.0	660
--	--	--	--	--	--	--	--	05-22-84	800	6.6	23.0	661
--	--	--	--	--	--	--	--	05-22-84	920	6.5	22.0	662
--	--	--	--	--	--	--	--	--	--	--	--	663
--	--	--	78.00	05-12-84	6	--	--	05-22-84	800	7.0	30	664
--	--	--	--	--	22	--	--	05-22-84	890	6.8	20.0	665
--	--	75/ 90	--	--	50	--	--	--	--	--	--	666
--	--	--	16.50	03-00-84	--	--	--	05-23-84	560	6.8	22.5	667
					--	--	--	10-19-84	665	7.2	16	
--	--	60/175	200.00	00-00-51	--	--	--	05-23-84	750	7.1	23.0	668
--	--	40	--	--	--	--	--	--	--	--	--	669
--	--	--	24.00	00-00-54	--	--	--	05-23-84	340	5.8	22.0	671
--	--	--	44.50	05-23-84	--	--	--	--	--	--	--	672
--	--	34	--	--	--	--	--	--	--	--	--	673
--	--	--	--	--	--	--	--	--	--	--	--	674
--	--	--	71.00	00-00-64	--	--	--	05-24-84	--	7.3	22.0	675
--	--	--	--	--	--	--	--	05-24-84	1,020	8.6	22.5	676
--	--	--	--	--	--	--	--	--	--	--	--	677
--	--	--	43.80	05-24-84	--	--	--	05-24-84	--	9.1	24.5	678
--	--	--	--	--	--	--	--	--	--	--	--	68
--	--	--	21.00	05-24-84	--	--	--	05-24-84	1,100	7	15	680
					--	--	--	08-30-84	1,140	8.2	12.5	
					--	--	--	10-25-84	11,100	8.3	13	
					--	--	--	05-29-85	1,170	8.4	14	
					--	--	--	09-26-85	1,030	8.1	22	
--	--	--	--	--	--	--	--	05-24-84	850	6.6	17.0	681
--	--	--	--	--	--	--	--	05-24-84	1,020	6.5	21.0	682
--	--	--	15.00	05-24-84	--	--	--	--	--	--	--	683
--	--	--	--	--	--	--	--	05-24-84	400	6.8	25.0	684
--	--	140	--	--	--	--	--	05-25-84	1,150	7.2	22.0	685
--	--	--	--	--	--	--	--	05-25-84	1,450	8.6	27.0	687
--	--	60/ 80/100	56.70	05-25-84	--	--	--	05-25-84	1,170	8.4	23.5	689
					--	--	--	05-29-85	1,280	8.5	25	
					--	--	--	09-27-85	1,370	8.3	20	
--	--	--	--	--	--	--	--	05-25-84	1,500	8.7	23.0	690
--	--	--	34.10	05-25-84	--	--	--	05-25-84	1,120	7.6	23	691
					--	--	--	10-25-84	1,100	7.9	18.5	
					--	--	--	05-29-85	--	7.9	24	
					--	--	--	09-26-85	1,090	7.9	21	
--	--	--	--	--	--	--	--	05-25-84	445	6.7	26.0	692
--	--	60	--	--	--	--	--	05-24-84	2,000	7.2	23	693
--	--	--	--	--	--	--	--	--	--	--	--	694
--	--	--	56.00	00-00-48	--	--	--	05-25-84	1,900	8.1	26.0	695
--	--	55	37.10	05-25-84	--	--	--	05-25-84	600	6.3	22	696
					--	--	--	08-30-84	565	7.3	16	
					--	--	--	10-25-84	650	7.3	17.0	

USGS well number	Location Latitude Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-696									
697	400436 0801017	Amwell	Frazee, James R.	1981	H	V	321UNNN	--	108
698	400533 0801026	Amwell	Curry, Vaughn	1952	H	V	321UNNN	--	85
699	400509 0801000	Amwell	Brewer, Lee	--	H	W	317WBRGL	--	27
700	400514 0800959	Amwell	Gregg, Frank	1965	H	W	321UNNN	--	120
702	400433 0801020	Amwell	Curry, Paul	--	U	V	321UNNN	--	16
703	395933 0802947	West Finley		1969	H	H	317GREN	--	90
704	395934 0802749	West Finley	Hughs, Charles	1969	H	H	317GREN	--	104
705	395937 0802803	West Finley	Mahon, Roy	1970	H	H	317GREN	--	080
706	395935 0802801	West Finley	Anderson, Kate	--	U	H	317GREN	--	38
707	395940 0802800	West Finley	Anderson, Kate	1971	H	H	317GREN	--	133
708	395933 0802751	West Finley	Raymer, Harry	1964	H	H	317GREN	--	129
709	395935 0802723	West Finley	Raymer, Harry	--	H	H	317GREN	--	30
710	395937 0802752	West Finley	Allum, Blaine	1981	H	H	317GREN	--	100
711	395930 0802737	West Finley	Hartzell, Jean	1968	H	H	317GREN	--	080
712	395935 0802747	West Finley	Allum, Blaine	1974	H	H	317GREN	--	98
713	395939 0802747	West Finley	Allum, Blaine	--	H	S	317GREN	--	28
714	395935 0802734	West Finley	Allum, Fred	--	H	S	317GREN	--	37
715	395935 0802734	West Finley	Braddock, Robert	1963	H	S	317GREN	--	32
716	395942 0802743	West Finley	Clutter, Ola	--	U	S	317GREN	--	60
717	395940 0802746	West Finley	Furmanek, Joseph	--	H	S	317GREN	--	29
718	395939 0802745	West Finley	Stollar, Lalla	--	U	S	317GREN	--	25
719	395930 0802745	West Finley	Earnest, Lloyd	1972	H	H	317GREN	--	107
720	395930 0802745	West Finley	Earnest, Lloyd	--	U	H	317GREN	--	62
721	395932 0802747	West Finley	Hartzell, Olive	--	H	H	317GREN	--	33
722	395932 0802748	West Finley	Iley, Dale	1980	H	H	317GREN	--	101
723	395933 0802748	West Finley	Emery, Stephen	1959	H	H	317GREN	--	100
724	395933 0802748	West Finley	Mahan, Lyssir	--	H	H	317GREN	--	080
725	395934 0802804	West Finley	Baker, Carol	1976	H	H	317GREN	--	76
726	395957 0802753	West Finley	Clutter, Sarah	1950	H	H	317GREN	--	115
727	395936 0802748	West Finley	Terrell, Charles E.	--	H	H	317GREN	--	22

Appendix C.--Record of wells--Continued

Casing					Measured yield			Field water quality				
Depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	USGS well number
					--	--	--	05-29-85	580	7	24	696
					--	--	--	09-27-85	530	6.7	19	
--	--	27	2.50	07-00-81	--	--	--	05-25-84	850	--	8.5	697
--	--	--	25.00	00-00-68	--	--	--	05-31-84	--	6.6	18.0	698
--	--	--	17.00	00-00-79	--	--	--	05-31-84	580	7.7	21	699
--	--	--	--	--	--	--	--	05-31-84	560	7.7	21	700
--	--	--	1.90	05-31-84	--	--	--	--	--	--	--	702
--	--	55/ 70	66.20	06-02-84	3	--	--	06-04-84	840	6.9	25.0	703
--	--	--	54.00	00-00-69	--	--	--	06-01-84	710	6.7	16.5	704
--	--	--	--	--	--	--	--	06-01-84	570	6.7	18.0	705
--	--	--	30.50	06-01-84	--	--	--	--	--	--	--	706
--	--	--	--	--	--	--	--	06-01-84	530	6.4	17.0	707
--	--	--	--	--	35	--	--	06-01-84	590	6.4	20	708
--	--	--	--	--	--	--	--	--	--	--	--	709
--	--	--	--	--	2	--	--	06-01-84	120	6.4	29.5	710
--	--	--	--	--	10	--	--	06-01-84	570	6.6	19.5	711
--	--	--	--	--	4	--	--	06-01-84	760	6.9	22.5	712
5	27	--	18.40	06-01-81	--	--	--	06-01-84	440	6.3	11.5	713
					--	--	--	05-24-85	495	7.6	25	
--	--	--	29.00	06-01-84	--	--	--	06-01-84	510	7.2	15	714
					--	--	--	08-23-84	--	7.2	21.5	
					--	--	--	09-21-84	430	7	21.5	
					--	--	--	05-29-85	445	7.3	18	
					--	--	--	09-26-85	405	7.2	20	
--	--	--	26.20	06-01-84	--	--	--	08-23-84	435	7.2	21.5	715
					--	--	--	09-21-84	430	7.0	21.5	
					--	--	--	05-29-85	445	7.3	18.0	
					--	--	--	09-26-85	405	7.2	20.0	
--	--	--	35.50	06-04-84	--	--	--	06-04-84	320	6.9	27.5	716
					--	--	--	09-21-84	405	7.1	25.5	
					--	--	--	05-29-85	445	7.4	18	
--	--	--	16.40	06-04-84	--	--	--	06-04-84	300	6.7	27	717
					--	--	--	05-24-85	365	7.5	24	
					--	--	--	09-26-85	320	7.3	21	
--	--	--	13.10	06-04-84	--	--	--	06-04-84	570	6.6	12.0	718
--	--	60	--	--	2	--	--	06-04-84	615	6.6	22.0	719
--	--	--	57.10	06-04-84	--	--	--	--	--	--	--	720
--	--	--	23.60	06-04-84	--	--	--	06-04-84	300	6.5	23	721
					--	--	--	09-21-84	275	7	19.5	
					--	--	--	05-24-85	300	7.6	22	
					--	--	--	09-26-85	290	7.1	14	
--	--	--	--	--	--	--	--	06-04-84	690	7.0	28.0	722
--	--	--	--	--	--	--	--	06-04-84	600	6.9	27.5	723
--	--	--	--	--	--	--	--	06-04-84	580	7.2	20.0	724
--	--	35	--	--	--	--	--	06-04-84	710	7.0	19.0	725
--	--	--	--	--	--	--	--	--	--	--	--	726
--	--	--	16.10	06-04-84	--	--	--	06-04-84	360	7.1	26	727
					--	--	--	08-23-84	475	7.4	26	
					--	--	--	09-21-84	470	7.3	23	

USGS well number	Location Latitude Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-727									
728	395936 0802748	West Finley	Terrell, Charles E.	--	H	H	317GREN	--	23
729	395937 0802749	West Finley	Danley, Lee	1973	H	H	317GREN	--	140
730	395936 0802749	West Finley	Danley, Lee	--	U	H	317GREN	--	17
731	401514 0800327	Independence	Pittman, Ralph	--	H	S	317WBRGL	--	21
732	401512 0803036	Independence	Cook, Margie	--	H	W	321UNNN	--	70
733	401516 0803035	Independence	Buxton, Alexandria I.	--	H	S	321PBRG	--	120
734	401515 0803029	Independence	Prtle, Florence	--	H	S	317WBRGL	--	15
735	401512 0803024	Independence	Hammond, Minnie	--	H	S	--	--	--
735	401512 0803024	Independence	Hammond, Minnie	--	H	S	--	--	--
736	401512 0803022	Independence	Dipiatro, Joseph	1925	H	H	317WBRGL	--	44
737	401514 0803023	Independence	Dipiatro, Robert	1977	H	H	321UNNN	--	100
738	401514 0803020	Independence	Dipiatro, Joseph	--	H	H	321UNNN	--	90
739	401513 0803026	Independence	Georgetti, Susan	1964	H	S	321UNNN	--	080
740	401535 0803018	Independence	Robison, Ernest	1977	H	H	317WBRGU	--	165
741	401511 0803023	Independence	Cutlip, William	1968	H	S	321PBRG	--	160
742	401512 0803020	Independence	Klages, Wayne	--	H	H	317WBRGL	--	60
743	401513 0803020	Independence	Rush, Ken	1966	H	H	317WBRGL	--	55
745	401515 0803016	Independence	Westlake, Wendell	--	H	S	317WBRGL	--	75
746	401517 0803014	Independence		--	H	S	317WSNGL	--	20
747	401518 0803016	Independence	Ryniawec, John	1952	H	H	317WBRGL	--	110
748	401515 0803017	Independence		--	H	S	317WBRGL	--	125
749	401516 0803026	Independence	Sella, Donald	--	H	S	317WBRGL	--	30
750	401514 0803022	Independence	Woodburn, Estelle	--	H	S	317WBRGL	--	15
751	401527 0803016	Independence	Pirillo, John	1976	H	S	317WBRGL	--	100
754	401455 0803008	Independence	Hopwood, Thelma	1960	U	W	321UNNN	--	--
755	400937 0802238	Blaine	Crawford, Joan	--	H	S	317WBRGL	--	18
756	400937 0802241	Blaine	Hubley, David	1981	H	S	317WBRGL	--	60
757	400932 0802300	Blaine	Lyle, Charles	1969	H	S	317WBRGL	--	125
759	400934 0802250	Blaine	Miller, Gale	1950	H	S	321UNNN	--	125

Appendix C.--Record of wells--Continued

Casing: Depth (feet)	Casing: Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
					--	--	--	05-29-85	480	7.6	18	
--	--	--	15.70	06-04-84	--	--	--	06-04-84	520	6.9	23	728
					--	--	--	09-21-84	490	7.1	19	
					--	--	--	05-29-85	565	7.8	12	
					--	--	--	09-26-85	480	7.2	18	
--	--	40/ 70/105	90.00	05-19-73	33	--	--	06-04-84	625	7.0	25.0	729
--	--	--	10.10	06-04-84	--	--	--	--	--	--	--	730
--	--	--	9.85	07-16-84	--	--	--	07-16-84	1,400	6.6	26.5	731
					--	--	--	10-17-84	1,560	6.8	21	
					--	--	--	05-24-85	1,700	7.1	19	
					--	--	--	09-27-85	1,170	7.6	16	
--	--	--	27.00	00-00-75	--	--	--	07-16-84	700	7.1	28.0	732
--	--	--	--	--	--	--	--	07-16-84	760	7.0	23.0	733
--	--	--	--	--	--	--	--	07-16-84	950	6.6	25.0	734
--	--	--	--	07-16-84	--	--	--	07-16-84	875	6.7	31	735
					--	--	--	08-08-84	925	7.1	20	
--	--	--	--	07-16-84	--	--	--	10-17-84	925	7	19	735
					--	--	--	05-24-85	735	7	20	
					--	--	--	09-27-85	775	6.9	19.5	
--	--	--	--	--	--	--	--	07-16-84	1,100	6.8	27.0	736
--	--	--	--	--	--	--	--	07-17-84	1,020	6.7	21.0	737
--	--	--	--	--	--	--	--	07-17-84	1,120	6.9	19.0	738
--	--	--	--	--	--	--	--	07-16-84	950	6.8	31.0	739
20	8	--	37.20	07-16-84	--	--	--	--	--	--	--	740
--	--	--	--	--	--	--	--	07-17-84	940	6.5	21.5	741
--	--	--	--	--	--	--	--	07-17-84	1,050	7.1	26.5	742
--	--	--	--	--	--	--	--	07-17-84	800	7.0	24.5	743
--	--	--	55.00	00-00-50	--	--	--	07-17-84	1,000	7.0	28.5	745
--	--	--	8.00	07-17-84	--	--	--	07-17-84	740	7.0	28.5	746
25	8	27/ 90	55.30	07-17-84	--	--	--	07-17-84	940	7	25	747
					--	--	--	10-17-84	1,080	7.1	16	
					--	--	--	05-24-85	900	7.1	18	
					--	--	--	09-27-85	1,090	7.1	17.5	
--	--	--	40.00	07-17-84	--	--	--	07-17-84	925	7.1	28.5	748
--	--	--	--	--	--	--	--	07-17-84	1,380	6.5	27.0	749
--	--	--	6.52	07-17-84	--	--	--	07-17-84	1,010	6.4	19	750
					--	--	--	10-25-84	820	7.0	13.5	
					--	--	--	05-24-85	1,070	7	17	
					--	--	--	09-27-85	800	6.9	19	
--	--	--	14.30	07-18-83	26	--	--	07-18-84	1,050	7	19	751
					--	--	--	05-24-85	1,020	7.2	17	
--	--	--	--	--	--	--	--	07-18-84	550	6.8	22	754
--	--	--	16.50	00-00-72	--	--	--	07-23-84	445	7.3	26.0	755
--	--	40	24.60	07-23-84	60	--	--	07-23-84	--	6.7	27	756
					--	--	--	10-17-84	1,130	7.1	19.5	
					--	--	--	04-23-85	1,290	7.2	22	
					--	--	--	09-18-85	980	6.9	21	
--	--	--	--	--	--	--	--	--	--	--	--	757
--	--	--	--	--	--	--	--	07-23-84	770	7.4	24.0	759

Appendix C.--Record of wells--Continued

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-760	400937	0802240	Blaine		--	H	S	321UNNN	--	70
761	400940	0802249	Blaine	Crowley	1960	H	S	317WBRGL	--	50
762	400940	0802249	Blaine	Dutton, Darlene	1980	H	S	317WBRGL	--	150
763	400933	0802249	Blaine	Witsberger, Mildred	1954	H	S	321UNNN	--	85
764	400935	0802243	Blaine		1973	H	S	317WBRGL	--	129
766	400938	0802248	Blaine	Shriver, Willis	1958	H	S	317WBRGL	--	080
767	400939	0802248	Blaine	Shriver, Willis	--	H	S	317WBRGL	--	34
768	400938	0802252	Blaine	Scott, Elanor	1952	H	S	321UNNN	--	70
769	400946	0802251	Blaine	Rascoe, Patricia	1980	H	S	321PBRG	--	180
770	400946	0802251	Baline	Rascoe, Patricia	--	U	S	321PBRG	--	180
771	400935	0802239	Blaine	Westfall, Paul	1954	H	S	321UNNN	--	59
772	400932	0802234	Blaine	Westfall, Thomas	1963	H	V	111ALVM	--	62
773	400937	0802230	Blaine		1956	H	V	321UNNN	--	49
774	400938	0802235	Blaine		1951	H	V	321UNNN	--	55
775	400937	0802239	Blaine	Grose, Walter R.	--	H	S	321UNNN	--	75
776	400938	0802242	Blaine	Grose, Walter R.	1975	C	S	317WBRGL	--	124
777	400936	0802241	Blaine	Lyle, Charles	1948	C	S	321UNNN	--	75
778	400938	0802258	Blaine	McGuier, Jay	--	H	S	317WBRGU	--	50
779	400936	0802259	Blaine	Blayney, Robert	1941	H	S	317WBRGU	--	53
780	400941	0802255	Blaine	Mumper, James	1981	H	S	317WBRGL	--	87
781	400932	0802235	Blaine	Grose, Walter R.	--	H	S	321PBRG	--	125
782	400939	0802246	Blaine	Pettit, Donna	--	H	S	321UNNN	--	50
783	400937	0802251	Blaine	Shriver, Willis	1981	H	S	317WBRGM	--	100
784	400936	0802244	Blaine	Cunningham, Donald	1964	H	S	317WBRGL	--	48
785	400934	0802247	Blaine	Graboski, Edward	--	H	S	321UNNN	--	87
786	400924	0802221	Blaine	Snodgrass, Harry	1956	H	V	317WBRGL	--	120
787	400925	0802222	Blaine	Till, Richard	--	H	S	321UNNN	--	90
789	400930	0802244	Blaine		1974	H	S	321UNNN	--	90
790	400928	0802227	Blaine	Holmes, Opal	--	H	V	317WBRGL	--	20
791	400931	0802227	Blaine	Butterfield, Emma	1955	H	V	321UNNN	--	53
792	400932	0802228	Blaine	Robson, Arthur	1969	C	V	--	--	150
793	400931	0802228	Blaine	Robson, Arthur	--	H	V	317WBRGL	--	30
794	400928	0802225	Blaine	Clutter, Lawrence	--	H	S	321UNNN	--	75
795	400802	0802003	Buffalo	Jarvis, Robert	1973	H	H	317WBRGL	--	175
796	400803	0802003	Buffalo	Holloway, Lucille	1964	H	H	317WBRGU	--	165
797	400801	0802004	Buffalo	Wright, Thomas	1979	H	S	317WBRGU	--	167
798	400804	0802003	Buffalo	McAdoo, Clifford	1974	H	S	317WBRGU	--	200

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
--	--	--	--	--	--	--	--	--	--	--	--	760
--	--	40	--	--	--	--	--	07-23-84	--	7	24	761
--	--	--	33.20	07-23-84	5	--	--	07-23-84	660	7.2	31	762
					--	--	--	04-23-85	735	--	16	
--	--	--	--	--	--	--	--	07-23-84	680	7.4	31.0	763
--	--	--	25.10	07-23-84	--	--	--	07-23-84	850	6.7	29.5	764
					--	--	--	08-22-84	770	7.4	19	
					--	--	--	10-17-84	830	7.3	25.5	
					--	--	--	04-23-85	835	7.4	20	
					--	--	--	09-18-85	890	7	18	
--	--	30	--	--	6	--	--	07-25-84	820	6.8	27.0	766
--	--	--	10.10	07-25-84	--	--	--	09-18-85	1,080	7.2	13	767
--	--	--	--	--	--	--	--	07-25-84	900	6.9	26.0	768
--	--	--	--	--	--	--	--	--	--	--	--	769
--	--	--	43.90	07-25-84	--	--	--	--	--	--	--	770
--	--	20/ 32/ 59	--	--	--	--	--	07-25-84	1,000	6.8	27.5	771
--	--	--	3.00	00-00-63	100	--	--	--	--	--	--	772
--	--	15/ 31/ 41/ 48	6.00	08-00-56	40	--	--	--	--	--	--	773
--	--	21/ 3/ 39	--	--	--	--	--	--	--	--	--	774
--	--	--	37.50	07-25-84	--	--	--	07-25-84	1,010	6.5	17	775
					--	--	--	08-22-84	925	7.2	16	
					--	--	--	10-17-84	930	7.1	7.5	
					--	--	--	09-18-85	975	7	21	
--	--	--	12.30	07-25-84	--	--	--	--	--	--	--	776
--	--	--	--	--	--	--	--	07-25-84	1,300	7.4	32.0	777
--	--	--	33.00	08-00-83	--	--	--	07-26-84	670	6.4	25.5	778
--	--	--	24.40	07-26-84	--	--	--	07-26-84	570	6.6	23.5	779
					--	--	--	10-18-84	570	6.6	20	
					--	--	--	09-18-85	560	6.5		
--	--	40	40.00	10-00-81	3	--	--	07-26-84	800	6.7	23.5	780
--	--	--	--	--	--	--	--	07-26-84	780	7.0	26.0	781
--	--	--	--	--	--	--	--	--	--	--	--	782
--	--	50	--	--	3	--	--	--	--	--	--	783
--	--	42/ 48	--	--	32	--	--	07-26-84	--	7.2	30.0	784
--	--	--	--	--	--	--	--	--	--	--	--	785
--	--	20	--	--	--	--	--	08-01-84	480	6.5	25.5	786
--	--	--	--	--	--	--	--	08-01-84	370	7.1	29.0	787
--	--	--	--	--	--	--	--	08-01-84	600	7.2	26.5	789
--	--	--	--	--	--	--	--	08-01-84	990	7.0	32	790
--	--	--	--	--	--	--	--	08-01-84	1,420	8.5	31.0	791
25	8	50	50.20	08-01-84	<1	--	--	08-01-84	1,400	8.8	32.0	792
--	--	--	3.22	08-01-84	--	--	--	08-01-84	1,000	7.0	30.0	793
6	--	--	--	--	--	--	--	08-01-84	1,120	8.7	27.0	794
--	--	--	--	--	2	--	--	08-02-84	520	7.4	27.5	795
--	--	--	--	--	--	--	--	08-02-84	600	7.7	25.5	796
--	--	125	58.00	08-02-84	3	--	--	08-02-84	490	7.4	26.5	797
					--	--	--	04-24-85	690	7.7	23	
					--	--	--	09-18-85	470	7.8	23	
--	--	--	106.00	08-02-84	--	--	--	08-02-84	625	7.7	27	798

USGS well number	Location Latitude	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-798										
799	400801	0802005	Buffalo	Bonar, William	1979	H	S	317WSNGM	--	--
800	400759	0802005	Buffalo	Mounts, Harry	1963	H	H	317WSNGM	--	93
801	400800	0802004	Buffalo	Hobberchalk, Ralph	1970	H	H	317WBRGL	--	175
802	400759	0802007	Buffalo	Roberts, Charles	1965	H	H	317WBRGU	--	150
803	400757	0802006	Buffalo	Silvers, George	1963	H	H	317WBRGU	--	160
805	400800	0802006	Buffalo	Burt, Jack	1965	H	H	317WBRGU	--	128
806	400803	0802004	Buffalo	Hall, Linda	1969	H	S	317WBRGU	--	145
807	400802	0802005	Buffalo	Johnson, David	1964	U	S	317WBRGU	--	175
808	400758	0802008	Buffalo	Waugh, Lenford	1964	U	S	317WSNGM	--	126
810	400830	0802216	Buffalo	Mcguffey High School	1961	P	V	317WBRGL	--	60
811	400808	0802028	Buffalo	Phillips, Larry	--	H	S	317WSNGL	--	90
812	400807	0802034	Buffalo	--	1954	H	S	317WSNGM	--	45
813	400809	0802032	Buffalo	--	1954	H	S	317WSNGM	--	90
814	400757	0802027	Buffalo	Beck, James	--	H	S	317WBRGU	--	100
815	400757	0802025	Buffalo	Nuzum, Kenneth	1969	H	S	317WBRGU	--	106
816	400757	0802024	Buffalo	--	1969	H	S	317WSNGL	--	75
817	400754	0801948	Buffalo	Westerman, Jean	1968	H	S	317WSNGM	--	080
818	400801	0801946	Buffalo	Hopkins, John	--	H	S	317WSNGM	--	135
819	400802	0801916	Buffalo	Nixon, Ed	1971	H	S	317WBRGU	--	180
820	400758	0801947	Buffalo	Whitley, Audry	1976	H	S	317WSNGM	--	180
821	400939	0801935	Buffalo	Zappi, Connie	1974	H	H	317GREN	--	100
822	400939	0801935	Buffalo	Dejohn, John	1976	H	H	317GREN	--	125
823	401304	0802242	Hopewell	--	1984	H	H	317WBRGL	--	125
824	401317	0802241	Hopewell	--	1984	H	H	317WBRGU	COAL	150
825	401310	0802240	Hopewell	--	--	U	H	317WBRGU	--	236
826	401315	0802241	Hopewell	Levers, Sally	1969	H	H	317WBRG	--	150
827	401339	0802136	Hopewell	Roney, James	--	H	H	317WSNGM	--	66
828	401336	0801238	Hopewell	Perry, Debby	1978	H	H	317WSNGL	--	--
829	402139	0801334	Hopewell	Burk, Donald	1961	H	H	317WBRGL	--	135
830	401359	0802117	Hopewell	Pushey, Darren	--	H	H	317WSNGM	--	--
831	401400	0802116	Hopewell	Plymira, Joe	1957	H	H	317WSNGM	--	75
832	402113	0801505	Hopewell	Coulter, Robert	1978	H	H	317WSNGM	--	120
833	401403	0802058	Hopewell	Brezenski, Richard	1974	H	H	317WSNGM	--	110
834	401403	0802052	Hopewell	Kovacicek, Joe	1975	H	H	317WSNGM	--	95
835	401405	0802050	Hopewell	Kovacicek, Joe	1978	H	H	317WSNGM	SHLE	106
836	401401	0802037	Hopewell	Richmond, Nancy	1977	H	H	317WSNGM	--	--

Casing: Depth (feet)	Casing: Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
					--	--	--	08-22-84	565	8	20.5	
					--	--	--	10-12-84	570	7.8	20	
					--	--	--	04-23-85	770	7.8	24	
--	--	--	30.10	08-06-84	3	--	--	08-06-84	570	7.4	28	799
					--	--	--	10-21-84	530	7.5	19.5	
					--	--	--	09-18-85	470	7.5	17.5	
--	--	--	--	--	--	--	--	08-06-84	510	7.3	28	800
--	--	--	--	--	--	--	--	08-06-84	510	7.4	29.0	801
--	--	--	--	--	--	--	--	--	--	--	--	802
--	--	--	--	--	--	--	--	08-06-84	475	7.4	28.5	803
--	--	--	--	--	--	--	--	08-06-84	560	7.5	27.0	805
--	--	--	--	--	--	--	--	08-06-84	540	7.1	31.0	806
--	--	--	--	--	--	--	--	--	--	--	--	807
--	--	--	34.20	08-06-84	--	--	--	--	--	--	--	808
--	--	--	10.30	08-06-84	--	--	--	10-12-84	1,030	7.1	15	810
					--	--	--	04-23-85	970	7.4	15	
					--	--	--	09-18-85	1,100	7	13	
--	--	--	--	--	--	--	--	08-07-84	525	7.1	28.0	811
21	6	30	--	--	5	--	--	08-07-84	270	6.9	28.0	812
21	--	30/ 60	--	--	3	--	--	--	--	--	--	813
--	--	--	--	--	--	--	--	08-06-84	335	6.7	28.0	814
--	--	--	21.00	00-00-80	--	--	--	08-07-84	365	6.7	25.0	815
--	--	--	--	--	--	--	--	--	--	--	--	816
--	--	--	40.00	00-00-82	--	--	--	08-07-84	625	6.8	26.0	817
--	--	--	78.80	08-07-84	--	--	--	08-07-84	700	7.4	31	818
					--	--	--	10-12-84	655	7.4	24	
					--	--	--	04-23-85	710	7.9	22	
					--	--	--	09-18-85	660	7.3	21	
--	--	--	--	--	--	--	--	08-07-84	600	7.0	28.5	819
--	--	--	80.90	08-07-84	--	--	--	08-07-84	600	7	28	820
					--	--	--	10-12-84	600	7.5	21	
					--	--	--	04-23-85	630	7.6	23	
					--	--	--	09-18-85	620	7.2	18	
--	--	--	--	08-07-84	--	--	--	08-07-84	650	6.8	23.5	821
--	--	70	62.10	08-07-84	7	--	--	08-07-84	700	7.0	20.0	822
--	--	90/ 38	43.20	08-16-84	6	--	--	--	--	--	--	823
--	--	--	95.90	08-16-84	5	--	--	--	--	--	--	824
--	--	--	97.30	08-16-84	--	--	--	--	--	--	--	825
--	--	--	--	--	5	--	--	08-16-84	225	6.9	27.0	826
60	4	--	43.70	08-16-84	--	--	--	08-16-84	800	6.9	28.5	827
--	--	--	46.40	08-16-84	--	--	--	08-16-84	900	6.6	27.0	828
--	--	55	--	--	--	--	--	08-17-84	750	7.0	30.0	829
--	--	--	12.60	08-17-84	--	--	--	--	--	--	--	830
--	--	--	--	--	--	--	--	08-17-84	500	6.9	28.0	831
--	--	60	--	--	8	--	--	08-17-84	580	6.9	26.0	832
--	--	--	60.30	08-17-84	15	--	--	08-17-84	700	6.8	31	833
--	--	38/ 65/ 84	18.30	08-17-84	15	--	--	08-17-84	700	7.0	26.0	834
--	--	50/ 65/ 86	26.80	08-17-84	8	--	--	08-17-84	--	7.1	25.0	835
--	--	--	16.30	08-17-84	--	--	--	08-17-84	580	6.8	28.0	836

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-837	401400	0802039	Hopewell	Clayton, Daniel	1976	H	H	317WSNGM	LMSN	105
838	401647	0802430	Cross Creek	Bongiorni, Frank	1983	H	S	321UNNN	--	220
839	401555	0802352	Cross Creek	Fowler, Albert	1982	H	S	317WBRGL	--	120
840	401557	0802349	Cross Creek	McClain, Richard	1979	H	S	317WSNGM	--	100
841	402106	0801403	Cecil	Lukon, Raymond	1981	H	H	321PBRG	--	150
842	402053	0801426	Cecil	Langhurst, Chris	1982	H	D	321PBRG	--	65
843	401925	0801315	Cecil	Yerkey, Robert	1980	H	V	321PBRG	--	73
844	401941	0801053	Cecil	Haye, Marleen	1978	H	S	321PBRG	--	115
845	401941	0801054	Cecil	Yarmeak, Joe	--	H	S	321PBRG	--	23
846	402053	0801401	Cecil	--	--	H	H	321PBRG	--	210
847	402123	0801944	Smith	Winters, Joe	1981	H	V	321PBRGL	--	55
848	402126	0801946	Smith	Shimon, John	1984	H	V	321PBRGL	--	30
849	401922	0802126	Smith	Community Medical Center	1978	P	V	321UNNN	--	--
850	401924	0802130	Smith	Community Medical Center	1977	U	V	321UNNN	--	150
851	402207	0802325	Smith	Gavatorta, Steve	1979	C	V	321PBRGC	--	75
852	402204	0801947	Smith	Roach, David	1975	H	V	321PBRGL	--	165
853	400323	0800857	East Finley	Raney, Calvin	1978	H	S	317WSNG	--	120
854	400220	0800842	East Finley	Glover, Kenneth	1970	H	S	317WSNG	SNDS	90
855	402102	0802703	Jefferson	Scopel, Jack	1972	H	S	321PBRGU	--	92
856	402005	0802739	Jefferson	Gillespie, Dick	1975	H	H	321PBRGU	--	150
857	402025	0802807	Jefferson	Riggs, Herbert	1970	H	H	321UNNN	--	140
858	402034	0802658	Jefferson	Vincenti, Robert	1972	H	S	321PBRGU	--	105
859	402121	0803002	Jefferson	--	1975	H	S	321RDSN	--	81
860	402120	0802959	Jefferson	--	--	U	S	321RDSN	--	105
861	402112	0803022	Jefferson	Jeffery, Dwight	1975	H	S	321RDSN	--	111
862	401303	0801835	Canton	Bradford, John	1978	H	H	321UNNN	--	180
863	401250	0801805	Canton	Griffin, Charles	1972	H	H	321PBRGU	--	150
865	401255	0801745	Canton	Kelley, Marie	1978	H	H	321PBRGU	--	--
866	401254	0801751	Canton	Carver, George	1979	H	S	321UNNN	--	200
867	401304	0801859	Canton	Poland, John	1985	H	S	317WBRGL	--	200
868	401851	0801220	Canton	Donaldson, Gary	1974	H	V	321UNNN	--	52
869	401738	0801414	Chartiers	Gossett, Wayne	1979	H	H	321UNNN	--	180
870	401722	0801408	Chartiers	--	1982	S	W	321PBRG	--	90
871	401408	0801334	Chartiers	Warcholak, Ted	1979	H	S	321CSLM	--	125
872	401535	0801401	Chartiers	--	1965	H	V	321CSLM	--	225
873	401346	0801535	Chartiers	--	1983	H	H	321UNNN	--	150
874	401350	0801536	Chartiers	Andy, Frank	--	U	H	317WBRGL	--	114
875	401348	0801535	Chartiers	--	--	H	H	317WBRGL	--	53
876	400610	0795500	California	Truskey, Elmer	1957	H	S	321FSPT	--	130
877	401007	0795613	Carroll	Fragello, Palmer	--	H	S	321PBRG	--	165
878	401009	0795811	Carroll	Panizzi, Leo	1961	U	S	321SCKL	--	150
879	401246	0801149	North Strabane	--	1971	C	V	321RDSN	--	165
880	401415	0801115	North Strabane	Binjotto, Phillip	1974	H	S	317WBRGL	--	220
881	401426	0800903	North Strabane	Chambers, Carl	1960	H	V	321PBRGU	--	080
882	401334	0800828	North Strabane	Sprence, Joe	1976	H	V	321PBRGU	--	108
883	401344	0800644	North Strabane	--	--	H	S	317WBRGL	--	187
885	401511	0800634	North Strabane	--	1983	H	S	317WBRGL	--	160
886	401439	0800416	Nottingham	Obringer, James	1978	H	S	321UNNN	--	130

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Temperature (deg C)	USGS well number
--	--	34/ 85	9.19	08-17-84	2	--	--	08-17-84	535	6.5	24.0	837
--	--	--	82.10	08-22-84	--	--	--	08-22-84	820	7.8	20.5	838
120	6	38/ 86	39.20	08-22-84	15	--	--	08-22-84	580	6.8	28.5	839
--	--	65	6.65	08-22-84	--	--	--	08-22-84	570	6.8	24.0	840
--	--	90	70.30	05-20-85	--	--	--	05-20-85	745	6.8	22	841
21	6	35	15.90	05-20-85	20	--	--	05-20-85	850	7	17	842
--	--	--	28.80	05-20-85	5	--	--	05-20-85	1,000	6.8	17	843
23	8	70	47.00	05-20-85	1	--	--	05-20-85	670	6.9	22.5	844
--	--	--	16.20	05-20-85	--	--	--	05-20-85	530	6.6	22	845
--	--	25/155	93.80	05-20-85	<1	--	--	--	--	--	--	846
20	8	25	7.59	05-21-85	20	--	--	05-21-85	850	7	16	847
--	--	--	12.80	05-21-85	--	--	--	05-21-85	825	6.7	15.5	848
--	--	--	5.41	05-21-85	--	--	--	--	--	--	--	849
--	--	--	3.02	05-21-85	--	--	--	--	--	--	--	850
--	--	--	14.00	05-21-85	--	--	--	05-21-85	1,400	6.2	21	851
--	--	20/125/135	56.90	05-21-85	10	--	--	05-21-85	--	7.3	15	852
--	--	100	--	--	4	--	--	05-22-85	510	6.8	21.5	853
--	--	40/ 65	68.30	05-22-85	6	--	--	05-22-85	490	6.7	21	854
27	8	40	31.20	05-23-85	2	--	--	05-23-85	825	6.5	20	855
--	--	90	70.00	05-23-85	--	--	--	05-23-85	590	6.9	17	856
--	--	--	70.00	05-23-85	--	--	--	05-23-85	660	6.6	15	857
105	6	--	35.50	05-23-85	3	--	--	05-23-85	590	6.9	17	858
21	8	33/ 50/ 60	41.30	05-23-85	5	--	--	05-23-85	575	6.8	16	859
--	--	--	44.60	05-23-85	--	--	--	--	--	--	--	860
--	--	43/ 93	--	--	2	--	--	05-23-85	650	7.1	22.5	861
--	--	--	--	--	1	--	--	--	--	--	--	862
--	--	--	--	--	4	--	--	05-20-85	--	6.9	23	863
--	--	--	111.00	05-30-85	12	--	--	05-30-85	700	7.2	19.5	865
--	--	--	76.80	05-30-85	--	--	--	--	--	--	--	866
--	--	--	74.50	05-20-85	--	--	--	05-30-85	740	7.3	20.5	867
20	8	21/ 36	5.00	10-04-74	--	.24	10	05-30-85	840	6.9	18	868
--	--	--	50.30	06-12-85	--	--	--	06-12-85	480	6.5	15.5	869
--	--	--	48.80	06-12-85	--	--	--	06-12-85	850	7.0	18	870
--	--	50	54.30	06-12-85	--	--	--	06-12-85	1,750	7.5	24.5	871
--	--	180	--	--	--	--	--	06-12-85	1,200	7.2	17	872
--	--	--	84.50	06-12-85	--	--	--	--	--	--	--	873
--	--	--	39.50	06-12-85	--	--	--	--	--	--	--	874
--	--	--	41.20	06-12-85	--	--	--	--	--	--	--	875
--	--	86	39.90	06-13-85	--	--	--	06-13-85	690	7	13.0	876
--	--	--	--	--	--	--	--	06-13-85	0800	7.0	20	877
--	--	--	55.90	06-13-85	--	--	--	--	--	--	--	878
--	--	10/ 20/ 65	69.90	06-14-85	10	--	--	06-13-85	5,500	7.2	15.5	879
					--	--	--	09-05-85	1,650	8.6	16	
220	8	--	117.00	06-14-85	--	--	--	06-14-85	875	6.4	21	880
--	--	--	--	--	--	--	--	06-14-85	760	6.8	24	881
19	8	31/ 65/ 85	34.00	06-14-85	1	--	--	06-14-85	600	6.8	20.5	882
--	--	--	--	--	--	--	--	06-14-85	920	6.8	19.5	883
--	--	--	41.90	06-14-85	--	--	--	--	--	--	--	885
21	8	50	71.30	07-09-85	20	--	--	07-09-85	550	--	19.5	886

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topo-graphic setting	Hydro-geologic unit	Lith-ology	Depth of well (feet)
Ws-886										
888	401358	0800304	Nottingham	Hultz, Ann	1965	H	S	321PBRG	--	100
889	401234	0800228	Nottingham	Patton, Robert	1974	H	S	321CSLM	--	110
890	400719	0800154	Somerset	Chippewa Golf Course	--	C	H	317WBRGL	--	110
891	400719	0800227	Somerset	Chippewa Golf Course	1975	C	S	317WBRGL	--	100
892	400616	0800148	Somerset	Puskarach, Frank	1982	H	S	321PBRGU	--	90
893	400616	0800148	Somerset	Puskarach, Frank	1982	U	S	321PBRGU	--	120
894	400549	0800041	West Pike Run	Femia, Frank	1977	H	S	317WBRGU	--	100
895	400302	0795803	West Pike Run	Vitte, Richard	1978	H	V	321PBRGL	--	90
896	400502	0795757	West Pike Run	Williams, Ronald	1969	H	S	321RDSN	--	87
897	400510	0795842	West Pike Run	Ames, Francis	1949	H	H	321UNNN	--	105
898	400451	0795906	West Pike Run	Kusman, Gregory	1976	H	S	321PBRGU	--	100
899	402720	0802844	Hanover	Cagnon, Merl	1967	H	S	321CSLM	--	85
901	401646	0802356	Cross Creek	--	--	U	S	321SCKL	--	23
902	401702	0802346	Cross Creek	--	1944	H	S	321PBRG	--	100
903	401700	0802348	Cross Creek	--	--	H	S	321UNNN	--	22
904	401639	0802355	Cross Creek	Bedillon, Warren	1970	H	S	321UNNN	--	--
905	401640	0802351	Cross Creek	--	--	H	S	321UNNN	--	100
906	401635	0802351	Cross Creek	Bail, Thomas	1975	H	S	321UNNN	--	120
907	401647	0802420	Cross Creek	Vettorel, Robert	1977	H	S	317WBRGL	--	100
908	401638	0802420	Cross Creek	Tranquill, James	1975	H	V	321UNNN	LMSN	080
909	401646	0802429	Cross Creek	Bongiorni, Frank	1974	H	S	321PBRG	--	120
910	401647	0802430	Cross Creek	Bongiorni, Frank	1982	H	S	321PBRG	--	250
911	401639	0802353	Cross Creek	Badillon, Warren	--	H	S	321UNNN	--	--
912	401642	0802429	Cross Creek	--	--	H	S	321UNNN	--	88
913	401644	0802409	Cross Creek	Rea, Charles	1975	H	S	321PBRG	--	100
914	402314	0801517	Robinson	Livingood, Gerald R.	1981	H	V	321PBRG	--	100
915	402442	0801838	Robinson	Kearns, George	1969	H	H	321CSLM	SNDS	176
916	402709	0802638	Hanover	Cumblidge, Charles	1967	H	S	321CSLM	SHLE	--
917	402758	0802250	Hanover	Koerbell	1975	H	S	321GLNS	SNDS	160
918	402553	0802835	Hanover	Shedlock, G.	1982	H	V	321GLNS	--	104
919	402348	0803003	Havover	Speicher, George	1977	H	S	321GLNS	SHLE	165

Appendix C.--Record of wells--Continued

Casing Depth (feet)	Casing Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Measured yield: Reported yield (gal/min)	Measured yield: Specific capacity (gal/min/ft)	Measured yield: Discharge (gal/min)	Field water quality: Date measured	Field water quality: Specific conductance (uS/cm)	Field water quality: pH (standard units)	Field water quality: Temperature (deg C)	USGS well number
					--	--	--	09-05-85	520	7.1		
--	--	--	--	--	--	--	--	07-09-85	0800	6.5	--	888
--	--	080	--	--	--	--	--	07-09-85	750	6.7	--	889
--	--	82	52.60	07-11-85	--	--	--	07-11-85	--	6.7	19	890
					--	--	--	07-15-85	600	--		
--	--	58	58.00	07-11-85	6	--	--	07-11-85	570	6.6	13.5	891
--	--	90	29.90	07-11-85	--	--	--	07-11-85	625	6.9	24	892
--	--	90/120	32.40	07-11-85	--	--	--	--	--	--	--	893
--	--	40	--	--	--	--	--	07-12-85	700	6.3	19	894
16	6	--	--	--	2	--	--	07-12-85	1,200	7	19	895
--	--	--	32.40	07-12-85	--	--	--	07-12-85	825	7	23.5	896
--	--	--	60.00	00-00-82	--	--	--	07-12-85	370	5.9	26.5	897
21	6	50	--	--	10	--	--	07-12-85	725	6.7	26.5	898
--	--	--	--	--	--	--	--	07-30-85	600	6.8	23	899
--	--	--	21.40	06-15-83	--	--	--	06-15-83	510	--	11.0	901
--	--	--	40.20	06-15-83	--	--	--	06-15-83	650	7.8	18.5	902
					--	--	--	08-11-83	660	7.8	21.5	
					--	--	--	08-22-84	565	7.8	21	
					--	--	--	04-17-85	645	7.5	12	
					--	--	--	09-13-85	675	7.7	18	
--	--	--	16.70	06-15-83	--	--	--	06-15-83	600	--	16.0	903
--	--	--	44.00	06-15-83	--	--	--	--	--	--	--	904
--	--	--	32.80	06-15-83	--	--	--	06-15-83	0800	9.1	17	905
					--	--	--	08-07-84	825	9.1	20	
					--	--	--	08-22-84	775	9	22.5	
					--	--	--	09-13-85	0800	9	18.5	
--	--	90	--	--	--	--	--	06-15-83	560	7.3	16.5	906
--	--	--	37.40	06-16-83	--	--	--	--	--	--	--	907
--	--	--	19.20	06-16-83	--	--	--	06-16-83	700	7.2	16	908
					--	--	--	08-22-84	590	7.2	22	
					--	--	--	09-13-85	640	6.9	22.5	
--	--	--	52.20	06-16-83	--	--	--	06-16-83	525	7.2	16.5	909
					--	--	--	08-16-83	615	8	18.5	
					--	--	--	08-22-84	690	7.6	19	
					--	--	--	04-17-85	528	7.3	12	
--	--	--	--	--	--	--	--	--	--	--	--	910
--	--	--	32.40	06-17-83	--	--	--	--	--	--	--	911
--	--	--	22.00	06-17-83	--	--	--	06-17-83	525	7	19	912
					--	--	--	08-07-84	550	7.4	19	
					--	--	--	08-22-84	575	7.1	20	
					--	--	--	09-13-85	445	7.2	20	
--	--	--	39.60	06-17-83	--	--	--	06-17-83	500	--	15	913
					--	--	--	09-12-85	690	7.5	19	
--	--	--	15.80	08-16-83	--	--	--	08-16-83	1,100	7.4	20	914
41	6	145	--	--	10	--	--	08-19-83	560	7.1	14	915
29	6	43	--	--	--	--	--	08-19-83	545	7.4	16.5	916
39	6	72	54.60	08-19-83	3	--	--	08-19-83	680	8.3	20.5	917
30	6	75	--	--	--	.52	20	08-19-83	1,400	8.2	18.5	918
26	6	125	--	--	1	--	--	08-19-83	520	7.5	23.5	919

USGS well number	Location Latitude (degrees)	Location Longitude (degrees)	Township or borough	Owner	Year drilled	Primary use of water	Topographic setting	Hydrogeologic unit	Lithology	Depth of well (feet)
Ws-920	402312	0801516	Robinson	Kalitz, Bernard	1981	H	V	321PBRG	--	130
921	401610	0800345	Peters	Schultz, Kenneth	1978	H	S	321PBRG	--	120
922	401609	0800340	Peters	Patterson, J.	1975	H	S	321PBRG	LMSN	85
923	401559	0800415	Peters	Moser, E.	1980	H	S	321PBRG	LMSN	148
924	401613	0800251	Peters	Groznik, Louis	1967	H	V	321PBRG	SHLE	50
925	401551	0800945	Peters	Bergmark, Robert	1981	H	S	317WBRGU	COAL	125
926	400232	0801739	Morris	Lindley, John	--	S	H	317GREN	--	185
927	401343	0801109	North Strabane	Shaw, Gene	1983	H	H	317WBRGL	--	172
928	400615	0800051	North Bethlehem	Conkle, Lois	1962	H	V	317WBRGL	--	146
929	400250	0801738	--	Lindley, John	--	U	V	317GREN	--	--
930	401502	0803045	Independence	Bown, Phil	--	S	S	321UNNN	--	100
931	401433	0802538	West Middletown	--	--	H	H	317GREN	--	49
932	401204	0802259	Hopewell	Boni, Dino	1983	H	S	321PBRGU	--	150
950	402742	0802916	Hanover	--	1978	H	H	321CSLM	--	210
951	402512	0802940	Hanover	Riddle, Paul	1963	H	V	321GLNS	--	85
952	402212	0802819	Hanover	Ohl, Jane	--	H	V	321GLNS	--	60
953	400818	0802935	Donegal	Collelo, Joe	1978	H	H	317GREN	--	140
954	400949	0800948	Donegal	Swoager, Sue	1981	H	H	317WSNGM	--	120
955	402653	0800954	Donegal	Titzed, Donald	1985	H	H	317WSNGM	--	150
956	400616	0802713	Donegal	Cortis, L.P.	1978	C	S	317WSNG	--	150
957	400654	0802700	Donegal	--	1971	C	V	317WSNG	--	70
958	400633	0802729	Donegal	Hartzell, Lyle	1978	U	S	317WSNG	LMSN	59
959	400512	0802724	Donegal	Minch	1977	H	H	317GREN	SHLE	125
960	400439	0802138	East Finley	--	1973	P	H	317GREN	--	102
961	400411	0802138	East Finley	--	1971	H	S	317WSNG	--	125
962	400418	0802128	East Finley	Lilley, Brice	1980	H	S	317GREN	--	120
963	401042	0800506	Somerset	Tremel, Bill	1980	H	H	317WBRGU	SNDS	100
964	401047	0800404	Somerset	Martin, Jerry	1981	H	H	317WBRGU	--	190
965	400806	0800133	Somerset	Goofrey, Robert	1954	H	V	321PBRG	--	60
966	400816	0800427	Somerset	Hazen, Gerald	1972	H	S	321UNNN	--	130
968	400732	0795812	Fallowfield	MacDonald, David	1976	H	S	317WBRGL	--	90
969	400710	0795801	Fallowfield	Matay, Mike	1980	U	H	317WBRG	--	92
970	400646	0795726	Fallowfield	Koslosky, James	1953	H	V	321UNNN	--	60
971	400704	0795617	Fallowfield	Greco, Gary	--	H	W	321PBRG	--	60
972	400658	0795640	Fallowfield	Lusk, Bob	1975	H	V	321RDSN	--	90
973	400758	0795823	Fallowfield	Voelker, Thomas	1981	H	S	--	--	175

Appendix C.--Record of wells--Continued

Casing					Measured yield			Field water quality				
Depth (feet)	Diameter (inches)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Specific capacity (gal/min/ft)	Discharge (gal/min)	Date measured	Specific conductance (uS/cm)	pH (standard units)	Temperature (deg C)	USGS well number
--	--	--	38.80	08-16-83	--	--	--	--	--	--	--	920
21	6	60	--	--	3	--	--	08-25-83	960	7.4	17	921
22	8	46/ 66	--	--	20	--	--	08-25-83	720	7.4	20.5	922
27	8	4/ 23/ 31	22.70	09-02-83	12	--	--	09-02-83	830	7	19	923
23	6	14	--	--	40	--	--	09-02-83	930	7.1	17	924
20	8	60	55.00	09-02-83	8	--	--	09-02-83	1,170	6.6	10.5	925
--	--	--	61.50	03-15-84	--	--	--	03-15-84	620	7.3	12.5	926
--	--	--	51.60	03-15-84	--	--	--	03-15-84	755	7.1	15.5	927
--	--	--	79.20	03-15-84	--	--	--	03-15-84	780	8.2	13.5	928
--	--	--	17.10	03-28-84	--	--	--	--	--	--	--	929
--	--	--	37.40	08-08-84	--	--	--	08-08-84	610	7.4	21.5	930
					--	--	--	10-17-84	595	7.0	18	
					--	--	--	05-24-85	620	7.3	16	
					--	--	--	09-27-85	510	7	15	
--	--	--	47.10	08-08-84	--	--	--	08-08-84	845	8	17.5	931
					--	--	--	10-17-84	935	7.3	18	
					--	--	--	04-23-85	710	7.8	24	
					--	--	--	09-18-85	900	7	19.5	
--	--	--	21.20	10-31-84	--	--	--	04-23-85	480	7.2	15.5	932
--	--	190	150.00	07-30-85	30	--	--	07-30-85	690	6.8	18	950
					--	--	--	09-04-85	650	8.2	19.5	
20	10	75	32.70	07-30-85	--	--	--	07-30-85	610	6.9	18	951
--	--	--	--	--	--	--	--	07-30-85	1,150	8.5	19	952
					--	--	--	09-04-85	1,210	8.9	14.5	
--	--	--	--	--	--	--	--	07-31-85	450	7	24	953
--	--	75	--	--	--	--	--	07-31-85	620	7.1	31	954
--	--	--	90.00	05-00-85	15	--	--	--	--	--	--	955
--	--	--	55.00	07-31-85	--	--	--	07-31-85	1,000	7.1	28	956
--	--	--	24.60	08-13-85	--	--	--	08-13-85	600	7	22	957
12	8	35	48.40	08-13-85	4	--	--	--	--	--	--	958
20	8	60/105	65.40	08-13-85	8	--	--	--	--	--	--	959
--	--	55	--	--	3	--	--	08-13-85	620	6.7	24.5	960
--	--	50/ 95	--	--	5	--	--	--	--	--	--	961
--	--	100	36.70	08-13-85	--	--	--	08-13-85	475	6.6	28	962
20	8	40	64.30	08-14-85	10	--	--	08-14-85	725	6.6	22	963
--	--	90	170.00	08-14-85	--	--	--	--	--	--	--	964
--	--	--	12.60	08-14-85	--	--	--	08-14-85	810	6.8	25	965
--	--	--	64.90	08-14-85	--	--	--	08-14-85	660	6.9	25.5	966
					--	--	--	09-05-85	690	7.4	16.5	
--	--	64	--	--	3	--	--	08-15-85	560	6.8	24.5	968
60	6	--	20.60	08-15-85	--	--	--	08-15-85	440	6.9	17.5	969
--	--	--	9.19	08-15-85	--	--	--	08-15-85	680	6.8	25	970
--	--	--	--	--	<1	--	--	08-15-85	750	7	18	971
--	--	--	--	--	--	--	--	08-15-85	850	6.9	22.5	972
					--	--	--	09-05-85	835	7.4	18.5	
--	--	100	148.00	08-00-81	--	--	--	--	--	--	--	973

Appendix D.--Record of springs

Local number: The number that is assigned to identify the spring.

Location map name: U.S. Geological Survey 7-1/2-minute topographic map.

Aquifer code: 317GREN, Greene Formation; 317WSNG, Washington Formation; 317WSNGM, Washington Formation, middle member; 317WSNGL, Washington Formation, lower member; 317WBRGU, Waynesburg Formation, upper member; 317WBRGM, Waynesburg Formation, middle member; 317WBRGL, Waynesburg Formation, lower member; 321UNNN, Uniontown Formation; 321PBRG, Pittsburgh Formation; 321PBRGU, Pittsburgh Formation, upper member; 321SCKL, Sewickley Member of Pittsburgh Formation; 321PBRGL, Pittsburgh Formation, lower member; 321PBRGC, Pittsburgh Coal; 321CSLM, Casselman Formation.

Use of water: H, domestic; S, stock; U, unused.

Permanance: P, perennial.

Improvements: B, boxed basin; C, concrete basin; H, spring house; P, pond; R, pipe; T, trough.

Discharge: gal/min, gallons per minute.

Method discharge measured: C, current meter; E, estimated; V, volumetric.

Specific conductance: μS/cm, microsiemens per centimeter at 25 degrees Celsius.

Water temperature: deg C, degrees Celsius.

Appendix D.--Record of springs

USGS spring number	Location: Latitude Longitude (degrees)	Quadrangle name	Township or borough	Owner	Primary use of water	Elevation of land surface (feet)
SP 10	401708 0802137	Midway	Cross Creek	Cowden	H	1,200
SP 11	401232 0802307	West Middletown	Cross Creek	West	S	1,140
SP 12	400433 0800400	Ellsworth	--	Buckingham	H	1,300
SP 13	400400 0800545	Ellsworth	--	Guza	H	1,040
SP 33	400431 0801038	400431	Amwell	Donahoo	H	1,030
SP 34	400426 0801037	Amity	Amwell	Paul	H	1,150
SP 35	400450 0801026	Amity	Amwell	--	H	1,120
SP 36	400339 0801022	Amity	Amwell	--	H	1,110
SP 37	400415 0801025	Amity	Amwell	Roberts	H	1,040
SP 38	400454 0801018	Amity	Amwell	Frazee	H	1,120
SP 39	400430 0801000	Amity	W Bethlehem	Montgomery	H	1,080
SP 40	400449 0801021	Amity	Amwell	Schwartz	H	1,120
SP 41	395947 0802747	Wind Ridge	West Finley	Anderson	H	1,330
SP 42	400926 0802217	Washington West	Blaine	Presto	H	1,040
SP 43	400926 0802221	Washington West	Blaine	Till	H	1,020
SP 44	401308 0802248	West Middletown	Hopewell	Yilit	H	1,220
SP 45	401228 0802134	Washington West	--	--	S	1,150
SP 46	401248 0802138	Washington West	Hopewell	--	S	1,210
SP 47	401305 0802127	Washington West	Hopewell	--	S	1,120
SP 48	401246 0802148	Washington West	Hopewell	--	S	1,110
SP 49	401305 0802040	Washington West	--	--	S	1,140
SP 50	401258 0802047	Washington West	Hopewell	Quarture	S	1,140
SP 51	401309 0802028	Washington West	Hopewell	Quarture	U	1,140
SP 52	401310 0802011	Washington West	Hopewell	Quarture	U	1,125
SP 53	401211 0802239	West Middletown	Hopewell	Richmond	S	1,120
SP 54	401219 0802237	West Middletown	Hopewell	Richmond	S	1,190
SP 55	401225 0802231	West Middletown	Hopewell	Richmond	S	1,130
SP 56	401216 0802235	West Middletown	Hopewell	Richmond	S	1,125
SP 57	401242 0802411	West Middletown	Hopewell	Miller	H	1,170
SP 58	401244 0802354	West Middletown	Hopewell	Miller	S	1,080
SP 59	401303 0802354	West Middletown	Hopewell	--	H	1,190
SP 60	401305 0802351	1180	Hopewell	Brownlee	S	1,180
SP 61	401256 0802346	West Middletown	Hopewell	--	H	1,140
SP 62	401158 0802417	West Middletown	Hopewell	--	U	1,000
SP 63	401351 0802304	West Middletown	Hopewell	--	U	1,280
SP 64	400236 0802350	Claysville	East Finley	--	H	1,110
SP 65	401723 0801409	Canonsburg	Chartiers	--	H	1,140
SP 66	400517 0795524	California	California	Russell	P	980
SP 67	400610 0795459	California	California	Truskey	S	1,200
SP 68	400839 0795825	Monogahela	Fallowfield	Lazzari	H	950
SP 69	401005 0795811	Monogahela	Carroll	Yanizzi	H	900
SP 70	400528 0795924	California	West Pike Twp	Weaver	U	1,080
SP 71	400447 0795907	California	West Pike Run	--	U	1,030
SP 72	400331 0795505	California	California	--	U	940
SP 73	402714 0802916	Burgettstown	Hanover	--	S	1,230
SP 74	402500 0802830	Burgettstown	Hanover	--	U	1,120
SP 75	402611 0802449	Burgettstown	Hanover	--	H	1,200
SP 76	402812 0802314	Burgettstown	Hanover	--	U	1,020
SP 77	400649 0802632	Claysville	Donegal	Clark	H	1,100
SP 78	400514 0802731	Claysville	Donegal	Degarmo	H	1,280
SP 79	400603 0802918	Claysville	Donegal	Deitt	S	1,310

Topo-graphic setting	Hydro-geologic unit	Measurements of discharge: Date measured	Rate (gal/min)	Method used	Perm-an-ence	Field water quality measurements: Date measured	Specific conductance (μS/cm)	Hardness (mg/L as $CaCO_3$)	Temper-ature (deg C)	USGS spring number
V	321UNNN	06-15-83	5	--	P	06-15-83	520	--	16	SP 10
		08-11-83	2	--	--	08-11-83	550	--	12.5	
S	317WBRGM	--	--	--	P	08-05-83	520	--	24.5	SP 11
S	317GREN	--	--	--	P	--	--	--	--	SP 12
S	317WBRGU	--	--	--	P	08-10-83	285	--	26	SP 13
S	--	--	--	--	--	05-23-84	415	--	21.5	SP 33
S	317WBRGL	--	--	--	--	05-24-84	380	--	28	SP 34
S	317WSNGL	--	--	--	--	05-24-84	420	--	22	SP 35
S	317WSNGM	--	--	--	--	05-25-84	550	--	15.5	SP 36
S	317WBRGU	--	--	--	--	--	--	--	--	SP 37
S	--	05-31-84	<1	V	--	05-31-84	470	--	18	SP 38
		10-25-84	<1	V	--	10-25-84	515	--	17	
		05-30-85	<1	V	--	05-30-85	500	--	19	
		09-27-85	<1	V	--	09-27-85	490	--	18	
S	317WBRGU	05-31-84	4	V	--	05-31-84	290	--	26.5	SP 39
		10-25-84	<1	V	--	10-25-84	475	--	18	
		05-30-85	<1	V	--	05-30-85	495	--	17	
		09-27-85	<1	V	--	09-27-85	430	--	18	
S	317WSNGL	05-31-84	5	V	--	05-31-84	380	--	18	SP 40
		10-25-84	<1	V	--	10-25-84	490	--	15	
		--	--	--	--	09-27-85	480	--	18	
S	317GREN	06-01-84	4	V	--	06-01-84	565	--	11	SP 41
		09-21-84	<1	V	--	09-21-84	670	--	14.5	
		05-24-85	1	V	--	05-24-85	650	--	11	
		09-26-85	<1	V	--	09-26-85	635	--	14	
S	317WBRGU	--	--	--	--	08-02-84	--	--	26	SP 42
		--	--	--	--	08-02-84	515	--	--	
S	--	--	--	--	--	08-01-84	475	--	26	SP 43
S	317WSNGL	08-00-84	7	--	--	08-16-84	725	--	35	SP 44
S	317WBRGL	03-05-85	12	--	--	03-05-85	580	--	7.5	SP 45
S	317WBRGU	03-05-85	3	--	--	--	--	--	--	SP 46
S	317WBRGL	03-05-85	1	--	--	03-05-85	385	--	7	SP 47
W	317WBRGL	03-05-85	5	--	--	03-05-85	585	--	5.5	SP 48
S	--	--	--	--	--	--	--	--	--	SP 49
S	317WBRGL	03-05-85	9	--	--	03-05-85	250	--	4.5	SP 50
S	317WBRGL	03-05-85	1	--	--	03-05-85	280	--	3	SP 51
S	317WBRGL	03-05-85	2	--	--	03-05-85	420	--	7	SP 52
S	317WBRGU	03-07-85	2	--	--	03-07-85	580	--	9.5	SP 53
S	317WSNGL	03-07-85	1	--	--	03-07-85	560	--	9	SP 54
W	317WBRGL	--	--	--	--	03-07-85	385	--	8	SP 55
S	317WBRGU	03-07-85	3	--	--	03-07-85	500	--	9	SP 56
S	317WSNGM	--	--	--	--	03-07-85	745	--	12	SP 57
S	317WBRGL	03-07-85	1	--	--	03-07-85	800	--	8	SP 58
S	317WBRGU	03-07-85	11	--	--	03-07-85	530	--	11	SP 59
S	317WBRG	00-00-77	15	--	--	--	--	--	--	SP 60
S	317WBRGU	03-07-85	18	--	--	03-07-85	520	--	9	SP 61
S	321UNNN	03-07-85	<1	--	--	03-07-85	320	--	10	SP 62
S	317WSNGM	03-07-85	3	--	--	03-07-85	675	--	9	SP 63
S	317WSNG	05-22-85	<1	V	P	05-22-85	365	--	11.5	SP 64
W	321UNNN	06-12-85	3	V	P	06-12-85	650	--	14	SP 65
S	321PBRGC	06-13-85	40	--	P	06-13-85	1,120	--	12.5	SP 66
W	321PBRGU	06-13-85	<1	--	P	06-13-85	520	--	14	SP 67
S	321PBRGU	06-01-85	1	V	P	06-13-85	690	--	14.5	SP 68
S	321SCKL	06-13-85	2	V	P	06-13-85	625	--	13	SP 69
V	317WBRGL	07-12-85	3	V	P	07-12-85	660	--	14	SP 70
V	321PBRGU	07-12-85	3	V	P	07-12-85	675	--	13	SP 71
S	321PBRGL	07-12-85	20	--	P	07-12-85	1,400	--	12.5	SP 72
		09-05-85	12	--	--	09-05-85	1,500	--	12	
S	321CSLM	07-30-85	<1	V	P	07-30-85	470	--	22	SP 73
S	321CSLM	07-30-85	3	V	--	07-30-85	470	--	15	SP 74
S	321PBRGL	07-30-85	2	V	P	07-30-85	900	--	20	SP 75
S	321CSLM	07-30-85	1	V	P	07-30-85	700	--	14	SP 76
S	317WSNG	07-31-85	<1	V	--	07-31-85	500	--	19.5	SP 77
W	317GREN	08-13-85	<1	E	P	08-13-85	568	--	18	SP 78
S	317GREN	08-13-85	1	V	P	08-13-85	460	--	22	SP 79

USGS spring number	Location Latitude (degrees)	Location Longitude (degrees)	Quadrangle name	Township or borough	Owner	Primary use of water	Elevation of land surface (feet)
SP 80	400406	0802920	Claysville	--	--	H	1,220
SP 81	400414	0802401	Claysville	East Finley	--	U	1,270
SP 82	400250	0802313	Claysville	East Finley	--	U	1,340
SP 83	400733	0795613	California	Fallowfield	--	--	1,170
SP 91	401650	0802346	Avella	--	--	H	1,180
SP 92	401709	0802418	Avella	--	--	H	1,100
SP 93	401630	0802416	Avella	Cross Creek	Ihnat	H	1,100
SP 94	400152	0801721	Prosperity	Morris	Shriver	H	1,060
SP 95	400314	0800527	Ellsworth	W. Bethlehem	Dunn	H	960
SP 96	400233	0801740	Prosperity	Morris	Lindley	H	1,180
SP 97	400239	0801746	Prosperity	Morris	Lindley	S	1,060

Appendix D.--Record of springs--Continued

Topo-graphic setting	Hydro-geologic unit	Measurements of discharge: Date measured	Rate (gal/min)	Method used	Perm-an-ence	Field water quality measurements: Date measured	Specific conductance (μS/cm)	Hardness (mg/L as $CaCO_3$)	Temper-ature (deg C)	USGS spring number
S	317GREN	08-13-85	1	E	P	--	--	--	--	SP 80
S	317GREN	08-13-85	<1	V	--	08-13-85	240	--	14	SP 81
S	317GREN	08-13-85	2	V	P	08-13-85	420	--	13	SP 82
S	321PBRG	08-15-85	<1	V	P	08-15-85	790	--	17	SP 83
S	317WSNGM	--	--	--	--	06-15-83	500	--	11	SP 91
S	317WBRGL	--	--	--	--	06-16-83	660	--	21.5	SP 92
S	321UNNN	06-17-83	1	--	--	06-17-83	560	--	14	SP 93
		08-16-83	<1	--	--	08-16-83	550	--	18	
		08-22-84	<1	--	--	08-22-84	590	--	22	
		04-17-85	2	--	--	04-17-85	550	--	11	
		09-13-85	<1	--	--	09-13-85	535	--	17	
S	317GREN	08-12-83	1	--	P	08-12-83	530	--	20	SP 94
S	317WBRGM	09-07-83	3	--	--	09-07-83	650	--	10.5	SP 95
		04-24-85	7	--	--	04-24-85	560	--	10	
		09-27-85	2	--	--	09-27-85	605	--	13.5	
S	317GREN	03-15-84	7	V	P	03-15-84	480	--	4.5	SP 96
		09-02-84	<1	V	--	09-20-84	550	--	16	
		04-24-85	5	V	--	04-24-85	560	--	16	
		09-27-85	<1	V	--	09-27-85	445	--	16	
W	317GREN	03-15-84	40	C	P	03-15-84	265	--	3	SP 97
		09-20-84	2	V	--	09-20-84	345	--	15.5	
		04-24-85	9	V	--	04-24-85	240	--	25	
		09-27-85	<1	--	--	--	--	--	--	

Appendix E.--Chemical analysis of ground water

[Geologic unit explanation is in Appendix C; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; --, no data]

Local identifier	Date of sample	Geologic unit	Depth of well, total (feet)	Depth below land surface (water level) (feet)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
19	09-25-26	321MNGL	90.00	7.00	--	--	11.0	--	2.8	2.1	440
23	09-28-26	317GREN	64.00	20.00	--	--	11.0	--	98	30	12
31	09-16-26	112ALVM	28.00	2.00	--	--	11.0	--	5.3	3.9	140
41	09-30-26	321MNGL	107	45.00	--	--	11.0	--	83	18	12
61	09-22-26	321CNMG	100	5.00	--	--	10.0	--	36	9.0	34
74	09-30-26	--	--	--	--	--	11.5	--	62	17	34
	08-11-83	321UNNN	126	--	880	7.1	22.0	--	110	24	34
92	09-22-26	321CNMG	60.00	36.00	--	--	10.0	--	64	30	12
93	09-22-26	321CNMG	48.00	.00	--	--	10.0	--	82	30	97
100	09-21-26	321CNMG	90.00	--	--	--	11.0	--	510	140	27
113	09-21-26	321CNMG	87.00	45.00	--	--	12.0	--	73	27	32
130	09-25-26	317GREN	100	--	--	--	11.0	--	120	7.3	8.2
137	09-23-26	321CNMG	44.00	.00	--	--	13.5	--	110	22	8.2
142	10-29-26	321MNGL	200	60.00	--	--	12.0	--	63	18	240
155	07-01-71	317WSNG	160	38.00	518	8.2	--	--	15	4.3	100
	08-23-83	317WSNG	160	--	490	7.9	12.0	0.1	27	6.6	83
156	11-12-67	317WSNG	55.00	--	347	8.3	--	--	35	16	18
181	08-19-83	317WBRGL	92.20	--	520	7.0	14.0	.9	87	8.3	4.4
182	08-26-83	317WBRGL	74.20	--	540	7.4	15.0	.3	76	13	6.5
189	08-30-84	317WBRGU	32.00	30.00	555	7.4	13.5	.3	75	18	4.3
197	08-22-84	321UNNN	100	15.83	640	7.5	20.0	.3	55	11	60
205	08-24-83	317WBRGL	90.90	--	580	7.2	15.0	.6	77	14	23
209	09-07-83	317WBRGM	110	28.03	600	6.9	17.5	.8	84	13	17
219	09-04-85	317WSNGM	100	56.40	605	7.7	19.0	.2	80	25	5.8
222	09-02-83	317WSNGL	88.00	--	825	7.4	16.5	.5	110	29	13
240	08-11-83	321PBRGU	48.00	--	4,400	8.0	16.5	--	12	6.1	900
244	08-07-84	321SCKL	200	84.97	1,180	7.7	16.0	.2	55	22	150
265	08-16-83	321UNNN	99.20	--	850	7.3	13.0	.8	110	27	11
269	08-07-84	321UNNN	40.00	12.36	780	7.6	19.0	.1	92	21	25
271	08-18-83	317WSNGL	176	--	520	6.8	12.0	1.9	96	14	5.3
289	09-02-83	321PBRGU	80.00	--	1,630	8.8	19.0	--	2.0	.88	370
290	09-02-83	321PBRGU	85.00	--	1,380	8.6	16.5	--	5.4	2.1	310
291	09-02-83	321PBRGU	77.00	--	410	7.8	19.5	.2	58	12	8.6
292	08-23-84	321UNNN	90.00	18.87	565	7.2	21.0	.7	69	14	26
297	09-07-83	317WSNGU	125	--	1,850	7.0	23.5	1.7	190	130	47
300	09-07-83	317WSNGU	135	--	1,550	7.2	16.0	.9	150	76	60
301	09-07-83	317WBRGL	120	--	640	7.3	18.0	.6	76	17	26
303	08-17-83	317WBRGM	64.60	--	425	6.7	12.0	1.3	65	16	13
304	09-07-83	317WBRGL	110	--	900	8.4	15.0	--	9.3	3.5	200
314	08-17-83	321PBRGR	78.00	--	675	7.4	13.5	.4	71	23	41
320	09-07-83	317GREN	127	--	680	7.4	21.0	.3	70	16	40
322	09-05-84	317WSNGM	127	--	690	7.3	12.0	.6	87	28	14
324	08-29-85	321MRGN	301	--	1,500	7.4	12.5	.5	130	48	120
403	08-07-84	317WBRGL	165	92.72	840	7.6	21.0	.4	79	18	65
408	08-31-84	317GREN	20.83	17.10	875	7.1	14.0	--	110	17	30
	08-31-84	317GREN	20.83	--	--	--	--	--	--	--	--
409	09-07-83	317WSNGM	120	--	1,100	7.1	19.5	.8	100	53	52
412	08-31-84	317WBRGU	--	132.30	545	7.2	16.5	.6	52	8.2	50
421	08-11-83	321PBRGU	35.00	<0.00	525	7.6	18.0	--	60	17	28
430	08-06-84	321PBRGU	150	92.53	610	7.6	16.5	.2	47	19	46
438	08-11-83	321PBRG	153	--	450	7.1	18.0	--	110	33	27
493	08-16-83	321PBRGU	140	--	670	7.2	19.5	--	94	22	15
498	08-11-83	321UNNN	148	16.83	600	7.1	20.0	--	88	18	15
503	08-06-84	317WSNGL	165	--	780	7.2	14.0	.8	110	19	17
544	08-06-84	317WBRGL	75.00	38.25	810	7.4	18.5	.5	92	22	15
555	08-11-83	321UNNN	76.83	19.40	640	7.3	15.5	--	99	17	8.6
576	08-09-84	317WSNGL	90.00	59.78	440	7.3	13.5	.4	73	3.6	4.0
586	08-12-83	317WBRGU	54.00	--	840	7.0	19.0	--	110	15	41
592	08-09-84	317WSNGM	175	61.10	725	8.6	14.5	--	14	3.0	140
594	08-16-83	317WSNGU	110	--	2,500	7.2	16.5	--	46	5.4	460

Appendix E.--Chemical analysis of ground water--Continued

[Geologic unit explanation is in Appendix C; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; --, no data]

Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)	Carbonate fet-fld (mg/L as CO_3)	Alkalinity field (mg/L as $CaCO_3$)	Sulfide, total (mg/L as S)	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)	Solids, residue at 180 °C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Local identifier
9.6	870	--	711	--	3.8	200	--	7.3	1,120	1,100	19
3.5	360	--	292	--	86	6.4	--	17	436	430	23
3.2	390	--	318	--	5.0	12	--	16	382	380	31
2.2	330	--	273	--	23	2.6	--	26	320	330	41
2.4	220	--	184	--	5.3	9.0	--	17	222	220	61
4.8	260	--	212	--	62	18	--	16	330	340	74
2.1	290	--	240	--	110	81	0.20	12	621	520	
1.8	300	--	250	--	46	3.7	--	10	321	320	92
5.9	380	--	314	--	200	18	--	17	637	640	93
12	240	--	198	--	1,600	16	--	24	2,590	2,500	100
5.0	45	--	37	--	210	38	--	12	495	490	113
3.2	270	--	223	--	61	20	--	12	411	410	130
3.7	290	--	235	--	130	1.4	--	10	439	420	137
6.1	480	--	391	--	77	220	--	17	898	880	142
1.7	330	0	268	--	3.7	1.5	.60	9.8	318	300	155
1.2	310	--	250	<0.5	18	3.2	.30	11	346	300	
--	150	4	129	--	36	18	--	--	--	--	156
1.3	220	--	180	<.5	55	6.6	.20	11	267	280	181
1.0	230	--	190	<.5	54	5.6	.20	10	359	280	182
2.3	270	--	220	<.5	49	4.7	.10	7.2	333	290	189
1.0	320	--	270	<.5	32	24	.60	13	362	350	197
2.1	310	--	250	<.5	52	4.9	.10	12	365	340	205
1.0	250	--	200	<.5	68	26	.20	15	342	350	209
1.3	320	--	260	--	36	3.1	.10	13	332	320	219
1.5	380	--	310	<.5	82	21	.20	13	460	460	222
2.9	540	--	440	--	2.9	1,200	4.6	6.8	2,460	2,400	240
2.3	300	--	250	<.5	62	180	.60	9.2	576	630	244
2.4	370	--	310	<.5	26	62	.30	15	475	440	265
1.0	270	--	220	<.5	81	62	<.10	9.5	516	420	269
1.3	270	--	220	<.5	97	4.5	.20	12	431	370	271
1.0	750	26	660	<.5	.5	130	7.0	7.0	982	940	289
1.1	630	14	540	<.5	1.2	120	5.5	8.5	779	790	290
1.5	240	--	200	<.5	8.1	2.9	.30	21	219	230	291
1.4	310	--	260	<.5	48	3.7	.20	16	337	330	292
3.9	510	--	420	<.5	600	48	.20	9.1	1,390	1,300	297
3.4	440	--	360	<.5	260	120	.20	13	968	900	300
1.9	340	--	280	<.5	33	11	.30	14	344	350	301
1.5	190	--	160	<.5	56	19	.20	16	359	280	303
1.1	550	5	460	.6	4.1	23	1.0	10	534	530	304
1.3	350	--	290	<.5	55	5.5	.30	8.8	408	380	314
4.1	180	--	150	<.5	72	49	.20	12	388	350	320
1.1	370	--	300	<.5	62	11	<.10	10	435	400	322
6.1	280	--	230	--	530	16	.20	12	1,000	1,000	324
1.6	370	--	300	<.5	73	46	.50	12	396	480	403
.80	250	--	210	<.5	130	.00	.20	9.2	553	420	408
--	--	--	--	--	--	--	--	--	--	--	
3.9	370	--	300	<.5	200	35	.20	9.5	654	640	409
1.2	320	--	260	<.5	30	3.1	.60	17	322	320	412
1.7	270	--	220	--	40	12	.30	15	317	310	421
2.0	280	--	230	<.5	53	23	.20	9.4	326	340	430
2.7	380	--	310	--	70	63	.30	19	566	510	438
1.6	280	--	230	--	63	50	.30	13	396	400	493
1.2	280	--	230	--	57	26	.40	11	401	350	498
1.3	370	--	300	<.5	85	10	.10	10	401	430	503
2.3	310	--	250	.5	85	20	.20	11	391	400	544
1.0	220	--	180	--	49	59	.20	12	414	350	555
.50	180	--	140	<.5	67	5.7	.10	9.5	280	250	576
1.9	250	--	200	--	52	120	.20	15	562	480	586
.60	280	12	310	<.5	26	24	.70	10	444	380	592
2.9	540	--	440	--	1.5	530	0.60	8.7	1,360	1,300	594

Appendix E.--Chemical analysis of ground water--Continued

[Geologic unit explanation is in Appendix C; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; --, no data]

Local identifier	Date of sample	Geologic unit	Depth of well, total (feet)	Depth below land surface (water level) (feet)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Acidity (mg/L as H)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
601	08-09-84	317GREN	20.70	10.51	540	7.3	20.0	0.4	74	11	11
609	08-09-84	317WBRGL	188	35.30	1,950	8.7	21.5	--	4.3	1.5	400
618	09-02-83	317WSNGM	90.00	--	2,900	8.4	18.0	--	2.6	.90	650
620	08-23-84	317WBRGL	145	33.46	470	7.4	15.0	.7	76	7.5	5.1
626	08-30-84	317WSNGM	150	--	760	7.3	20.0	.4	64	23	50
636	08-08-84	317WSNGM	250	80.58	635	7.6	19.0	.3	69	14	38
652	08-30-84	317WSNGM	60.00	24.70	670	7.2	16.5	.6	85	18	15
680	08-30-84	321UNNN	60.00	20.93	1,140	8.2	12.5	.0	7.1	3.2	240
696	08-30-84	317WBRGL	80.00	52.11	565	7.3	16.0	.4	78	14	4.6
715	08-23-84	317GREN	32.00	28.60	435	7.2	21.5	.3	65	6.8	7.4
727	08-23-84	317GREN	22.80	19.00	475	7.4	17.5	.1	63	7.9	12
735	08-08-84	317WBRGL	<30.00	4.90	925	7.1	20.0	1.1	140	13	33
764	08-22-84	317WBRGL	129	25.15	770	7.4	19.0	.7	61	16	88
775	08-22-84	321UNNN	75.00	37.12	925	7.2	16.0	1.1	84	21	73
798	08-22-84	317WBRGU	200	82.69	565	8.0	20.5	.1	46	21	39
820	08-22-84	317WSNGM	180	96.54	605	7.5	18.0	.4	69	22	20
879	09-05-85	321RDSN	165	63.10	1,650	8.6	16.0	--	4.2	2.7	350
886	09-05-85	321UNNN	130	76.50	520	7.1	19.5	.4	63	15	11
902	08-11-83	321PBRG	100	41.65	660	7.8	21.5	--	25	15	100
905	08-07-84	321UNNN	100	33.20	825	9.1	20.0	--	1.5	.59	180
909	08-16-83	321PBRG	120	54.81	615	8.0	18.5	--	27	7.0	110
912	08-07-84	321UNNN	88.38	21.10	550	7.4	19.0	.4	72	12	21
914	08-16-83	321PBRG	100	15.81	1,100	7.4	20.0	--	120	24	68
915	08-19-83	321CSLM	176	--	560	7.1	14.0	--	72	22	11
917	08-19-83	321GLNS	160	54.65	680	8.3	20.5	--	14	4.5	150
918	08-19-83	321GLNS	104	--	1,400	8.2	18.5	--	4.7	1.3	310
919	08-19-83	321GLNS	165	--	520	7.5	23.5	--	32	8.8	81
921	08-25-83	321PBRG	120	--	960	7.4	17.0	--	120	26	23
922	08-25-83	321PBRG	85.00	--	720	7.4	20.5	--	95	20	20
923	09-02-83	321PBRG	148	22.69	830	7.0	19.0	1.0	110	27	18
924	09-02-83	321PBRG	50.00	--	930	7.1	17.0	.8	93	42	32
925	09-02-83	317WBRGU	125	55.00	1,170	6.8	10.5	1.9	140	33	30
930	08-08-84	321UNNN	100	37.39	610	7.4	21.5	.4	80	22	6.7
931	08-08-84	317GREN	49.16	47.10	845	8.0	17.5	.1	120	16	22
950	09-04-85	321CSLM	210	--	650	8.2	19.5	--	12	3.4	130
952	09-04-85	321GLNS	60.00	--	1,210	8.9	14.5	--	4.6	1.6	250
955	09-06-85	317WSNGM	150	83.40	650	7.4	13.0	.5	93	20	5.6
966	09-05-85	321UNNN	130	68.50	690	7.4	16.5	.5	64	20	47
972	09-05-85	321RDSN	90.00	55.30	835	7.4	18.5	.8	100	35	13
SP 10	08-11-83	321UNNN	--	--	550	7.9	12.5	--	78	19	13
SP 11	09-02-83	317WBRGM	--	--	520	7.3	19.5	.4	84	12	3.4
SP 72	09-05-85	321PBRGL	--	--	1,500	7.4	12.0	.6	140	55	92
SP 93	08-16-83	321UNNN	--	--	550	7.9	18.0	--	110	4.9	2.4
SP 94	08-12-83	317GREN	--	--	530	7.9	20.0	--	95	10	4.2
SP 95	09-07-83	317WBRGM	--	--	650	7.5	10.5	.4	60	11	59

Appendix E.--Chemical analysis of ground water--Continued

[Geologic unit explanation is in Appendix C; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; --, no data]

Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)	Carbonate fet-fld (mg/L as CO_3)	Alkalinity field (mg/L as $CaCO_3$)	Sulfide, total (mg/L as S)	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)	Solids, residue at 180 °C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Local identifier
1.3	230	--	190	<0.5	42	20	.10	10	316	280	601
1.1	680	19	590	<.5	2.0	390	2.5	8.1	1,110	1,200	609
1.0	800	2	660	<.5	.8	550	2.4	7.0	1,590	1,600	618
1.3	230	--	190	<.5	51	4.2	.10	10	305	270	620
1.9	270	--	220	<.5	60	70	.20	11	467	410	626
2.8	200	--	160	<.5	86	43	.30	9.3	450	360	636
1.3	270	--	220	<.5	70	31	.20	14	381	370	652
1.8	470	--	380	<.5	.6	130	1.1	8.7	634	620	680
1.7	270	--	220	<.5	50	6.7	.20	14	340	300	696
.70	190	--	150	--	46	7.1	.10	7.4	290	230	715
6.7	180	--	150	--	53	9.5	.10	9.8	311	250	727
1.9	340	--	280	<.5	140	47	.20	11	603	550	735
3.1	220	--	180	<.5	1.7	49	.20	17	510	340	764
3.0	450	--	370	<.5	47	58	.20	16	397	520	775
1.9	340	--	280	<.5	28	3.7	.30	14	306	320	798
1.8	330	--	270	<.5	31	13	.20	21	336	340	820
1.2	840	--	720	--	92	70	2.5	7.8	948	940	879
1.3	160	--	130	--	83	15	.10	13	301	280	886
2.1	380	--	310	--	21	21	.70	11	396	380	902
.60	460	34	380	<.5	6.6	36	1.6	8.4	469	530	905
1.8	390	--	320	--	27	4.0	.80	10	396	380	909
1.5	310	--	250	<.5	40	3.2	.30	11	266	310	912
1.7	320	--	270	--	160	93	.20	10	690	630	914
2.1	200	--	160	<.5	100	20	.10	13	381	340	915
1.0	430	--	350	<.5	11	2.4	1.1	8.8	419	400	917
1.1	480	--	390	<.5	3.4	210	2.7	6.9	734	780	918
1.4	300	--	250	<.5	22	5.8	.50	14	288	310	919
1.4	270	--	220	<.5	77	120	.20	16	539	520	921
1.2	280	--	230	<.5	55	55	.30	17	386	400	922
1.4	330	--	270	<.5	76	53	.20	12	526	460	923
1.5	380	--	310	<.5	68	73	.30	9.6	559	510	924
3.5	310	--	250	<.5	130	130	.40	14	718	630	925
1.7	310	--	250	<.5	70	.00	.20	12	340	350	930
2.4	230	--	190	<.5	92	.00	.10	9.9	512	380	931
1.5	360	--	290	--	31	4.0	.40	11	373	370	950
.50	390	--	360	--	5.1	160	1.9	7.0	682	620	952
1.4	320	--	260	--	54	8.5	.10	13	302	350	955
2.1	300	--	240	--	84	9.7	.20	9.8	381	380	966
1.6	--	--	340	--	55	27	.10	14	381	450	972
1.6	260	--	210	--	71	5.0	.30	12	380	330	SP 10
1.1	240	--	200	<.5	52	7.6	.40	11	303	290	SP 11
3.4	350	--	280	--	440	19	.20	6.4	984	930	SP 72
.70	300	--	240	--	50	2.2	.20	8.7	267	330	SP 93
.80	260	--	210	--	44	6.1	.20	10	304	300	SP 94
1.4	330	--	270	<.5	58	2.6	.30	10	356	360	SP 95

Appendix F.--Trace-element analyses of ground water

[See Appendix C for explanation of geologic unit; µg/L, micrograms per liter; <, less than; --, no data]

Local identifier	Date of sample	Geologic unit	Aluminum, dissolved (µg/L as Al)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, hexavalent, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)
19	09-25-26	321MNGL	--	--	--	--	--	--	--	--	--
23	09-28-26	317GREN	--	--	--	--	--	--	--	--	--
31	09-16-26	112ALVM	--	--	--	--	--	--	--	--	--
41	09-30-26	321MNGL	--	--	--	--	--	--	--	--	--
61	09-22-26	321CNMG	--	--	--	--	--	--	--	--	--
74	09-30-26	--	--	--	--	--	--	--	--	--	--
	08-11-83	321UNNN	--	--	--	70	--	--	--	--	130
92	09-22-26	321CNMG	--	--	--	--	--	--	--	--	--
93	09-22-26	321CNMG	--	--	--	--	--	--	--	--	--
100	09-21-26	321CNMG	--	--	--	--	--	--	--	--	--
113	09-21-26	321CNMG	--	--	--	--	--	--	--	--	--
130	09-25-26	317GREN	--	--	--	--	--	--	--	--	--
137	09-23-26	321CNMG	--	--	--	--	--	--	--	--	--
142	10-29-26	321MNGL	--	--	--	--	--	--	--	--	--
155	07-01-71	317WSNG	--	--	--	--	--	--	--	--	--
	08-23-83	317WSNG	<10	3	--	100	<1	<1	5	1	1,900
156	11-12-67	317WSNG	1,200	--	--	--	--	--	--	--	--
181	08-19-83	317WBRGL	--	--	--	30	--	--	--	--	240
182	08-26-83	317WBRGL	10	3	--	20	<1	<1	3	5	850
189	08-30-84	317WBRGU	--	--	--	<20	--	--	--	--	3,300
197	08-22-84	321UNNN	--	--	--	140	--	--	--	--	460
205	08-24-83	317WBRGL	1,000	3	--	50	<1	1	7	2	17,000
209	09-07-83	317WBRGM	--	--	--	<20	--	--	--	--	250
219	09-04-85	317WSNGM	--	--	--	20	--	--	--	--	20
222	09-02-83	317WSNGL	--	--	--	70	--	--	--	--	100
240	08-11-83	321PBRGU	--	--	--	490	--	--	--	--	390
244	08-07-84	321SCKL	--	--	--	150	--	--	--	--	110
265	08-16-83	321UNNN	10	3	--	60	<1	1	5	6	2,100
269	08-07-84	321UNNN	--	--	--	40	--	--	--	--	110
271	08-18-83	317WSNGL	<100	4	--	50	<1	<1	9	6	3,400
289	09-02-83	321PBRGU	--	--	--	450	--	--	--	--	120
290	09-02-83	321PBRGU	--	--	--	390	--	--	--	--	110
291	09-02-83	321PBRGU	--	--	--	40	--	--	--	--	160
292	08-23-84	321UNNN	--	--	--	50	--	--	--	--	200
297	09-07-83	317WSNGU	--	--	--	40	--	--	--	--	490
300	09-07-83	317WSNGU	--	--	--	60	--	--	--	--	950
301	09-07-83	317WBRGL	--	--	--	50	--	--	--	--	110
303	08-17-83	317WBRGM	<10	3	--	50	<1	<1	4	10	1,000
304	09-07-83	317WBRGL	--	--	--	140	--	--	--	--	110
314	08-17-83	321PBRGR	--	--	--	--	--	--	--	--	--
320	09-07-83	317GREN	--	--	--	80	--	--	--	--	360
322	09-05-84	317WSNGM	90	1	--	<20	<1	<1	2	8	4,500
324	08-29-85	321MRGN	<10	<1	79	--	<1	<1	2	3	1,700
403	08-07-84	317WBRGL	--	--	--	140	--	--	--	--	120
408	08-31-84	317GREN	--	--	--	60	--	--	--	--	450
409	09-07-83	317WSNGM	--	--	--	90	--	--	--	--	130
412	08-31-84	317WBRGU	--	--	--	40	--	--	--	--	520
421	08-11-83	321PBRGU	--	--	--	120	--	--	--	--	340
430	08-06-84	321PBRGU	--	--	--	80	--	--	--	--	130
438	08-11-83	321PBRG	--	--	--	90	--	--	--	--	160
493	08-16-83	321PBRGU	--	--	--	50	--	--	--	--	130
498	08-11-83	321UNNN	--	--	--	40	--	--	--	--	170
503	08-06-84	317WSNGL	--	--	--	70	--	--	--	--	350
544	08-06-84	317WBRGL	--	--	--	60	--	--	--	--	100
555	08-11-83	321UNNN	--	--	--	<20	--	--	--	--	210
576	08-09-84	317WSNGL	--	--	--	<20	--	--	--	--	100
586	08-12-83	317WBRGU	--	--	--	30	--	--	--	--	1,700
592	08-09-84	317WSNGM	--	--	--	110	--	--	--	--	90
594	08-16-83	317WSNGU	--	--	--	120	--	--	--	--	3,300
601	08-09-84	317GREN	--	--	--	30	--	--	--	--	260

Appendix F.--Trace-element analyses of ground water--Continued

[See Appendix C for explanation of geologic unit; µg/L, micrograms per liter; <, less than; --, no data]

Local identifier	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as AG)	Strontium, dissolved (µg/L as SR)	Zinc, dissolved (µg/L as ZN)
19	220	--	--	--	--	--	--	--	--	--
23	930	--	--	--	--	--	--	--	--	--
31	70	--	--	--	--	--	--	--	--	--
41	1,300	--	--	--	--	--	--	--	--	--
61	1,700	--	--	--	--	--	--	--	--	--
74	70	--	--	--	--	--	--	--	--	--
	<3	--	20	2	--	--	--	--	--	--
92	520	--	--	--	--	--	--	--	--	--
93	170	--	--	--	--	--	--	--	--	--
100	2,300	--	--	--	--	--	--	--	--	--
113	700	--	--	--	--	--	--	--	--	--
130	810	--	--	--	--	--	--	--	--	--
137	800	--	--	--	--	--	--	--	--	--
142	70	--	--	--	--	--	--	--	--	--
155	500	--	--	40	--	--	--	--	--	--
	17	<1	290	30	<0.1	<1	<1	--	580	9
156	9,100	--	--	500	--	--	--	--	--	--
181	16	--	30	16	--	--	--	--	--	--
182	5	<1	70	6	<.1	<1	1	--	310	29
189	5	--	50	10	--	--	--	--	--	--
197	51	--	40	26	--	--	--	--	--	--
205	2,100	1	810	750	<.1	<1	<1	--	580	33
209	<3	--	40	15	--	--	--	--	--	--
219	7	--	10	5	--	--	--	--	--	--
222	5	--	<10	1	--	--	--	--	--	--
240	50	--	10	20	--	--	--	--	--	--
244	5	--	10	7	--	--	--	--	--	--
265	140	<1	370	340	<.1	<1	<1	--	810	23
269	5	--	10	1	--	--	--	--	--	--
271	3,100	<1	350	340	<.1	<1	<1	--	750	34
289	10	--	<10	<1	--	--	--	--	--	--
290	14	--	<10	1	--	--	--	--	--	--
291	20	--	40	42	--	--	--	--	--	--
292	10	--	80	70	--	--	--	--	--	--
297	15	--	30	31	--	--	--	--	--	--
300	25	--	10	4	--	--	--	--	--	--
301	16	--	20	12	--	--	--	--	--	--
303	8	<1	330	120	<.1	<1	<1	--	500	49
304	11	--	10	3	--	--	--	--	--	--
314	47	--	40	5	--	--	--	--	--	--
320	6	--	20	9	--	--	--	--	--	--
322	19	4	100	14	<.1	3	<1	--	490	1,100
324	900	1	160	140	.1	5	<1	<1	6,700	54
403	7	--	10	2	--	--	--	--	--	--
408	100	--	50	33	--	--	--	--	--	--
409	14	--	10	<1	--	--	--	--	--	--
412	8	--	40	2	--	--	--	--	--	--
421	5	--	30	22	--	--	--	--	--	--
430	12	--	10	1	--	--	--	--	--	--
438	3	--	20	16	--	--	--	--	--	--
493	15	--	10	1	--	--	--	--	--	--
498	3	--	10	3	--	--	--	--	--	--
503	18	--	<10	15	--	--	--	--	--	--
544	4	--	10	2	--	--	--	--	--	--
555	8	--	20	8	--	--	--	--	--	--
576	4	--	<10	1	--	--	--	--	--	--
586	1,400	--	1,100	1,100	--	--	--	--	--	--
592	7	--	<10	1	--	--	--	--	--	--
594	30	--	210	180	--	--	--	--	--	--
601	4	--	<10	2	--	--	--	--	--	--

Appendix F.--Trace-element analyses of ground water--Continued

[See Appendix C for explanation of geologic unit; µg/L, micrograms per liter; <, less than; --, no data]

Local identifier	Date of sample	Geologic unit	Aluminum, dissolved (µg/L as Al)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, hexavalent, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)
609	08-09-84	317WBRGL	--	--	--	310	--	--	--	--	170
618	09-02-83	317WSNGM	--	--	--	240	--	--	--	--	60
620	08-23-84	317WBRGL	--	--	--	20	--	--	--	--	240
626	08-30-84	317WSNGM	--	--	--	60	--	--	--	--	130
636	08-08-84	317WSNGM	--	--	--	130	--	--	--	--	730
652	08-30-84	317WSNGM	--	--	--	40	--	--	--	--	1,400
680	08-30-84	321UNNN	--	--	--	250	--	--	--	--	290
696	08-30-84	317WBRGL	--	--	--	30	--	--	--	--	160
715	08-23-84	317GREN	--	--	--	<20	--	--	--	--	140
727	08-23-84	317GREN	--	--	--	150	--	--	--	--	150
735	08-08-84	317WBRGL	--	--	--	260	--	--	--	--	130
764	08-22-84	317WBRGL	--	--	--	260	--	--	--	--	300
775	08-22-84	321UNNN	--	--	--	130	--	--	--	--	970
798	08-22-84	317WBRGU	--	--	--	60	--	--	--	--	90
820	08-22-84	317WSNGM	--	--	--	70	--	--	--	--	120
879	09-05-85	321RDSN	--	--	--	420	--	--	--	--	70
886	09-05-85	321UNNN	--	--	--	30	--	--	--	--	90
902	08-11-83	321PBRG	--	--	--	240	--	--	--	--	200
905	08-07-84	321UNNN	--	--	--	300	--	--	--	--	130
909	08-16-83	321PBRG	--	--	--	220	--	--	--	--	150
912	08-07-84	321UNNN	--	--	--	80	--	--	--	--	4,300
914	08-16-83	321PBRG	--	--	--	120	--	--	--	--	850
915	08-19-83	321CSLM	--	--	--	60	--	--	--	--	140
917	08-19-83	321GLNS	--	--	--	250	--	--	--	--	160
918	08-19-83	321GLNS	--	--	--	280	--	--	--	--	130
919	08-19-83	321GLNS	--	--	--	120	--	--	--	--	170
921	08-25-83	321PBRG	--	--	--	50	--	--	--	--	450
922	08-25-83	321PBRG	--	--	--	40	--	--	--	--	280
923	09-02-83	321PBRG	--	--	--	30	--	--	--	--	80
924	09-02-83	321PBRG	--	--	--	50	--	--	--	--	120
925	09-02-83	317WBRGU	--	--	--	120	--	--	--	--	2,100
930	08-08-84	321UNNN	--	--	--	40	--	--	--	--	1,900
931	08-08-84	317GREN	--	--	--	80	--	--	--	--	150
950	09-04-85	321CSLM	--	--	--	150	--	--	--	--	50
952	09-04-85	321GLNS	--	--	--	350	--	--	--	--	160
955	09-06-85	317WSNGM	--	--	--	30	--	--	--	--	60
966	09-05-85	321UNNN	--	--	--	80	--	--	--	--	50
972	09-05-85	321RDSN	--	--	--	30	--	--	--	--	400
SP 10	08-11-83	321UNNN	--	--	--	60	--	--	--	--	140
SP 11	09-02-83	317WBRGM	--	--	--	30	--	--	--	--	150
SP 72	09-05-85	321PBRGL	--	--	--	90	--	--	--	--	50
SP 93	08-16-83	321UNNN	--	--	--	<20	--	--	--	--	120
SP 94	08-12-83	317GREN	--	--	--	<20	--	--	--	--	410
SP 95	09-07-83	317WBRGM	--	--	--	50	--	--	--	--	130

Appendix F.--Trace-element analyses of ground water--Continued

[See Appendix C for explanation of geologic unit; µg/L, micrograms per liter; <, less than; --, no data]

Local iden- tifier	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Manga- nese, total recov- erable (µg/L as Mn)	Manga- nese, dis- solved (µg/L as Mn)	Mercury, dis- solved (µg/L as Hg)	Nickel, dis- solved (µg/L as Ni)	Sele- nium, dis- solved (µg/L as Se)	Silver, dis- solved (µg/L as AG)	Stron- tium, dis- solved (µg/L as SR)	Zinc, dis- solved (µg/L as ZN)
609	13	--	<10	4	--	--	--	--	--	--
618	40	--	10	10	--	--	--	--	--	--
620	4	--	<10	1	--	--	--	--	--	--
626	24	--	60	2	--	--	--	--	--	--
636	4	--	110	33	--	--	--	--	--	--
652	97	--	220	230	--	--	--	--	--	--
680	11	--	10	8	--	--	--	--	--	--
696	6	--	60	41	--	--	--	--	--	--
715	5	--	<10	6	--	--	--	--	--	--
727	5	--	10	3	--	--	--	--	--	--
735	8	--	10	3	--	--	--	--	--	--
764	42	--	60	32	--	--	--	--	--	--
775	140	--	130	120	--	--	--	--	--	--
798	5	--	<10	<1	--	--	--	--	--	--
820	7	--	30	2	--	--	--	--	--	--
879	18	--	10	6	--	--	--	--	--	--
886	10	--	20	6	--	--	--	--	--	--
902	20	--	10	7	--	--	--	--	--	--
905	19	--	<10	5	--	--	--	--	--	--
909	9	--	20	4	--	--	--	--	--	--
912	66	--	100	100	--	--	--	--	--	--
914	5	--	110	83	--	--	--	--	--	--
915	20	--	340	320	--	--	--	--	--	--
917	11	--	10	2	--	--	--	--	--	--
918	8	--	20	13	--	--	--	--	--	--
919	13	--	20	11	--	--	--	--	--	--
921	11	--	310	290	--	--	--	--	--	--
922	5	--	40	17	--	--	--	--	--	--
923	6	--	50	40	--	--	--	--	--	--
924	<3	--	20	11	--	--	--	--	--	--
925	15	--	60	48	--	--	--	--	--	--
930	320	--	80	80	--	--	--	--	--	--
931	7	--	10	<1	--	--	--	--	--	--
950	18	--	50	32	--	--	--	--	--	--
952	18	--	10	5	--	--	--	--	--	--
955	12	--	20	15	--	--	--	--	--	--
966	43	--	90	85	--	--	--	--	--	--
972	12	--	80	49	--	--	--	--	--	--
SP 10	4	--	130	120	--	--	--	--	--	--
SP 11	15	--	10	3	--	--	--	--	--	--
SP 72	4	--	10	3	--	--	--	--	--	--
SP 93	<3	--	10	<1	--	--	--	--	--	--
SP 94	11	--	20	14	--	--	--	--	--	--
SP 95	<3	--	10	<1	--	--	--	--	--	--

Appendix G.--Surface-water quality data

[ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (μS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
03085237 CHARTIERS CREEK AT HOUSTON, PA Site 1 (LAT 40 14 26 LONG 080 12 31)											
MAY 13, 1983	0750	48	660	7.7	14.5	250	5.0	74	16	35	3.6
SEPT 02, 1983	1550	--	820	7.6	23.0	260	--	78	15	65	7.5
AUG 28, 1984	0800	13	750	7.3	21.0	230	--	69	14	54	6.5
AUG 22, 1985	1510	13	850	7.4	21.0	250	9.9	75	15	64	12
03085240 CHARTIERS RUN AT HOUSTON, PA Site 2 (LAT 40 14 54 LONG 080 12 39)											
MAY 13, 1983	0845	20	710	8.0	12.5	350	5.0	86	32	27	2.2
AUG 31, 1983	1400	8.5	1,050	7.9	21.0	530	--	130	49	32	4.0
AUG 28, 1984	0900	5.6	760	7.8	18.5	320	--	83	27	29	5.9
AUG 22, 1985	1235	1.9	930	7.8	20.5	440	5.0	110	40	49	4.0
03085300 LITTLE CHARTIERS CREEK AT LINDEN, PA Site 3 (LAT 40 14 14 LONG 080 08 20)											
MAY 13, 1983	1100	33	500	8.5	15.5	210	--	66	11	18	1.4
AUG 31, 1983	0815	12	480	7.9	20.5	190	--	59	9.5	24	4.3
AUG 27, 1984	1500	2.5	600	8.3	22.0	220	--	67	13	34	3.1
AUG 22, 1985	1610	2.4	625	8.1	22.0	230	.0	71	13	36	3.9
03085310 RES #2 LITTLE CHARTIERS CREEK NEAR MCMURRAY, PA Site 4 (LAT 40 15 27 LONG 080 06 05)											
MAY 13, 1983	1150	.75	510	8.4	17.0	230	--	67	16	20	1.5
AUG 31, 1983	0920	.28	570	8.0	18.0	240	--	73	15	23	5.0
AUG 28, 1984	0920	.11	655	8.2	17.0	270	--	79	18	23	2.1
AUG 22, 1985	1740	.06	625	8.1	19.0	280	.0	80	19	24	2.1

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recov-erable (μg/L as Fe)	Iron, dissolved (μg/L as Fe)	Manga-nese, total recov-erable (μg/L as Mn)	Manganese, dissolved (μg/L as Mn)
03085237 CHARTIERS CREEK AT HOUSTON, PA Site 1 (LAT 40 14 26 LONG 080 12 31)										
MAY 13, 1983	140	110	40	0.70	5.0	411	410	41	170	160
SEPT 02, 1983	140	140	69	1.4	11	561	990	37	330	280
AUG 28, 1984	130	110	.00	2.2	8.8	459	1,200	49	310	280
AUG 22, 1985	120	150	73	1.3	9.5	535	830	38	140	120
03085240 CHARTIERS RUN AT HOUSTON, PA Site 2 (LAT 40 14 54 LONG 080 12 39)										
MAY 13, 1983	160	210	40	.40	7.3	501	340	22	330	320
AUG 31, 1983	110	440	14	.50	9.8	783	430	16	490	490
AUG 28, 1984	160	210	20	.40	7.6	500	1,000	47	170	140
AUG 22, 1985	160	330	18	.60	7.7	600	490	23	240	220
03085300 LITTLE CHARTIERS CREEK AT LINDEN, PA Site 3 (LAT 40 14 14 LONG 080 08 20)										
MAY 13, 1983	150	66	20	.20	4.5	290	200	13	40	56
AUG 31, 1983	140	61	31	.20	7.5	296	2,600	28	190	12
AUG 27, 1984	170	84	44	.30	5.0	372	410	13	30	19
AUG 22, 1985	170	74	48	.30	6.4	373	470	6	40	21
03085310 RES #2 LITTLE CHARTIERS CREEK NEAR MCMURRAY, PA Site 4 (LAT 40 15 27 LONG 080 06 05)										
MAY 13, 1983	170	62	23	.20	8.1	323	210	19	60	57
AUG 31, 1983	180	68	28	.20	12	352	1,300	45	240	110
AUG 28, 1984	240	54	32	.10	11	355	1,600	12	190	86
AUG 22, 1985	230	56	32	.30	11	378	640	8	80	33

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (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)
03075081 PETERS CREEK AT GASTONVILLE, PA Site 5 (LAT 40 15 56 LONG 079 58 58)											
MAY 13, 1983	1740	12	1,430	7.3	20.0	460	9.9	120	39	160	2.0
AUG 31, 1983	0905	11	1,740	7.6	19.5	370	--	99	30	200	3.8
AUG 28, 1984	1225	2.9	3,500	8.3	20.5	520	--	130	48	520	3.6
AUG 23, 1985	0745	2.4	4,300	8.0	15.5	600	5.0	140	60	810	4.3
03075058 MINGO CREEK AT RIVER VIEW, PA Site 6 (LAT 40 12 31 LONG 079 57 53)											
MAY 13, 1983	1550	20	730	8.6	19.5	270	--	71	22	56	1.8
AUG 31, 1983	1120	15	1,150	8.0	20.0	370	--	110	24	100	3.4
AUG 28, 1984	1055	1.8	1,550	8.3	19.0	470	--	130	36	150	4.4
AUG 23, 1985	0745	.70	2,000	7.9	16.0	610	5.0	160	50	220	5.8
03075037 PIGEON CREEK AT HAZEL HURST, PA Site 7 (LAT 40 10 38 LONG 079 57 25)											
MAY 13, 1983	1350	50	1,230	9.1	18.0	360	--	95	29	150	2.8
AUG 30, 1983	1730	13	2,420	8.5	26.5	490	--	130	40	410	7.2
AUG 28, 1984	0955	7.6	2,250	8.6	20.0	390	--	100	34	340	5.4
AUG 23, 1985	1030	7.1	2,800	8.6	18.0	460	--	120	38	470	6.3
03075035 NORTH BRANCH PIGEON CREEK AT BENTLYVILLE, PA Site 8 (LAT 40 07 54 LONG 080 00 19)											
MAY 13, 1983	1120	10	700	8.5	--	330	--	89	25	21	1.7
AUG 31, 1983	1305	5.9	675	7.9	21.0	280	--	79	21	21	4.7
AUG 25, 1984	0835	.38	945	8.3	19.0	420	--	110	35	47	4.0
AUG 23, 1985	1145	.33	1,000	7.6	19.0	460	15	120	38	43	4.3

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03075081 PETERS CREEK AT GASTONVILLE, PA Site 5 (LAT 40 15 56 LONG 079 58 58)										
MAY 13, 1983	110	480	100	0.50	11	1,030	1,800	19	1,300	990
AUG 31, 1983	82	570	130	.50	8.9	1,020	4,000	19	970	520
AUG 28, 1984	152	980	610	.70	7.9	2,280	430	40	310	320
AUG 23, 1985	170	1,700	430	.80	8.2	3,290	520	40	390	370
03075058 MINGO CREEK AT RIVER VIEW, PA Site 6 (LAT 40 12 31 LONG 079 57 53)										
MAY 13, 1983	140	200	21	.20	5.4	491	220	18	10	20
AUG 31, 1983	140	380	45	.40	7.7	771	1,300	20	140	33
AUG 28, 1984	182	440	63	.40	6.7	1,050	230	8	70	65
AUG 23, 1985	170	830	90	.30	7.4	1,580	160	30	90	100
03075037 PIGEON CREEK AT HAZEL HURST, PA Site 7 (LAT 40 10 38 LONG 079 57 25)										
MAY 13, 1983	150	390	60	.30	5.4	822	140	14	40	29
AUG 30, 1983	200	930	210	.50	4.9	1,880	350	20	90	50
AUG 28, 1984	240	530	180	.50	2.9	1,400	210	20	30	20
AUG 23, 1985	230	920	230	.60	4.6	2,020	270	30	30	30
03075035 NORTH BRANCH PIGEON CREEK AT BENTLYVILLE, PA Site 8 (LAT 40 07 54 LONG 080 00 19)										
MAY 13, 1983	170	190	11	.20	7.0	474	460	22	250	210
AUG 31, 1983	110	200	16	.30	8.1	440	9,200	160	710	340
AUG 25, 1984	200	250	29	.30	5.2	632	360	14	40	19
AUG 23, 1985	220	300	31	.20	6.7	741	240	12	30	19

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (µS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
	03074800	PIKE RUN AT DAISYTOWN, PA Site 9 (LAT 40 03 32 LONG 079 55 32)									
MAY 13, 1983	0950	20	890	8.4	11.5	350	--	89	31	62	2.8
AUG 30, 1983	1430	5.9	750	8.5	25.5	390	--	100	34	120	5.8
AUG 27, 1984	0920	2.2	1,230	8.2	15.5	400	--	100	36	170	4.4
AUG 22, 1985	1300	6.4	1,540	8.4	21.0	390	--	96	36	170	5.0
	03072820	DANIELS RUN AT WEST ZOLLARSVILLE, PA Site 10 (LAT 40 01 51 LONG 080 05 32)									
MAY 12, 1983	1250	15	1,140	8.8	15.0	260	--	76	17	160	1.8
AUG 30, 1983	1150	3.5	6,900	8.3	19.5	600	--	160	48	1100	6.6
AUG 27, 1984	1135	3.2	7,000	8.3	17.0	490	--	87	67	1700	6.9
AUG 22, 1985	1000	3.5	7,000	8.1	17.5	590	5.0	130	65	1400	6.1
	03072818	DANIELS RUN NEAR WEST ZOLLARSVILLE, PA Site 11 (LAT 40 03 06 LONG 080 05 37)									
OCT 19, 1982	1530	.25	4,700	8.3	16.5	390	--	110	29	840	4.9
MAY 12, 1983	1455	8.1	690	8.7	20.0	190	--	59	11	61	2.1
JUNE 23, 1983	1415	2.2	1,210	8.5	25.5	220	--	66	13	190	2.7
AUG 30, 1983	1300	1.2	1,950	8.3	25.5	250	--	73	16	280	4.5
JAN 30, 1984	1245	3.9	610	8.1	1.5	170	--	54	9.7	59	2.3
APR 13, 1984	1415	11	500	8.7	18.0	180	--	56	9.9	35	1.6
AUG 27, 1984	1050	.56	2,120	8.2	19.0	290	--	85	20	380	3.7
NOV 09, 1984	0830	2.0	1,690	7.9	10.0	--	6.0	76	17	260	3.3
FEB 01, 1985	0845	2.5	1,030	7.9	.0	210	--	64	13	170	2.1
APR 24, 1985	1300	5.0	580	8.3	23.0	190	--	58	12	45	2.4
AUG 22, 1985	1100	.48	2,900	8.2	22.5	330	.0	90	25	520	4.6

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recov-erable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manga-nese, total recov-erable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03074800 PIKE RUN AT DAISYTOWN, PA Site 9 (LAT 40 03 32 LONG 079 55 32)										
MAY 13, 1983	170	290	16	0.20	6.8	654	4,800	<3	590	87
AUG 30, 1983	120	510	28	.30	8.5	930	180	20	90	39
AUG 27, 1984	190	430	32	.30	6.7	1,030	210	8	30	30
AUG 22, 1985	204	500	38	.40	8.5	1,070	220	12	70	36
03072820 DANIELS RUN AT WEST ZOLLARSVILLE, PA Site 10 (LAT 40 01 51 LONG 080 05 32)										
MAY 12, 1983	180	290	67	.20	5.5	710	130	<3	50	55
AUG 30, 1983	370	2,100	350	.30	8.0	4,060	360	50	80	50
AUG 27, 1984	460	2,600	910	.40	9.2	6,050	220	50	70	60
AUG 22, 1985	370	2,600	480	.40	10	5,300	180	30	260	250
03072818 DANIELS RUN NEAR WEST ZOLLARSVILLE, PA Site 11 (LAT 40 03 06 LONG 080 05 37)										
OCT 19, 1982	270	950	720	.80	4.7	2,680	230	20	150	100
MAY 12, 1983	150	110	55	.20	5.6	420	140	4	40	23
JUNE 23, 1983	210	220	140	.40	6.1	778	260	<3	50	53
AUG 30, 1983	180	320	250	.40	7.6	1,100	530	22	120	69
JAN 30, 1984	150	94	50	<.10	6.5	392	520	12	60	50
APR 13, 1984	140	84	27	.20	5.2	305	270	9	40	27
AUG 27, 1983	210	370	420	.50	5.5	1,350	350	30	90	80
NOV 09, 1983	210	320	190	.40	5.6	988	200	14	60	52
FEB 01, 1985	190	220	120	.30	6.4	725	340	14	110	81
APR 24, 1985	170	83	27	.20	3.8	334	590	15	60	28
AUG 22, 1985	250	680	410	.70	6.3	1,970	240	20	90	80

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (µS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
03072817 LITTLE TENMILE CREEK NEAR TENMILE, PA Site 12 (LAT 40 01 15 LONG 080 07 41)											
MAY 12, 1983	1025	23	375	8.5	12.0	170	--	53	9.1	14	1.5
AUG 30, 1983	0955	11	395	8.0	19.5	160	--	53	7.2	13	4.3
AUG 27, 1984	1313	1.7	475	8.3	19.0	180	--	56	9.2	22	3.1
AUG 22, 1985	0900	1.2	480	7.8	18.5	190	9.9	59	10	30	3.9
03072815 TENMILE CREEK NEAR AMITY, PA Site 13 (LAT 40 01 11 LONG 080 12 20)											
MAY 12, 1983	0820	50	320	8.0	12.5	150	.0	48	6.3	7.1	1.1
AUG 31, 1983	0840	5.4	360	7.8	21.5	150	--	51	6.2	10	3.9
AUG 27, 1984	0800	2.5	390	7.8	17.0	160	--	52	6.7	12	2.9
AUG 22, 1985	0745	3.5	360	7.7	18.0	170	5.0	55	7.3	11	3.5
03072813 TENMILE CREEK AT PROSPERITY, PA Site 14 (LAT 40 02 44 LONG 080 17 38)											
MAY 12, 1983	1010	13	380	8.3	12.0	160	--	55	6.7	7.3	1.1
AUG 31, 1983	1000	.49	430	7.8	21.5	180	--	59	7.9	16	5.4
AUG 27, 1984	0945	.66	430	7.6	18.0	170	--	56	8.0	16	3.1
AUG 22, 1985	0745	.70	440	7.5	18.5	180	9.9	59	7.9	17	3.6
03111580 TEMPLETON FORK NEAR WEST FINLEY, PA Site 15 (LAT 39 58 40 LONG 080 26 46)											
MAY 12, 1983	1030	21	270	8.8	12.0	130	--	42	5.7	5.2	1.1
AUG 30, 1983	0845	.00	355	7.1	17.0	170	--	58	7.3	8.3	2.5
AUG 27, 1984	0805	.48	340	8.0	15.5	150	--	50	6.5	6.4	2.4
AUG 22, 1985	1030	.96	370	7.9	16.5	160	5.0	52	6.8	6.6	2.7

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recov-erable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manga-nese, total recov-erable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03072817 LITTLE TENMILE CREEK NEAR TENMILE, PA Site 12 (LAT 40 01 15 LONG 080 07 41)										
MAY 12, 1983	130	55	9.0	0.20	4.2	240	180	11	50	36
AUG 30, 1983	110	55	15	.20	9.0	236	930	35	130	36
AUG 27, 1984	160	81	21	.20	4.3	293	370	24	40	25
AUG 22, 1985	170	56	20	.20	5.7	299	650	20	100	72
03072815 TENMILE CREEK NEAR AMITY, PA Site 13 (LAT 40 01 11 LONG 080 12 20)										
MAY 12, 1983	110	40	5.8	.10	4.2	197	220	14	40	40
AUG 31, 1983	110	37	13	.20	7.8	204	1,300	31	190	75
AUG 27, 1984	140	35	14	.20	3.8	208	940	20	60	40
AUG 22, 1985	140	33	15	.20	5.3	235	480	25	90	76
03072813 TENMILE CREEK AT PROSPERITY, PA Site 14 (LAT 40 02 44 LONG 080 17 38)										
MAY 12, 1983	130	39	7.2	.10	5.1	219	220	8	50	54
AUG 31, 1983	150	40	17	.20	7.1	255	1,900	30	410	340
AUG 27, 1984	150	36	18	<.10	3.3	231	1,500	22	220	170
AUG 22, 1985	160	31	21	.20	4.4	255	530	18	150	140
03111580 TEMPLETON FORK NEAR WEST FINLEY, PA Site 15 (LAT 39 58 40 LONG 080 26 46)										
MAY 12, 1983	100	36	3.5	.10	4.1	161	190	7	10	7
AUG 30, 1983	150	27	5.7	.20	8.1	210	390	11	290	260
AUG 27, 1984	130	35	5.2	.10	4.4	174	290	15	20	14
AUG 22, 1985	130	31	6.2	.30	4.7	202	140	10	10	9

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (µS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
03111585 ENLOW FORK NEAR WEST FINLEY, PA Site 16 (LAT 39 58 06 LONG 080 26 53)											
MAY 12, 1983	1000	36	280	8.7	11.0	130	--	43	5.8	6.2	1.2
AUG 30, 1983	0915	.16	610	7.6	18.5	210	--	70	9.5	33	3.4
JAN 25, 1984	0900	171	212	7.6	.0	83	--	27	3.8	6.6	2.3
AUG 27, 1984	0915	1.3	590	7.9	16.0	150	--	49	7.1	51	2.5
FEB 01, 1985	1030	30	315	8.0	.0	130	--	44	6.0	15	1.3
AUG 22, 1985	0940	3.3	650	8.0	17.5	170	0.0	55	8.1	60	3.0
03111603 ROBINSON FORK AT WEST FINLEY, PA Site 17 (LAT 39 59 33 LONG 080 28 40)											
MAY 12, 1983	0845	16	285	8.1	9.0	130	.0	44	5.6	3.9	1.0
AUG 30, 1983	1030	.00	375	7.3	18.5	170	--	56	8.0	7.0	3.0
AUG 27, 1984	1020	.15	340	8.4	18.5	150	--	50	6.7	5.6	2.4
AUG 22, 1985	1535	.35	340	8.4	21.0	150	5.0	50	6.9	6.0	2.8
03111900 MIDDLE WHEELING CREEK NEAR W. ALEXANDER, PA Site 18 (LAT 40 03 59 LONG 080 30 59)											
MAY 12, 1983	1200	9.3	310	8.9	14.5	150	--	50	6.2	5.2	1.1
AUG 30, 1983	1115	.56	350	7.1	20.5	170	--	55	6.9	7.4	5.0
AUG 27, 1984	1110	.07	430	7.8	18.0	180	--	60	8.3	10	3.2
AUG 22, 1985	1620	.27	410	8.0	21.5	180	5.0	58	7.8	8.8	3.0
03111220 DUTCH FORK CREEK NEAR CLAYSVILLE, PA Site 19 (LAT 40 07 22 LONG 080 28 26)											
MAY 12, 1983	1330	14	390	8.8	17.0	180	--	60	8.0	8.6	1.3
AUG 30, 1983	1220	3.6	465	7.3	21.5	210	--	68	9.2	15	3.9
AUG 27, 1984	1300	.71	640	8.0	19.5	250	--	81	12	27	3.0
AUG 22, 1985	1850	.55	650	7.7	19.0	260	5.0	83	12	28	3.5

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03111585 ENLOW FORK NEAR WEST FINLEY, PA Site 16 (LAT 39 58 06 LONG 080 26 53)										
MAY 12, 1983	94	37	6.1	0.10	5.0	168	130	120	20	30
AUG 30, 1983	130	31	85	.20	4.0	331	530	25	50	26
JAN 25, 1984	52	33	10	.10	5.7	147	1,900	61	100	34
AUG 27, 1983	120	45	81	.20	3.0	313	380	11	20	10
FEB 01, 1985	120	42	18	<.10	5.7	218	190	21	40	16
AUG 22, 1985	130	57	81	.20	3.7	361	180	7	20	8
03111603 ROBINSON FORK AT WEST FINLEY, PA Site 17 (LAT 39 59 33 LONG 080 28 40)										
MAY 12, 1983	98	39	3.0	.10	3.9	166	110	9	20	11
AUG 30, 1983	140	32	6.6	.20	6.5	205	620	21	200	150
AUG 27, 1984	120	37	5.8	.10	4.1	182	210	19	20	12
AUG 22, 1985	120	32	6.0	.20	4.3	188	160	11	10	7
03111900 MIDDLE WHEELING CREEK NEAR W. ALEXANDER, PA Site 18 (LAT 40 03 59 LONG 080 30 59)										
MAY 12, 1983	110	42	5.2	.10	4.7	186	140	<3	30	27
AUG 30, 1983	100	48	10	.20	7.1	211	750	26	70	26
AUG 27, 1984	150	46	16	.20	3.6	247	280	16	50	41
AUG 22, 1985	--	34	11	.20	4.5	225	180	9	20	16
03111220 DUTCH FORK CREEK NEAR CLAYSVILLE, PA Site 19 (LAT 40 07 22 LONG 080 28 26)										
MAY 12, 1983	120	57	12	.20	5.1	251	230	15	30	38
AUG 30, 1983	130	68	19	.20	9.5	287	1,100	34	80	59
AUG 27, 1984	180	78	40	.20	6.7	334	500	17	120	110
AUG 22, 1985	180	72	41	.10	7.2	392	490	10	130	110

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (µS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
03085217 CHARTIERS CREEK AT LAGONDA, PA Site 20 (LAT 40 07 19 LONG 080 17 25)											
MAY 12, 1983	1610	3.7	390	9.2	21.0	170	--	57	7.3	8.8	1.6
AUG 30, 1983	0925	1.9	380	7.6	19.5	170	--	55	7.2	13	3.2
JAN 25, 1984	1115	4.9	330	7.8	1.5	120	--	41	5.4	14	2.9
AUG 27, 1984	1135	.66	550	8.2	19.5	200	--	66	9.5	25	3.0
FEB 01, 1985	1045	2.4	451	8.0	.0	200	--	64	8.6	23	1.8
AUG 22, 1985	0840	.20	630	7.7	18.0	220	9.9	70	11	40	4.3
03085220 UNNAMED TRIB #2B TO CHARTIERS CREEK AT LAGONDA, PA Site 21 (LAT 40 07 27 LONG 080 15 42)											
MAY 12, 1983	1140	.65	410	7.7	15.5	170	5.0	59	6.7	7.5	.90
JAN 25, 1984	1315	.61	378	8.0	3.0	170	--	59	5.8	8.4	1.7
AUG 27, 1984	1335	.06	480	7.4	20.0	210	--	72	7.3	11	1.4
AUG 28, 1985	0855	.03	510	7.9	15.5	230	5.0	78	8.2	13	1.7
03085221 UNNAMED TRIB #1 TO CHARTIERS CREEK AT LAGONDA, PA Site 22 (LAT 40 07 45 LONG 080 15 10)											
MAY 12, 1983	1205	1.2	460	8.5	16.0	210	--	75	6.5	7.4	1.1
AUG 30, 1983	1150	.44	450	7.7	21.0	210	--	73	6.2	9.2	3.0
JAN 25, 1984	1230	2.2	358	7.9	3.0	140	--	49	4.8	11	4.6
DEC 27, 1984	1410	.15	530	7.7	21.0	230	--	79	7.0	14	2.4
FEB 01, 1985	1200	.35	489	7.9	.0	220	--	75	6.9	23	1.5
AUG 22, 1985	1000	.06	560	8.0	17.0	260	9.9	90	8.3	19	2.8

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03085217 CHARTIERS CREEK AT LAGONDA, PA Site 20 (LAT 40 07 19 LONG 080 17 25)										
MAY 12, 1983	130	47	10	0.20	5.2	232	410	15	100	79
AUG 30, 1983	120	44	17	.20	9.1	234	1,300	39	330	270
JAN 25, 1984	88	40	23	.10	6.3	217	1,900	30	170	99
AUG 27, 1984	180	52	30	.20	5.6	311	840	19	160	130
FEB 01, 1985	140	47	38	.10	7.0	284	620	35	200	170
AUG 22, 1985	200	41	51	.20	7.7	374	830	26	340	260
03085220 UNNAMED TRIB #2B TO CHARTIERS CREEK AT LAGONDA, PA Site 21 (LAT 40 07 27 LONG 080 15 42)										
MAY 12, 1983	120	59	9.3	.20	7.6	239	1,900	57	330	360
JAN 25, 1984	130	43	14	.10	6.6	251	1,000	27	70	59
AUG 27, 1984	170	40	15	.20	8.3	265	550	19	70	56
AUG 28, 1985	200	34	20	.20	8.9	313	730	17	70	71
03085221 UNNAMED TRIB #1 TO CHARTIERS CREEK AT LAGONDA, PA Site 22 (LAT 40 07 45 LONG 080 15 10)										
MAY 12, 1983	170	50	7.0	.20	8.7	284	260	13	50	50
AUG 30, 1983	160	45	11	.20	11	263	780	18	170	140
JAN 25, 1984	110	43	19	.20	6.8	242	3,100	81	290	100
DEC 27, 1984	200	46	.00	.20	9.6	297	700	15	130	110
FEB 01, 1985	160	49	39	.20	7.8	313	490	150	240	190
AUG 22, 1985	230	37	28	.20	9.6	361	660	12	160	130

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (μS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
03085224 RES #3, CHARTIERS CREEK NEAR WASHINGTON, PA Site 23 (LAT 40 08 35 LONG 080 15 05)											
MAY 12, 1983	1305	0.87	400	8.7	18.0	200	--	69	7.1	8.0	1.1
AUG 30, 1983	1445	.44	430	7.8	--	200	--	67	7.0	12	2.5
AUG 28, 1984	1130	.05	530	8.2	--	230	--	79	8.3	13	1.9
AUG 22, 1985	1030	.06	530	7.9	17.5	240	5.0	83	8.9	12	1.9
03111140 BUFFALO CREEK AT TAYLORTOWN, PA Site 24 (LAT 40 09 56 LONG 080 22 47)											
MAY 12, 1983	1430	32	370	8.8	17.0	170	--	56	7.9	9.5	1.2
AUG 30, 1983	1345	4.0	490	7.8	25.5	200	--	64	9.4	20	4.0
AUG 27, 1984	1400	3.2	540	8.3	22.0	200	--	64	10	19	2.5
AUG 22, 1985	1030	1.6	420	7.9	22.0	210	5.0	68	10	21	2.9
03111150 BRUSH RUN NEAR BUFFALO, PA Site 25 (LAT 40 11 54 LONG 080 24 28)											
OCT 20, 1982	1315	.19	500	8.0	11.5	220	--	69	12	14	5.1
MAY 13, 1983	1230	8.5	490	8.5	15.5	220	--	73	9.4	6.5	1.4
JUNE 24 1983	1215	3.0	450	8.1	23.5	220	.0	73	10	6.8	2.2
AUG 30, 1983	1500	.25	425	7.8	25.0	190	--	60	10	11	4.2
JAN 30, 1984	1000	4.9	390	8.0	.5	180	--	61	7.9	6.4	2.5
APR 12, 1984	1315	13	390	8.5	14.0	190	--	64	8.1	5.2	1.4
AUG 28, 1984	0900	.59	450	8.1	19.0	190	--	61	10	9.5	3.4
NOV 08, 1984	1245	3.2	445	8.1	6.0	200	--	67	9.0	8.4	2.8
FEB 01, 1985	0930	3.4	447	7.9	.0	230	--	75	9.5	11	1.6
APR 23, 1985	1255	6.5	435	8.4	21.5	200	--	66	9.5	6.2	1.6
AUG 23, 1985	1045	1.4	360	8.1	17.0	210	.0	66	11	10	3.7

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03085224 RES #3, CHARTIERS CREEK NEAR WASHINGTON, PA Site 23 (LAT 40 08 35 LONG 080 15 05)										
MAY 12, 1983	150	51	13	.20	8.0	268	300	17	40	40
AUG 30, 1983	140	45	15	.20	13	259	450	19	90	43
AUG 28, 1984	170	57	24	.10	10	304	390	12	50	58
AUG 22, 1985	190	55	28	.20	11	331	960	13	110	100
03111140 BUFFALO CREEK AT TAYLORTOWN, PA Site 24 (LAT 40 09 56 LONG 080 22 47)										
MAY 12, 1983	120	48	13	.20	5.1	222	200	18	30	24
AUG 30, 1983	140	45	32	.20	7.3	281	880	19	120	55
AUG 27, 1984	160	50	.00	.20	5.0	259	460	20	60	56
AUG 22, 1985	170	45	32	.20	5.6	301	840	44	110	82
03111150 BRUSH RUN NEAR BUFFALO, PA Site 25 (LAT 40 11 54 LONG 080 24 28)										
OCT 20, 1982	190	40	17	.20	3.7	297	220	40	50	30
MAY 13, 1983	160	54	8.4	.20	5.1	254	240	20	30	22
JUNE 24, 1983	180	50	10	.20	6.6	295	600	3	50	33
AUG 30, 1983	150	41	13	.20	5.3	245	600	21	100	49
JAN 30, 1984	140	52	12	.10	6.6	265	320	9	30	25
APR 12, 1984	140	58	9.4	.10	4.9	248	240	7	40	26
AUG 28, 1984	160	49	14	.20	3.9	236	470	20	50	34
NOV 08, 1984	160	56	13	.10	7.2	250	280	15	50	42
FEB 01, 1985	170	48	16	.20	7.0	307	270	17	90	33
APR 23, 1985	160	51	9.1	.10	3.6	246	430	20	40	25
AUG 23, 1985	160	44	13	.10	4.6	268	310	11	50	37

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (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)
03111250 SUGARCAMP RUN AT FROGTOWN, PA Site 26 (LAT 40 12 25 LONG 080 31 05)											
MAY 13, 1983	1100	7.7	440	8.3	13.5	210	--	69	9.7	5.2	1.4
AUG 31, 1983	1100	3.5	390	7.1	20.5	180	--	58	9.0	6.2	4.1
AUG 28, 1984	1100	.50	450	8.2	20.0	210	--	66	10	6.7	2.8
AUG 23, 1985	1204	.14	350	7.7	17.0	220	9.9	70	11	6.6	2.7
03111005 NORTH FORK CROSS CREEK AT AVELLA, PA Site 27 (LAT 40 16 38 LONG 080 27 41)											
MAY 13, 1983	0945	20	545	8.1	12.0	260	.0	74	18	10	1.4
AUG 31, 1983	0930	12	650	7.3	20.5	280	--	77	21	29	3.8
AUG 28, 1984	1300	2.7	710	8.3	24.0	300	--	83	23	27	3.0
AUG 22, 1985	1515	1.4	855	8.0	--	360	.0	98	28	37	3.6
03111001 CROSS CREEK NEAR HICKORY, PA Site 28 (LAT 40 15 08 LONG 080 21 29)											
MAY 13, 1983	0830	3.8	445	8.4	11.0	230	--	75	9.2	4.6	1.1
AUG 31, 1983	1315	.74	470	7.3	22.0	--	26	67	9.7	6.5	9.7
AUG 28, 1984	0745	.39	480	8.0	19.0	220	--	70	11	6.7	2.8
AUG 22, 1985	1630	.15	443	8.4	25.0	190	--	59	11	8.4	5.3
03107690 RACCOON CREEK NEAR HICKORY, PA Site 29 (LAT 40 19 13 LONG 080 19 14)											
MAY 13, 1983	0915	3.4	460	8.1	10.5	220	.0	72	10	8.0	1.6
AUG 30, 1983	1415	.31	515	8.1	24.5	230	--	72	12	14	5.2
AUG 27, 1984	1340	.60	465	8.4	21.5	200	--	59	12	12	3.2
AUG 22, 1985	1245	.30	505	8.3	20.0	220	--	68	12	15	3.6

Appendix G.--Surface-water quality data--Continued

[ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (μg/L as Fe)	Iron, dissolved (μg/L as Fe)	Manganese, total recoverable (μg/L as Mn)	Manganese, dissolved (μg/L as Mn)
03111250 SUGARCAMP RUN AT FROGTOWN, PA Site 26 (LAT 40 12 25 LONG 080 31 05)										
MAY 13, 1983	160	52	5.2	0 .20	4.6	238	130	10	10	4
AUG 31, 1983	130	50	6.9	.20	7.6	235	3,100	46	130	5
AUG 28, 1984	170	51	7.6	.20	6.5	251	240	9	10	4
AUG 23, 1985	170	48	7.2	.10	7.2	284	610	5	10	1
03111005 NORTH FORK CROSS CREEK AT AVELLA, PA Site 27 (LAT 40 16 38 LONG 080 27 41)										
MAY 13, 1983	170	95	5.5	.20	6.0	338	820	24	150	120
AUG 31, 1983	140	190	8.1	.20	7.4	432	2,000	57	220	120
AUG 28, 1984	150	210	8.2	.20	7.1	478	460	4	110	99
AUG 22, 1985	150	280	9.1	.30	7.2	605	140	6	150	150
03111001 CROSS CREEK NEAR HICKORY, PA Site 28 (LAT 40 15 08 LONG 080 21 29)										
MAY 13, 1983	170	54	4.2	.20	5.7	293	280	14	40	42
AUG 31, 1983	130	77	11	.20	9.1	300	2,700	72	270	160
AUG 28, 1984	190	83	6.0	.20	6.3	269	900	18	140	120
AUG 22, 1985	170	43	9.7	<.10	6.9	261	470	25	100	91
03107690 RACCOON CREEK NEAR HICKORY, PA Site 29 (LAT 40 19 13 LONG 080 19 14)										
MAY 13, 1983	160	63	9.3	.20	6.7	307	320	9	60	62
AUG 30, 1983	190	54	16	.20	9.1	308	310	22	190	140
AUG 27, 1984	150	62	16	.20	5.1	301	1,200	21	160	63
AUG 22, 1985	190	56	15	.30	6.3	301	600	13	160	120

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (µS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
	03085400	MILLERS RUN AT CECIL, PA Site 30 (LAT 40 19 38 LONG 080 11 21)									
MAY 13, 1983	0830	13	550	8.3	10.0	260	--	71	19	22	1.6
AUG 30, 1983	1530	.91	790	8.5	23.5	290	--	80	23	46	4.1
AUG 28, 1984	0800	2.4	850	8.1	18.0	300	--	81	24	47	3.3
AUG 23, 1985	0745	1.0	960	8.1	14.5	310	.0	84	25	61	4.2
	03085450	ROBINSON RUN AT MCDONALD, PA Site 31 (LAT 40 21 55 LONG 080 14 38)									
MAY 13, 1983	1200	8.8	1,750	6.4	14.0	720	55	170	72	87	3.5
AUG 30, 1983	0745	2.6	2,200	6.2	16.5	960	--	230	93	150	6.6
AUG 27, 1984	1500	3.5	2,500	6.3	18.0	840	--	180	95	160	5.6
AUG 22, 1985	1350	2.3	2,450	6.5	17.5	820	55	190	83	180	19
	03107600	RACCOON CREEK AT RACCOON, PA Site 32 (LAT 40 23 01 LONG 080 22 05)									
MAY 12, 1983	1340	26	950	6.8	--	370	45	100	28	35	2.1
AUG 30, 1983	0915	3.6	1,650	4.4	16.0	610	--	160	50	99	3.4
AUG 27, 1984	1230	3.7	1,290	4.6	17.0	480	--	130	38	44	2.9
AUG 22, 1985	1140	2.8	1,330	4.7	17.0	490	55	130	41	45	3.0
	03110920	HARMON CREEK NEAR HANLIN STATION, PA Site 33 (LAT 40 21 56 LONG 080 30 34)									
MAY 12, 1983	1300	23	1,500	8.2	15.0	730	5.0	190	62	16	3.2
AUG 30, 1983	1300	7.4	1,800	8.0	21.5	970	--	250	83	19	4.2
AUG 27, 1984	1115	5.0	1,740	7.9	17.0	830	--	210	74	22	4.2
AUG 22, 1985	1015	3.1	1,680	7.9	17.0	880	5.0	230	75	29	4.5

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03085400 MILLERS RUN AT CECIL, PA Site 30 (LAT 40 19 38 LONG 080 11 21)										
MAY 13, 1983	190	80	31	0.20	5.4	391	210	18	40	40
AUG 30, 1983	200	110	73	.30	6.8	472	150	14	80	26
AUG 28, 1984	200	91	96	.20	5.7	499	230	12	70	31
AUG 23, 1985	200	100	120	.30	5.5	568	330	6	40	22
03085450 ROBINSON RUN AT MCDONALD, PA Site 31 (LAT 40 21 55 LONG 080 14 38)										
MAY 13, 1983	16	960	15	.60	21	1,490	16,000	16,000	3,700	4,000
AUG 30, 1983	14	1,300	25	.60	18	2,030	19,000	16,000	5,400	5,400
AUG 27, 1984	24	1,300	23	.60	18	1,940	33,000	29,000	--	3,900
AUG 22, 1985	36	1,200	26	.60	15	1,910	23,000	14,000	3,700	3,900
03107600 RACCOON CREEK AT RACCOON, PA Site 32 (LAT 40 23 01 LONG 080 22 05)										
MAY 12, 1983	96	360	38	.50	14	696	9,500	4,000	1,400	1,300
AUG 30, 1983	--	740	100	<.10	30	1,240	10,000	10,000	2,700	3,100
AUG 27, 1984	0	460	53	.80	25	928	14,000	13,000	2,800	2,600
AUG 22, 1985	2	570	40	.60	24	950	12,000	12,000	2,700	2,700
03110920 HARMON CREEK NEAR HANLIN STATION, PA Site 33 (LAT 40 21 56 LONG 080 30 34)										
MAY 12, 1983	82	700	41	.40	9.8	1,210	540	6	1,600	1,500
AUG 30, 1983	70	860	69	.90	11	1,460	150	30	870	860
AUG 27, 1984	94	680	49	.10	8.7	1,310	210	13	190	180
AUG 22, 1985	100	780	54	.20	7.6	1,380	200	19	90	74

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conduc-tance (µS/cm)	pH (stan-dard units)	Temper-ature (°C)	Hardness (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
	03110812	KINGS CREEK NEAR FLORENCE, PA Site 34 (LAT 40 25 26 LONG 080 29 22)									
MAY 12, 1983	0900	6.6	420	7.6	9.0	200	5.0	56	15	5.8	1.5
AUG 30, 1983	1030	.69	595	8.1	18.0	290	--	76	24	10	2.4
AUG 27, 1984	0840	.84	595	8.0	14.0	280	--	75	23	8.6	2.4
AUG 22, 1985	0800	.30	585	7.9	16.0	280	5.0	74	23	11	2.4
	03110820	AUNT CLARA FORK NEAR PARIS, PA Site 35 (LAT 40 25 39 LONG 080 30 43)									
MAY 12, 1983	0945	12	475	8.3	9.5	240	--	63	19	5.7	1.5
AUG 30, 1983	1140	1.2	680	8.0	19.5	340	--	87	29	8.4	3.0
AUG 27, 1984	0945	1.4	760	8.0	14.5	360	--	91	32	7.7	2.6
AUG 22, 1985	0900	.79	638	7.8	16.0	310	5.0	82	26	7.6	2.6

Appendix G.--Surface-water quality data--Continued

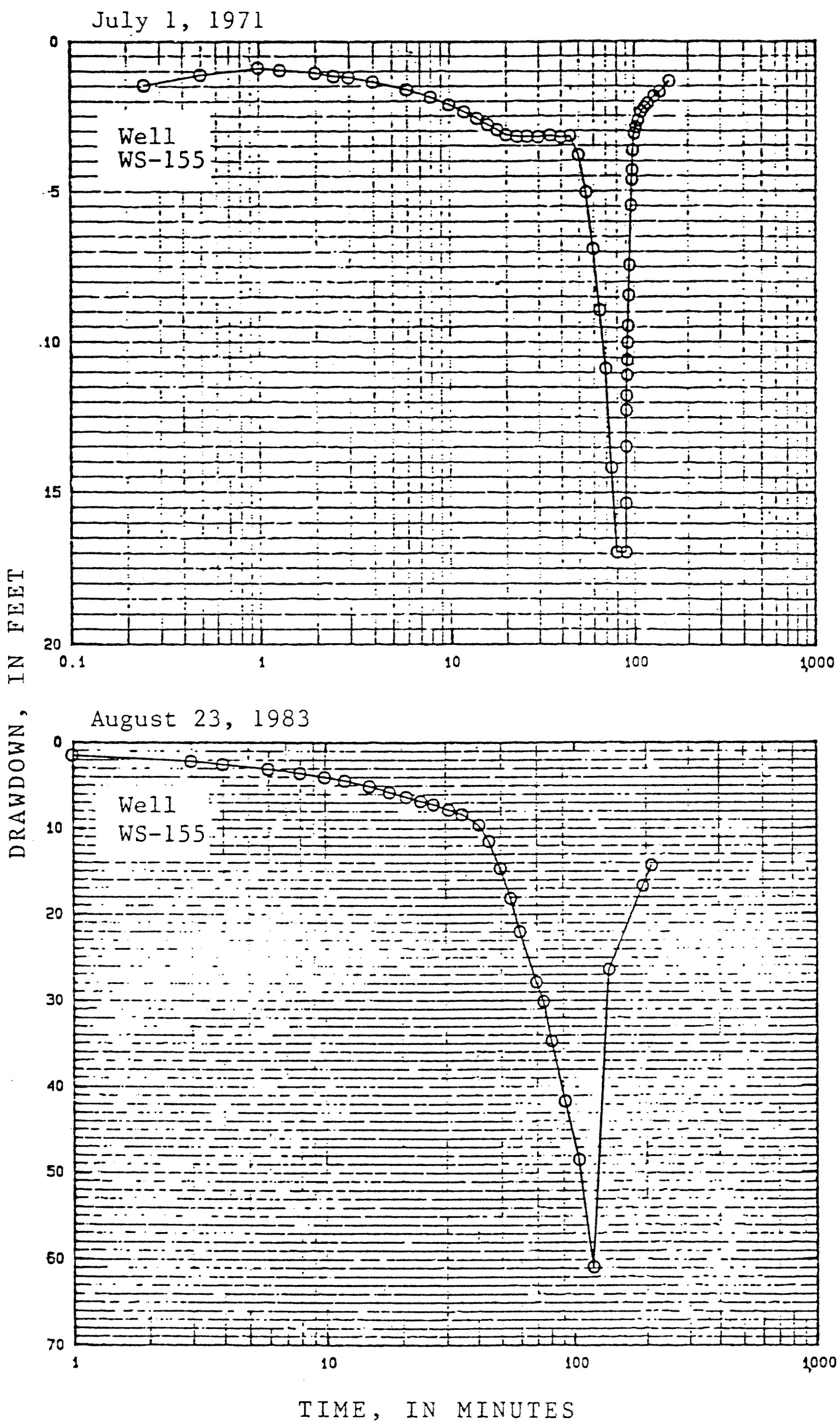
[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Alkalinity, field (mg/L as $CaCO_3$)	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)	Solids, residue at 180 °C dissolved (mg/L)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03110812 KINGS CREEK NEAR FLORENCE, PA Site 34 (LAT 40 25 26 LONG 080 29 22)										
MAY 12, 1983	74	140	6.3	0.20	7.2	291	280	<3	40	39
AUG 30, 1983	110	190	8.6	.20	7.1	395	230	12	90	43
AUG 27, 1984	110	200	8.6	.30	6.3	402	430	8	50	38
AUG 22, 1985	120	170	9.4	.20	6.4	397	640	7	130	79
03110820 AUNT CLARA FORK NEAR PARIS, PA Site 35 (LAT 40 25 39 LONG 080 30 43)										
MAY 12, 1983	80	170	5.3	.20	6.0	306	170	<3	10	20
AUG 30, 1983	110	230	6.0	.20	5.3	461	240	7	100	63
AUG 27, 1984	100	240	7.3	<.10	4.7	484	220	4	40	35
AUG 22, 1985	110	220	5.9	.20	4.7	453	170	9	50	45

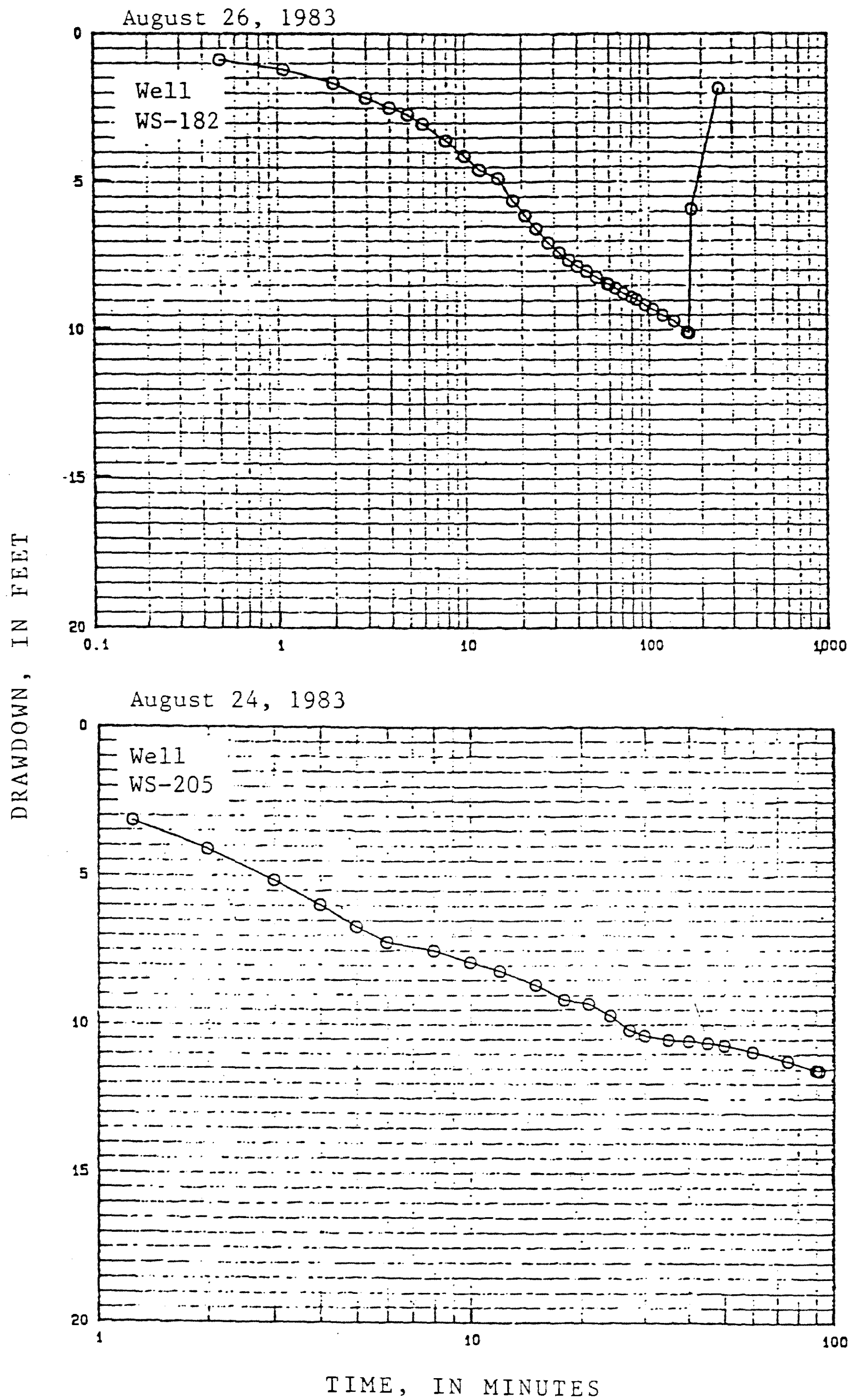
APPENDIX H.--AQUIFER TEST DRAWDOWN GRAPHS

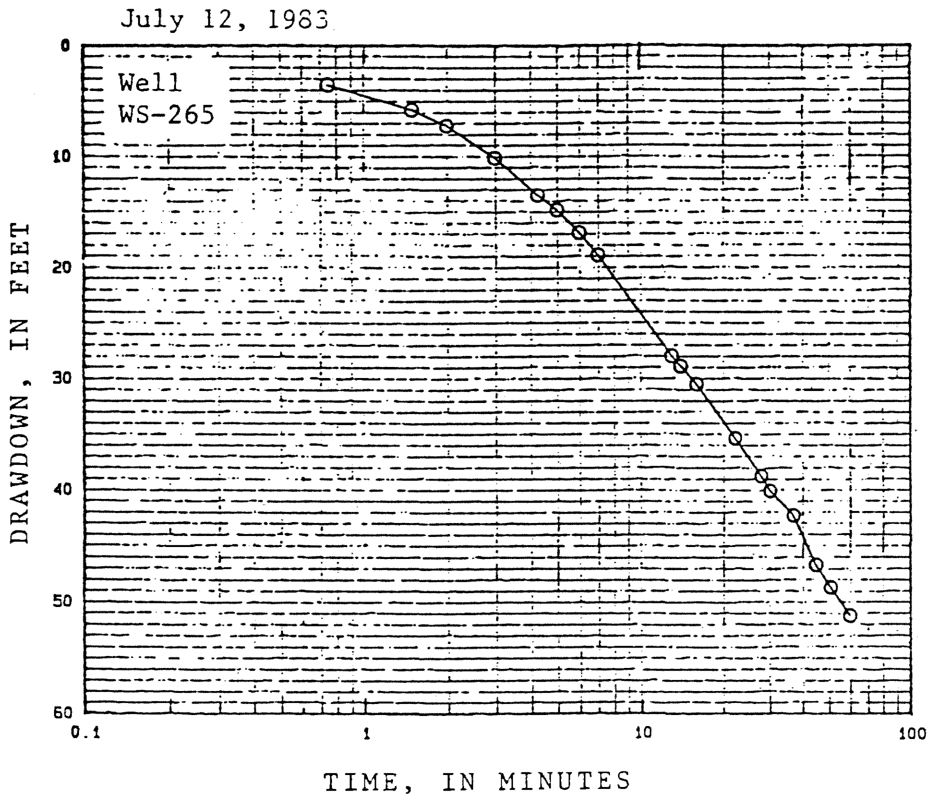
[Drawdown in feet on all graphs should be a positive number, not a negative number as plotted.]

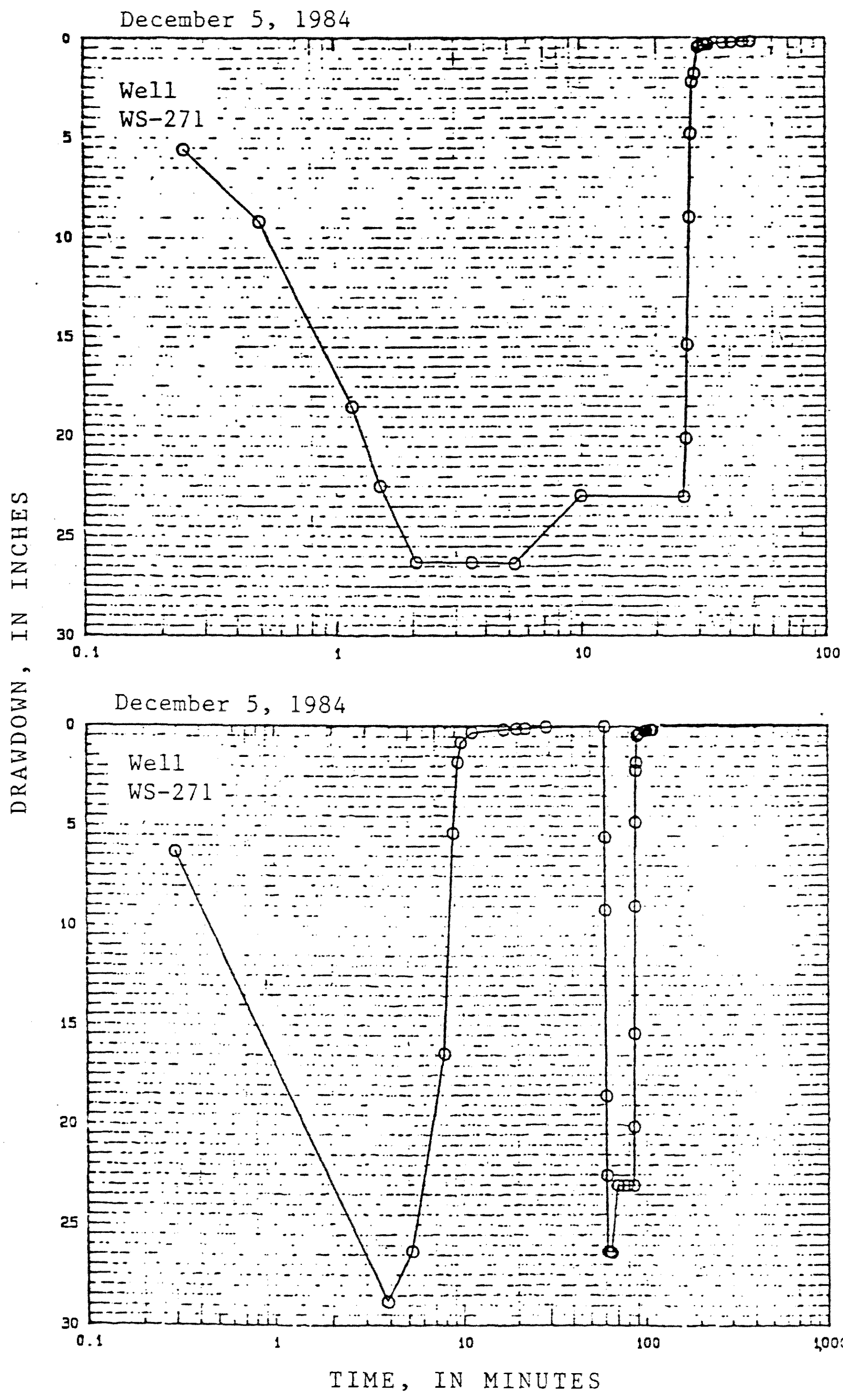
Observation well	Date of aquifer test
WS-155	07-01-71
WS-155	08-23-83
WS-182	08-26-83
WS-205	08-24-83
WS-265	07-12-83
WS-271	12-05-84
WS-271	12-05-84
WS-277	07-13-83
WS-277	08-19-83
WS-321	05-03-84
WS-322	05-03-94
GR-802-pumping well	07-29-81
GR-802 (Recovery)	07-30-81
GR-803-observation well	07-27-81
GR-803 (Recovery)	07-30-81
GR-804	09-29-80

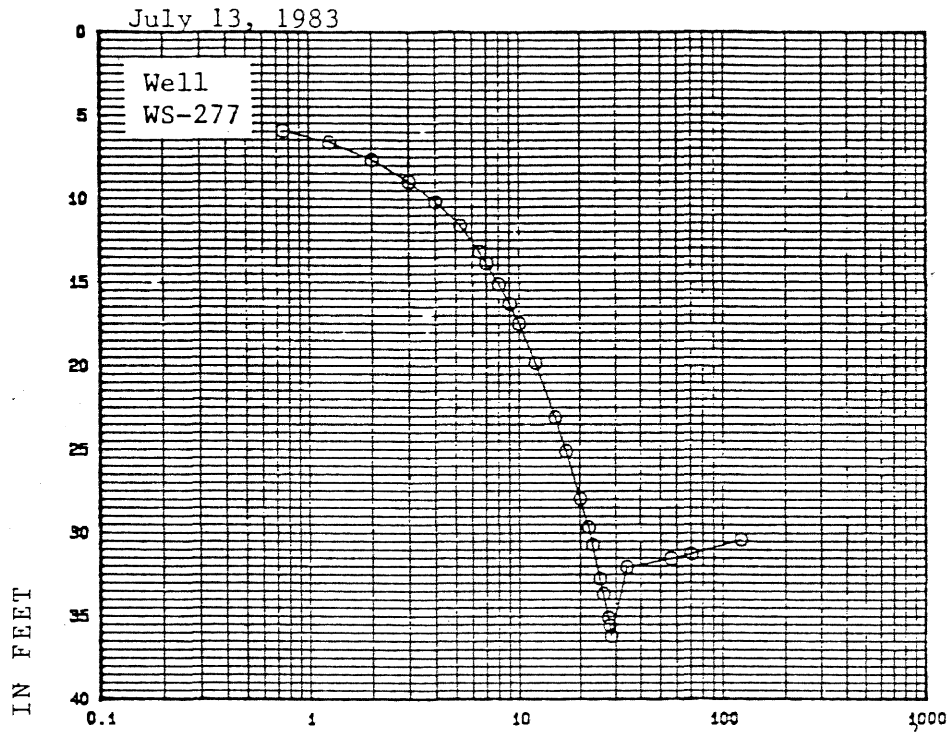


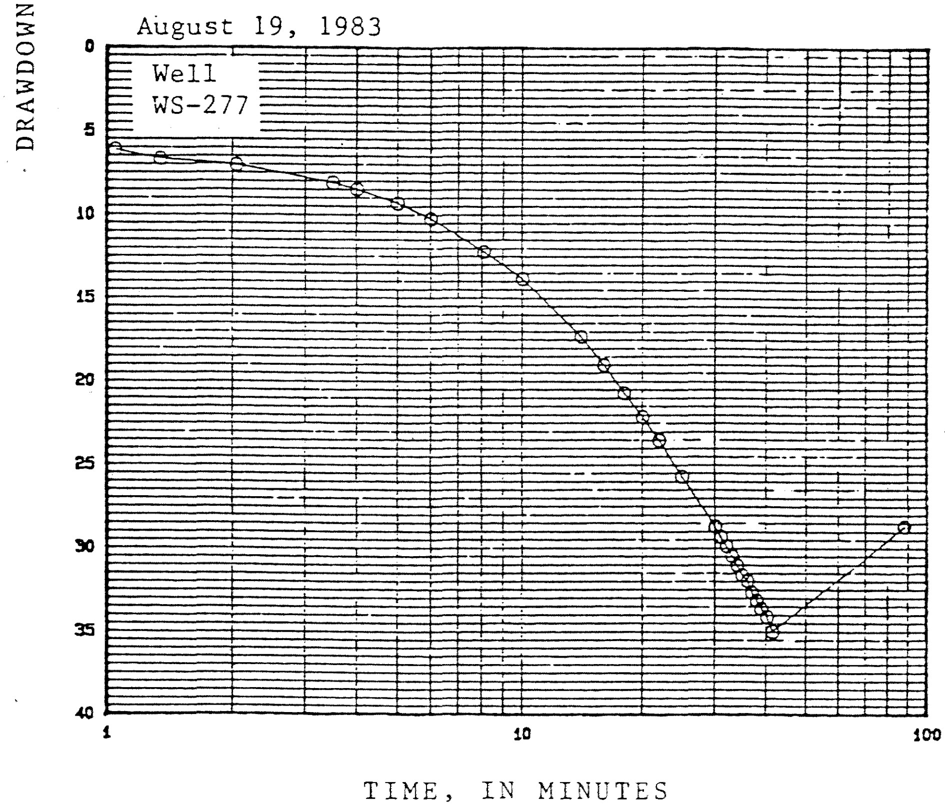
July 1, 1971
Well
WS-155
August 23, 1983
Well
WS-155
DRAWDOWN, IN FEET
TIME, IN MINUTES
0
5
10
15
20
0.1
1
10
100
1000
0
10
20
30
40
50
60
70
1
10
100
1000

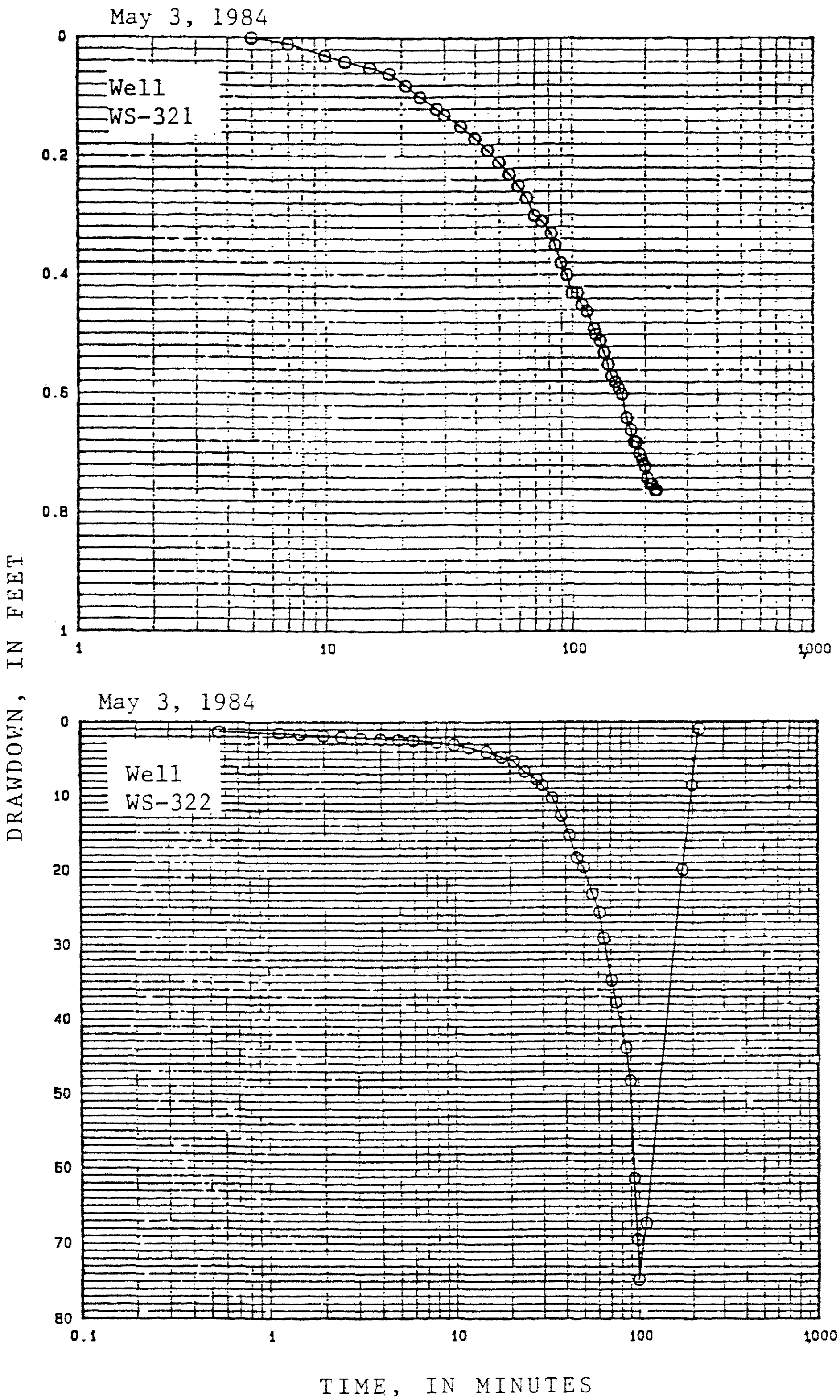

August 26, 1983
Well
WS-182
0
5
10
15
20
0.1
1
10
100
1000
DRAWDOWN, IN FEET
August 24, 1983
Well
WS-205
0
5
10
15
20
1
10
100
TIME, IN MINUTES

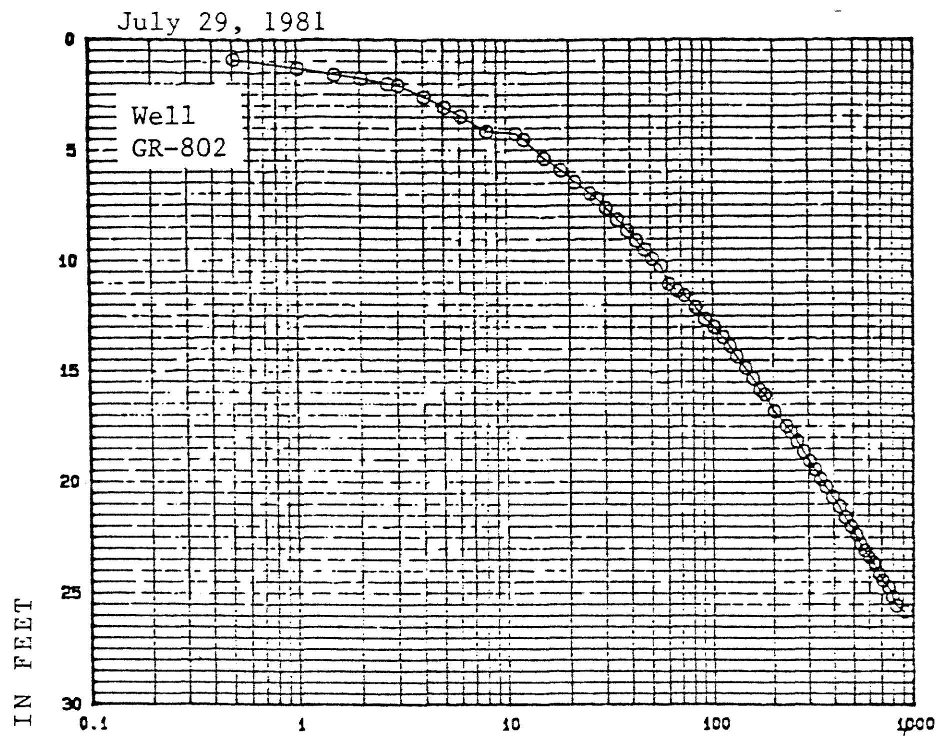

July 12, 1983
Well
WS-265
DRAWDOWN, IN FEET
0
10
20
30
40
50
60
0.1
1
10
100
TIME, IN MINUTES

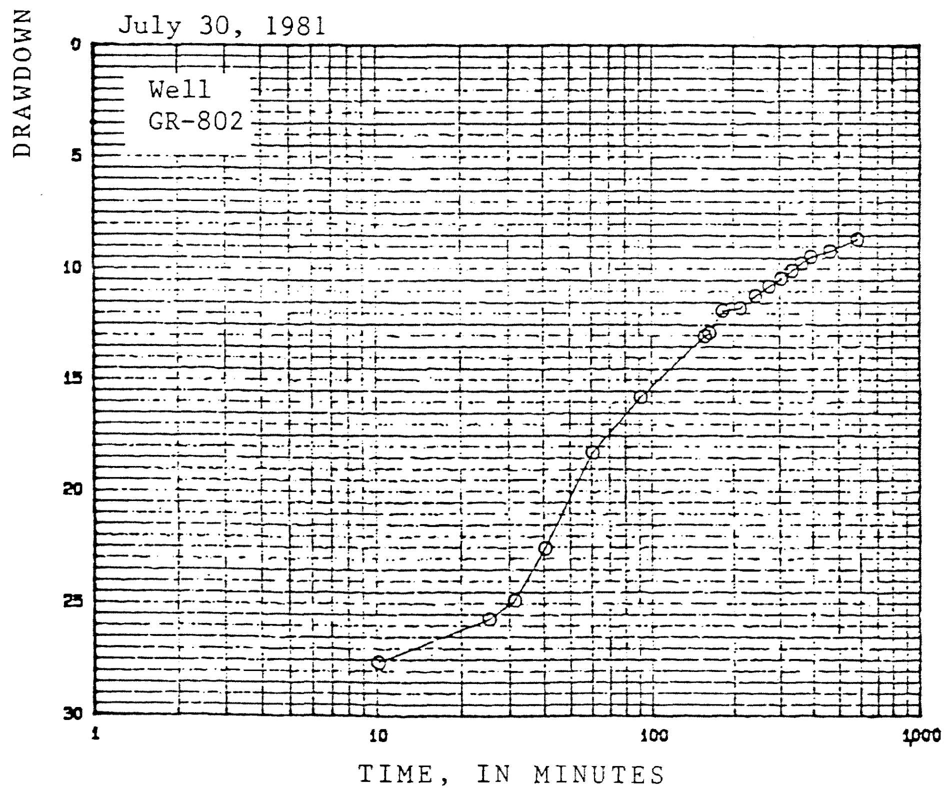

December 5, 1984
Well
WS-271
0
5
10
15
20
25
30
0.1
1
10
100
December 5, 1984
Well
WS-271
0
5
10
15
20
25
30
0.1
1
10
100
1,000
DRAWDOWN, IN INCHES
TIME, IN MINUTES


July 13, 1983
Well
WS-277
0
5
10
15
20
25
30
35
40
0.1
1
10
100
1000


August 19, 1983
Well
WS-277
0
5
10
15
20
25
30
35
40
1
10
100
DRAWDOWN, IN FEET
TIME, IN MINUTES

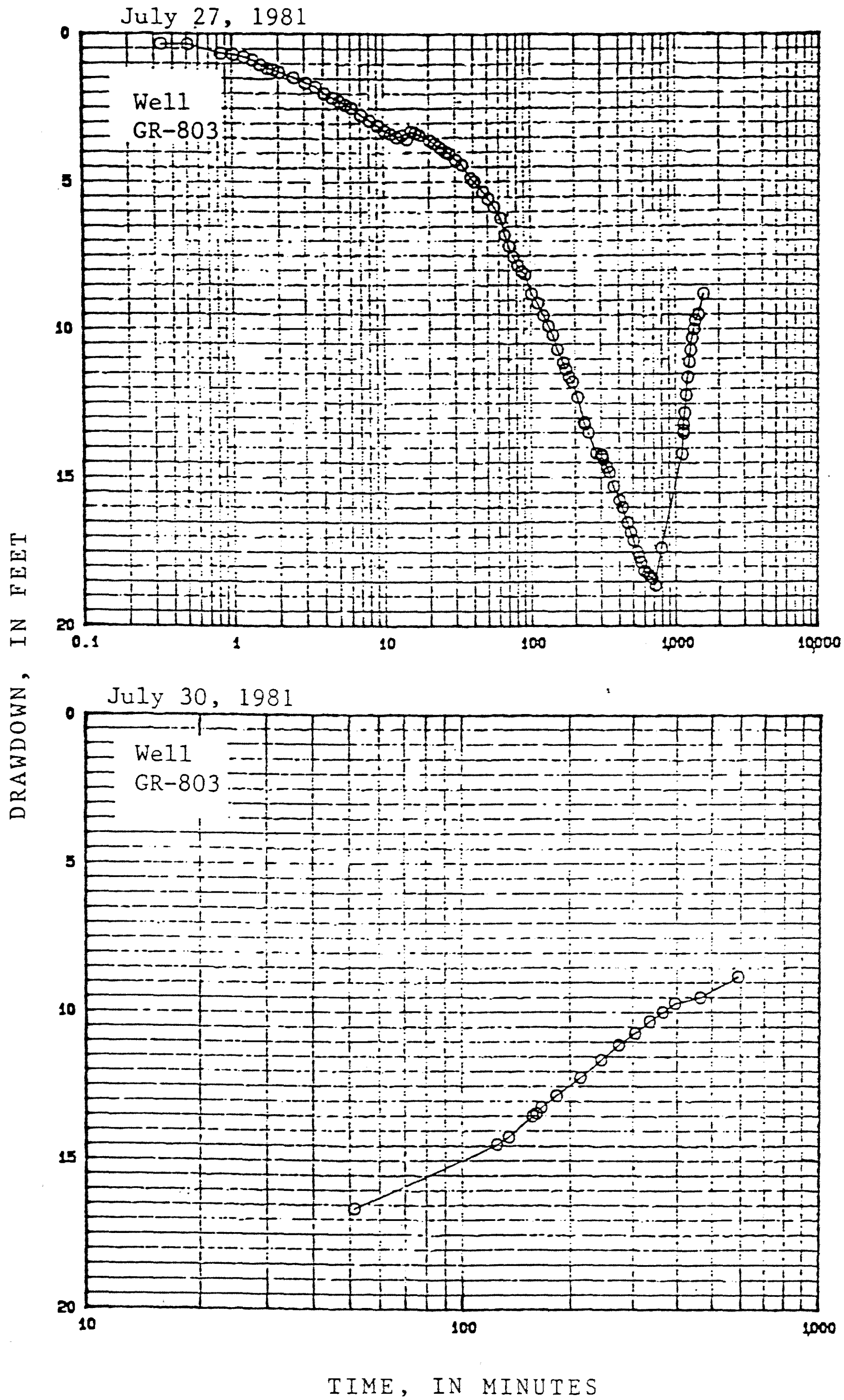

May 3, 1984
Well
WS-321
0
0.2
0.4
0.6
0.8
1
1
10
100
1000
DRAWDOWN, IN FEET
May 3, 1984
Well
WS-322
0
10
20
30
40
50
60
70
80
0.1
1
10
100
1000
TIME, IN MINUTES

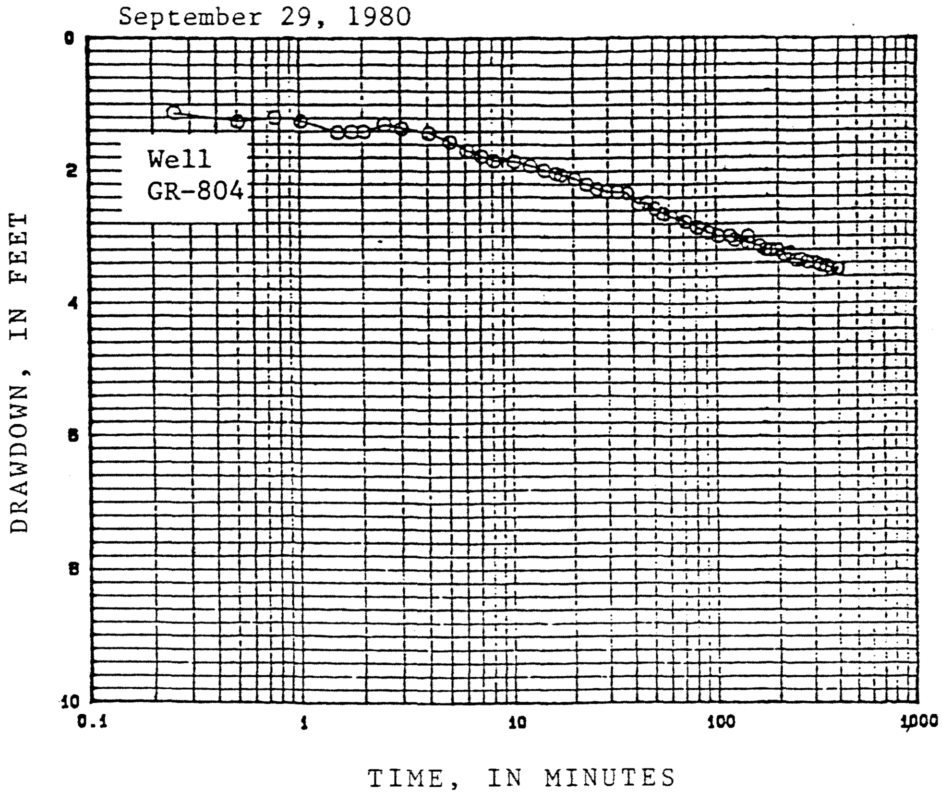




DRAWDOWN, IN FEET

TIME, IN MINUTES


July 27, 1981
Well
GR-803
0
5
10
15
20
0.1
1
10
100
1,000
10,000
DRAWDOWN, IN FEET
July 30, 1981
Well
GR-803
0
5
10
15
20
10
100
1,000
TIME, IN MINUTES



September 29, 1980
Well
GR-804
DRAWDOWN, IN FEET
0
2
4
6
8
10
0.1
1
10
100
1000
TIME, IN MINUTES

GLOSSARY

Acidity.--The capacity of a water for neutralizing a basic solution. Acidity, as used in this report, is primarily caused by the presence of hydrogen ions produced by hydrolysis of the salts of strong acids and weak bases.

Alkalinity.--The capacity of a water for neutralizing an acidic solution. Alkalinity in natural water is caused primarily by the presence of carbonate and bicarbonate.

Alluvium.--Sand, gravel, or other similar particle material deposited by running water.

Anticline.--An upfold or arch of stratified rock in which the beds dip in opposite directions from the crest.

Aquifer.--A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield usable quantities of water to wells and springs.

Aquifer test.--A test or controlled field experiment involving either the withdrawal of measured quantities of water from, or addition of water to, a well (or wells) and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition.

Base flow.--Discharge entering stream channels as effluent from the ground-water reservoir; the dry-weather flow of streams.

Bedrock.--A general term for the rock, generally solid, that underlies soil or other unconsolidated or semiconsolidated surficial material.

Confined aquifer.--An aquifer which is bounded above and below by relatively impermeable rocks.

Cubic feet per second (ft^3/s).--The rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second (equivalent to 7.48 gallons per second or 448.8 gallons per minute).

Cubic feet per second per square mile [$(ft^3/s)/mi^2$].--The average number of cubic feet of water per second flowing from each square mile of area drained by a stream, assuming that the runoff is distributed uniformly, in time and area.

Dissolved.--Refers to that material in a representative water sample which passes through a 0.45 micrometer membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of "dissolved" constituents are made on subsamples of the filtrate.

Dip.--The angle or rate of drop at which a layer of rock is inclined from the horizontal.

Dissolved solids.--The dissolved mineral constituents in water; they form the residue after evaporation and drying at a temperature of 180 °C; they may also be calculated by adding concentrations of anions and cations.

Drawdown.--The lowering of the water table or potentiometric surface caused by pumping (or artesian flow) of a well.

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

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

Fold.--A bend or flexure produced in rock strata by forces operating after deposition of the rock.

Formation.--The fundamental unit in rock-stratigraphic classification. It is a body of internal homogeneous rock; it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface.

Ground water.--That part of the subsurface water in the zone of saturation.

Ground-water discharge.--Release of water in springs, seeps, or wells from the ground-water reservoir.

Ground-water recharge.--Addition of water to the ground-water reservoir by infiltrating precipitation or seepage from a streambed.

Hardness.--A physical-chemical characteristic that is commonly recognized by the increased quantity of soap required to produce lather. It is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalent calcium carbonate ($CaCO_2$).

Head (static).--The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. In this report, head is synonymous to water level.

Hydraulic conductivity.--Hydraulic conductivity (K) of water-bearing rocks is the volume of water (at the existing kinematic vicosity and temperature) that will move at right angles through a unit cross sectional area in unit time and by a unit hydraulic gradient. It is a measure of the capacity of the material to transmit fluid. The hydraulic gradient is expressed in feet of hydraulic head per foot of flow distance (dimensionless), and hydraulic conductivity is expressed in cubic feet per day per square foot [$(ft^3/d)/ft^2$] or feet per day (ft/d). The hydraulic conductivity was determined from well tests by dividing the determined value of transmissivity by the thickness of the aquifer tested, thus representing an average formation property measured in a horizontal direction.

Hydraulic gradient.--Change in head per unit of distance measured in the direction of the steepest change.

Joint.--A fracture in a rock, generally more or less vertical, along which no differential movement has taken place.

Lithology.--The physical characteristics of a rock, generally as determined by examination with the naked eye or with the aid of a low-power magnifier.

Longwall mining.--A system of mining on straight faces 80 yards or more in length. A method of working coal seams in which the seam is removed in one operation by means of a long working face or wall. The workings advance (or retreat) in a continuous line which may be several hundred yards in length. The space from which the coal has been removed is either allowed to collapse (caving) or is completely or partially filled with stone or debris.

Micrograms per liter (μg/L).--A unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligrams per liter (mg/L).--A unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represent the mass of solute per unit volume (liter) of water.

pH.--A measure of the acidity or alkalinity of water. Mathematically, the pH is the negative logarithm of the hydrogen-ion activity; $pH=-\log_{10}[H^+]$, where $[H^+]$ is the hydrogen-ion concentration in moles per liter. 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 greater than 7.0.

Permeability.--The capacity of a porous rock, sediment, or soil to transmit a fluid under a hydraulic head; it is a measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

Primary permeability.--The permeability of a material due to its soil or rock matrix.

Secondary permeability.--The increase or decrease in primary permeability in the soil or rock due to fracturing, solution, or cementation.

Potentiometric surface.--A surface that represents the static head of an aquifer.

Room-and-pillar mining.--A system of mining by supporting the roof by pillars left at regular intervals. The coal is mined in rooms separated by narrow ribs or pillars. The first working in rooms is an advancing, and the winning of the rib (pillar) a retreating method.

Runoff.--That part of the precipitation that appears in streams. It is the same as streamflow unaffected by diversions, storage, or other works of man in or on the stream channels.

Specific capacity.--The well yield divided by the drawdown (pumping water level minus static water level) necessary to produce this yield. It is usually expressed as gallons per minute per foot [(gal/min)/ft].

Specific conductance.--Is a measure of the ability of a water to conduct an electrical current. It is expressed in micromhos per centimeter at 25 degrees Celsius. Specific conductance is related to the type and concentration of ions in the solution and can be used for approximating the dissolved-solids content of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos). This relation is not constant from stream to stream, and it may vary in the same source with changes in the composition of the water.

Specific storage.--The specific storage (Ss) of water-bearing rocks is the volume of water released from or taken into storage per unit volume of the porous material per unit change in head. Specific storage may be expressed in per foot (ft^{-1}). In this report, specific storage is determined from pumping tests by dividing the storage coefficient by the thickness of the tested water-bearing formation.

Storage coefficient.--The storage coefficient (S) of an aquifer is the volume of water an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit change in head normal to that surface. With volume, area, and hydraulic head expressed in consistent units, storage coefficient is a dimensionless quantity.

Streamflow.--Is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow in a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Syncline.--A downfold or depression of stratified rock in which the beds dip inward toward the axis of the fold.

Transmissivity.--Transmissivity (T) is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It may be expressed in cubic feet per day per foot [$(ft^3/d)/ft$] or feet squared per day (ft^2/d).

Unconfined aquifer.--An aquifer which contains the water table.

Water table.--The upper surface of the zone of saturation.

Water year.--October 1 through September 30 of the designated year. For example, water year 1984 starts October 1, 1983, and ends September 30, 1984.

GLOSSARY OF GROUND-WATER-MODEL TERMS

Anisotropy.--In this report it is the ratio of the horizontal hydraulic conductivity (Kh) to the vertical hydraulic conductivity (Kv).

Boundary conditions.--The condition of flow at the aquifer limits in a ground-water flow model. Specific types of boundaries used in this report are defined below:

Constant-head boundary.--Head does not change with time, but flow across the boundary is possible.

No-flow boundary.--Ground water does not flow across the boundary.

Specified flux boundary.--A boundary where the flux across a given surface is specified as a function of position and time.

Free-surface boundary.--The surface between the atmosphere and the saturated flow field which may rise and fall with time.

Head-dependent flux boundary.--Flux across the boundary changes in response to changes in head within the aquifer adjacent to the boundary.

Calibration.--The matching procedure used to refine initial estimates of aquifer properties and boundary conditions. Input data are modified as necessary until model-computed heads and flow compare sufficiently close to field observed values of head and flow at specific locations. Steady-state calibration is accomplished assuming no change in aquifer storage.

Finite-difference method.--An approximation technique for solving a system of nonlinear equations of ground-water flow. The aquifer system is subdivided into discrete blocks at which the equation variables are specified or computed.

Flux.--Volume of fluid per unit time crossing a unit cross-sectional surface area.

Grid block, finite-difference.--The subdivision of the aquifer system by rows and columns into rectangular blocks in which aquifer properties such as transmissivity and storage coefficient are specified for model input data.

Node.--The central point within each grid block at which a value of head is specified for or computed by a finite-difference model. Nodes in this report are identified by row and column number.

Numerical model.--A system of mathematical equations generally solved with the use of a computer to represent a physical process. The numerical model used in this report solves ground-water flow in a generalized cross section of the aquifer system.

Sensitivity analysis.--A method in modeling in which several simulations are made to determine the sensitivity of computed heads to specific changes in input data.