Geohydrology, Ground-Water Availability, and Ground-Water Quality of Berkeley County, West Virginia, with Emphasis on the Carbonate-Rock Area

U.S. Geological Survey

Water-Resources Investigations Report 93-4073

Prepared in cooperation with the

EASTERN PANHANDLE REGIONAL PLANNING AND DEVELOPMENT COUNCIL, REGION 9

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day[1] (ft^2/d)	0.0929	meter squared per day
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon (gal)	3.785	liter
gallon per cubic foot (gal/ft^3)	133.6	liter per cubic meter
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot [(gal/min)/ft)]	0.2070	liters per second per meter
gallon per minute per square mile [(gal/min)/mi^2]	1.461	liter per minute per square kilometer
billion gallons per year (Ggal/yr)	0.1200	cubic meter per second

[1] The standard unit for transmissivity (T) is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. This mathematical expression reduces to foot squared per day (ft^2/d).

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

Water temperature, specific conductance, and chemical concentration are given in metric units.

Water temperature given in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the following equation:

$$^{o}F = 1.8\,(^{o}C) + 32$$

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

Chemical concentration in water is expressed in milligrams per liter (mg/L) and micrograms per liter (µg/L).

Geohydrology, Ground-Water Availability, and Ground-Water Quality of Berkeley County, West Virginia, with Emphasis on the Carbonate-Rock Area

By R. A. Shultz, W. A. Hobba, Jr., and M. D. Kozar

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Charleston, West Virginia
1995

U.S. DEPARTMENT OF THE INTERIOR

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ABSTRACT

Berkeley County is underlain by carbonate rocks, upon which karst topography has developed, and by noncarbonate rocks. Ground-water levels tend to follow seasonal trends and fluctuate more in carbonate areas than in noncarbonate areas. Well yields of greater than 100 gallons per minute are possible from the carbonate rocks but such yields are unlikely from the noncarbonate rocks. The largest springs, which discharge more than 2,000 gallons per minute, are located in the carbonate rocks and are typically on or near faults or the limestone-shale contacts. Ground-water-flow velocities in the carbonate rocks ranged from 32 to 1,879 feet per day. Recharge was estimated to be about 10 inches per year for a 60-square-mile area of carbonate rocks. Specific yield for carbonate rocks ranged from 0.044 to 0.049. Estimated transmissivity values for carbonate rocks ranged from 730 to 9,140 feet squared per day.

Concentrations of the following constituents exceeded the maximum and secondary maximum contaminant levels set by the U.S. Environmental Protection Agency in ground water from at least one site: iron, manganese, nitrate, fecal coliform and fecal streptococcal bacteria, pH, total dissolved solids, and chloride. Analyses of the ground water indicated that the following organochlorine and organophosphate insecticides were present in detectable concentrations: chlordane, DDE, DDT, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, and malathion. Triazine herbicides that were present in detectable concentrations were atrazine, cyanazine, and simazine. Radon concentrations ranged from 92 to 1,600 picocuries per liter. Ground water from four springs in the carbonate rocks was analyzed for 36 volatile organic compounds. None of the compounds were present in detectable concentrations.

INTRODUCTION

Berkeley County is located in eastern West Virginia, about 65 mi northwest of Washington, D.C. Many people who work in the Washington, D.C. area are relocating to this area, and the county is experiencing rapid population growth. The population in the county increased 26.7 percent from 1980-90 (U.S. Department of Commerce, 1991). The primary source of water for most domestic and community water-supply systems in Berkeley County is **ground water**.[1] State and local officials are concerned about the effects that the escalating demands for water and land-use changes are having on the ground-water resources of the county.

The western half of the county is underlain by shale, sandstone, and some limestone; the eastern half of the county is underlain by limestone and some shale. **Karst** topography has developed in some areas. Ground-water recharge in karst areas is rapid and occurs indirectly by infiltration of precipitation, and directly through **sinkholes** and streams. Ground-water velocities are highly variable. Chemical contaminants entering the ground-water-flow system can spread quickly or slowly; they can be quickly flushed out of the system, or remain for a long time.

The U.S. Geological Survey, in cooperation with the Eastern Panhandle Regional Planning and Development Council, Region 9, conducted a countywide investigation of the ground-water resources

[1] Words in boldface type are defined in the Glossary.

because of the increasing demand for potable water and the vulnerability of the ground-water supplies to contamination.

Purpose and Scope

The purpose of this report is to describe the geohydrology, the ground-water availability, and the ground-water quality for Berkeley County, West Virginia. Areas of Berkeley County are identified where changes in water quality have occurred. Because most of the populated areas, farms, orchards, and industrial areas are underlain by **carbonate rocks**, most of the data-collection activities were concentrated in the carbonate areas. The water-quality data collected during this study were compared with previously published water-quality data.

Description of Study Area

Berkeley County encompasses a land area of 325 mi^2 and is located in the eastern panhandle of West Virginia (fig. 1). The county is bounded by Opequon Creek and Jefferson County, West Virginia, to the east; Morgan County, West Virginia, to the west; the State of Virginia to the south; and the Potomac River to the north.

The eastern half of Berkeley County is in the Shenandoah Valley. This area is characterized by gently rolling topography, with elevations ranging from about 310 to 800 ft above sea level. The western half of the county is characterized by northeastward-trending parallel ridges and valleys. The major ridges and valleys are, from east to west, North Mountain, Back Creek Valley, Third Hill Mountain, and Sleepy Creek Mountain. The top of Sleepy Creek Mountain forms the border between Berkeley and Morgan Counties. Elevations range from about 310 ft above sea level where the Potomac River leaves the county, to almost 2,200 ft above sea level on Third Hill Mountain west of Shanghai.

The Potomac River drains all of Berkeley County. The principal tributaries of the Potomac River are Meadow Branch, Cherry Run, Back Creek, Harlan Run, Opequon Creek, and Rockymarsh Run. All are **subsequent streams** flowing in the general direction of bedrock strike. A **trellis drainage pattern** has developed to the west of North Mountain. A **dendritic drainage pattern** has developed in the Shenandoah Valley. Four other streams are of significant size--Tuscarora Creek, Evans Run, Middle Creek, and Mill Creek. All four are tributaries to Opequon Creek, and flow generally across the strike of bedrock.

In 1973, 46.5 percent of Berkeley County was composed of forest, 31.4 percent pasture, 12.9 percent cropland, 4.7 percent urban or commercial and industrial land, 3.6 percent orchard, 0.7 percent barren land, and 0.2 percent water (McColloch and Lessing, 1980; West Virginia Department of Agriculture, 1975). Barren land includes quarries, strip mines, gravel pits, and transitional areas. Recent land-use surveys include only cropland statistics. Crops covered about 13.4 percent of the county in 1989 (West Virginia Department of Agriculture, 1990). These crops are, in order from greatest to least acreage, hay, corn, wheat, and oats.

Methods of Study

Data collection began in February 1989 and ended in September 1990. Wells and springs were inventoried, from which sites were chosen to study the ground-water-flow system and the geohydrologic characteristics of the aquifers. Ground-water-level changes were measured in a network of 31 observation wells. Four wells were equipped with water-level recorders, and measurements were made monthly with a steel tape at the remaining 27 wells. Seventeen wells with three recorders were located in the carbonate areas and 14 wells with one recorder were located in the noncarbonate areas. Well-yield data were gathered from 390 inventoried sites, previous reports, and drillers' reports. A springflow-observation network was established. Springflow (stage) was measured hourly at five springs by using a continuous recorder, and then was converted to discharge by use of a stage-discharge relation for each spring. Springflow was measured monthly at four springs. The flow of one artesian well was measured monthly. Ground-water-flow direction and velocity were studied by

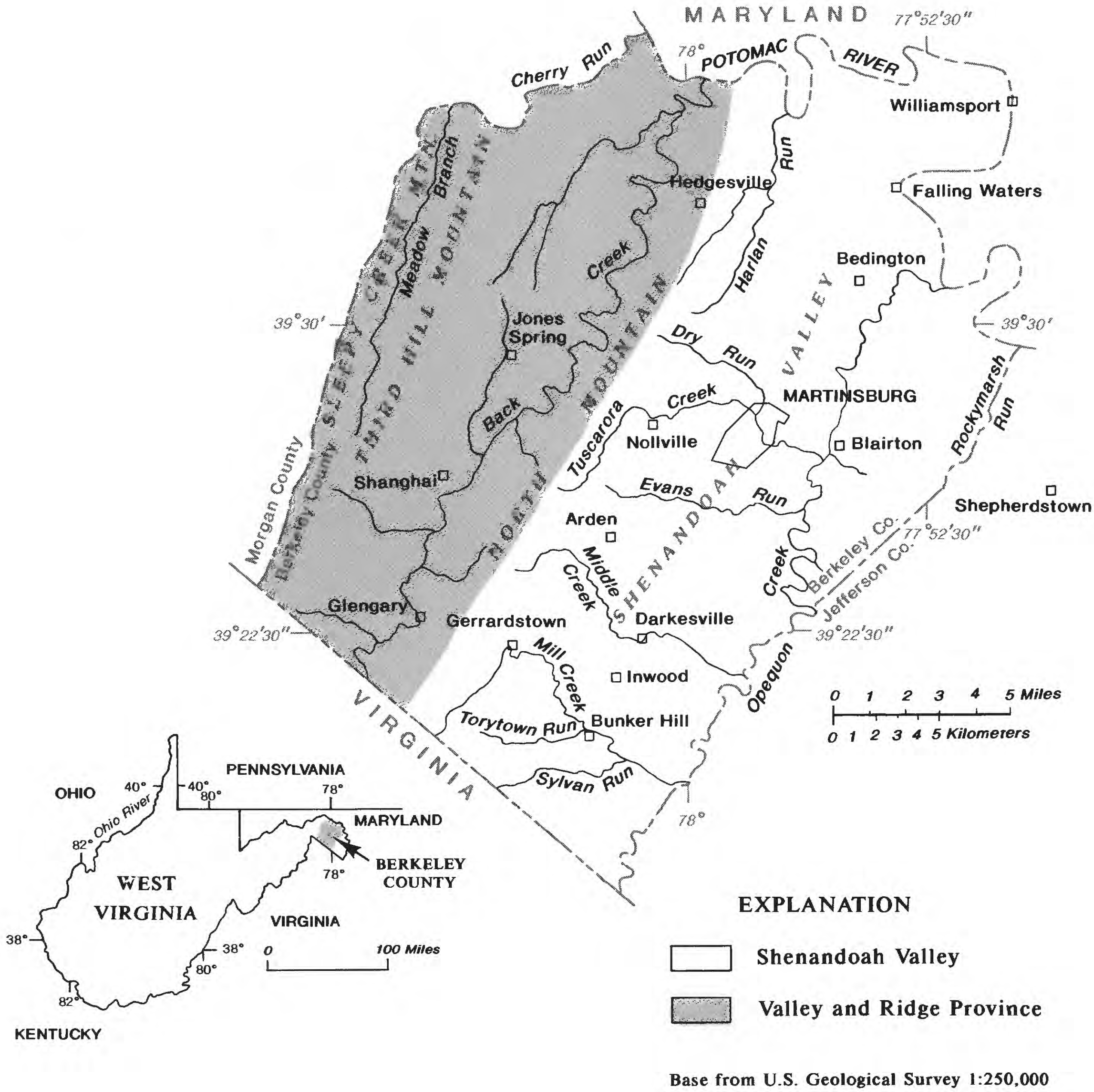


Figure 1. Location of study area.

use of **dye-tracer tests** made in three locations. **Recharge, specific yield**, and **transmissivity** were estimated for a 60-mi^2 area of carbonate rock.

The ground-water quality was determined by analyzing water samples from wells and springs throughout the county. Ground-water-quality samples were collected from a network of 46 wells and 14 springs August 21-24, 1989. Ground-water-quality samples were collected from a second network of 54 wells and 6 springs March 5-9, 1990. Additional water samples were collected quarterly at seven springs. All of the water samples were analyzed for **fecal coliform** and **fecal streptococci bacteria**, major ions, and nutrients. Some of the water samples also were analyzed for **pesticides**, volatile organic compounds, and radon-222.

Previous Studies

The geology of Berkeley County was described by Grimsley (1916) in a study on Jefferson, Berkeley, and Morgan Counties, and by Cardwell and others (1986) as part of a West Virginia Statewide geologic map. Dean and others (1987) mapped the geology of the Hedgesville, Martinsburg, Shepherdstown, and Williamsport 7 1/2-minute topographic quadrangles within Berkeley County. Taylor (1974) studied folds, faults, joints, cleavage, tectonics, lineaments, and fracture traces of the rocks in the Hedgesville and Williamsport 7 1/2-minute topographic quadrangles within Berkeley County. Taylor also studied the influence of lithology, topography, and structure on the ground-water resources of that area. Jeffords (1945) discussed the relation of geology to water supply and the ground-water quality at Martinsburg. Graeff (1953) studied ground-water supply in relation to the geology near Inwood. Beiber (1961) studied the ground-water features of Berkeley and Jefferson Counties. Beiber's report included discussions on water levels, lithologic effects on ground water, ground-water use, the water-bearing properties of various stratigraphic units, and ground-water quality. Hobba and others (1972) included Berkeley County in a study of the water resources of the Potomac River Basin in West Virginia. The data in that study were presented in a later report by Friel and others (1975). Trainer and Watkins (1975) described the hydrologic characteristics of the rocks in the Upper Potomac River Basin and included Berkeley County as part of their study. Hobba (1976) studied the ground-water hydrology of Berkeley County, and included discussions on ground-water levels, underground dye tracing, and water quality in his report. McColloch (1986) gave locations and descriptions for 53 springs in Berkeley County in a report on the springs of West Virginia.

Acknowledgments

The authors thank James Barnhart, Kathleen Dilley, Carl Franklin, and Kevin Lilly of the West Virginia Department of Natural Resources, and Charles Bennett of Knouse Foods Corporation for their help in collecting data for the dye-tracer tests. Thanks to William Isherwood, Douglas Dirting, Kenneth Lowe, James Miller, Vernon Hiett, B & W Watercress, Knouse Foods Corporation, the Woods Homeowners Association, and the Bunker Hill Public Service District for allowing access to their properties for installation of water-level and spring-flow-monitoring equipment. Appreciation also is given to the residents of Berkeley County who granted access to sample their wells and springs, and for providing information about their wells and springs.

GEOHYDROLOGY

Ground water is stored in and flows through **fractures** in rock. These fractures include **joints, faults**, and **bedding-plane** partings, and constitute **secondary porosity** of the rocks. **Primary porosity** is not an important consideration of ground-water storage and flow in Berkeley County because most intergranular spaces are filled with cementing material. The size and directional orientation of the fractures is controlled by the geologic setting.

Geologic Setting

The rocks of Berkeley County are of Cambrian, Ordovician, Silurian, Devonian, and Mississippian ages (Cardwell and others, 1986). The rocks crop out in beds of differing width, and the strike of the beds is oriented northeast-southwest (fig. 2). The rocks were folded and faulted during the formation of the Appalachian Mountains; fold axes generally trend northeast. Taylor (1974) states that the average trend of fold hinges on the Hedgesville and Williamsport 7 1/2-minute quadrangles is N. 20° E. The major folds are the Meadow Branch **syncline**, the Ferrel Ridge **anticline**, and the large Massanutten syncline underlying the Shenandoah Valley. The center of the large synclinal structure underlies Opequon Creek, which forms much of the boundary with Jefferson County.

Cambrian and Ordovician rocks crop out in the Shenandoah Valley to the east of North Mountain. They are, in order of oldest to youngest: the Elbrook and Conococheague Formations of Cambrian age; and the Beekmantown, St. Paul, Black River, and Trenton Groups, and the Martinsburg Formation of Ordovician age. The Black River and Trenton Groups are referred to as the "Chambersburg Limestone" in this report. These rocks are mostly limestone and dolomite, with the exception of the shales of the Martinsburg Formation. The Martinsburg Formation is at the center of the Massanutten syncline. All Cambrian and Ordovician rocks mentioned above crop out on the eastern and western sides of the Martinsburg Formation, with the exception of the Elbrook Formation, which crops out only on the western side.

The Silurian, Devonian, and Mississippian rocks crop out from the eastern slope of North Mountain to the western border with Morgan County. These rocks decrease in age from east to west, except where faults have brought older rocks to the surface. Silurian rocks include the Tuscarora Sandstone, Clinton Group, McKenzie Formation, and the Williamsport, Wills Creek, and Tonoloway Formations. Devonian rocks include the Helderberg Group, Oriskany Sandstone, Needmore Shale, the Marcellus and Mahantango Formations, Harrell Shale, Brallier Formation, Chemung Group, and the Hampshire Formation. Mississippian rocks include only the Pocono Group. All of these geologic units consist of shale and sandstone, except for the Helderberg Group and the Tonoloway and Wills Creek Formations, which contain limestone. These limestones form a band about 1/4 to 1 1/4 mi in width in the Back Creek Valley, beginning about 2 mi south of Jones Spring and striking northeastward for about 7 1/2 mi.

The carbonate areas are characterized by sinkholes, caves, and dry-surface streams that indicate underground drainage, often referred to as "karst topography." The carbonate areas include a large part of the Shenandoah Valley and a part of Back Creek Valley. Carbonate rocks of Berkeley County include the Elbrook Formation, Conococheague Formation, Beekmantown Group, Chambersburg Limestone, Helderberg Group, Tonoloway Formation, and Wills Creek Formation. **Noncarbonate rocks** include the Martinsburg Formation, Tuscarora Sandstone, Clinton Group, McKenzie Formation, Williamsport Formation, Oriskany Sandstone, Needmore Shale, Marcellus Formation, Mahantango Formation, Harrell Shale, Brallier Formation, Chemung Group, Hampshire Formation, and Pocono Group.

Quaternary deposits of unconsolidated alluvial material are present along the Potomac River, Opequon Creek, Back Creek, and Meadow Branch. This material consists of clay, silt, sand, and gravel, and the thickness of the bed material is no greater than 35 ft (Beiber, 1961, p. 55). There are no ground-water data on these deposits, and they are not discussed elsewhere in this report.

Fractures including faults, joints, and bedding-plane separations are present in the bedrock. Faults were formed by compression during the formation of the Appalachian Mountains. The carbonate areas contain more faults than the noncarbonate areas. Longitudinal faults are present throughout the carbonate area. **Cross faults** are more common in the carbonate area to the north of Martinsburg than in the carbonate area to the south of Martinsburg, as observed from a map prepared by Hobba (1976). Taylor (1974) gives dominant trends of N. 15° E. to N. 20° E. and N. 80° E. to N. 90° E. for longitudinal and cross faults, respectively. These values are for the area north of Martinsburg within the Hedgesville and Williamsport 7 1/2-minute quadrangles. Taylor also states that the cross faults are not well developed, and that some of the longitudinal faults dip steeply to the east and others dip steeply to the west.

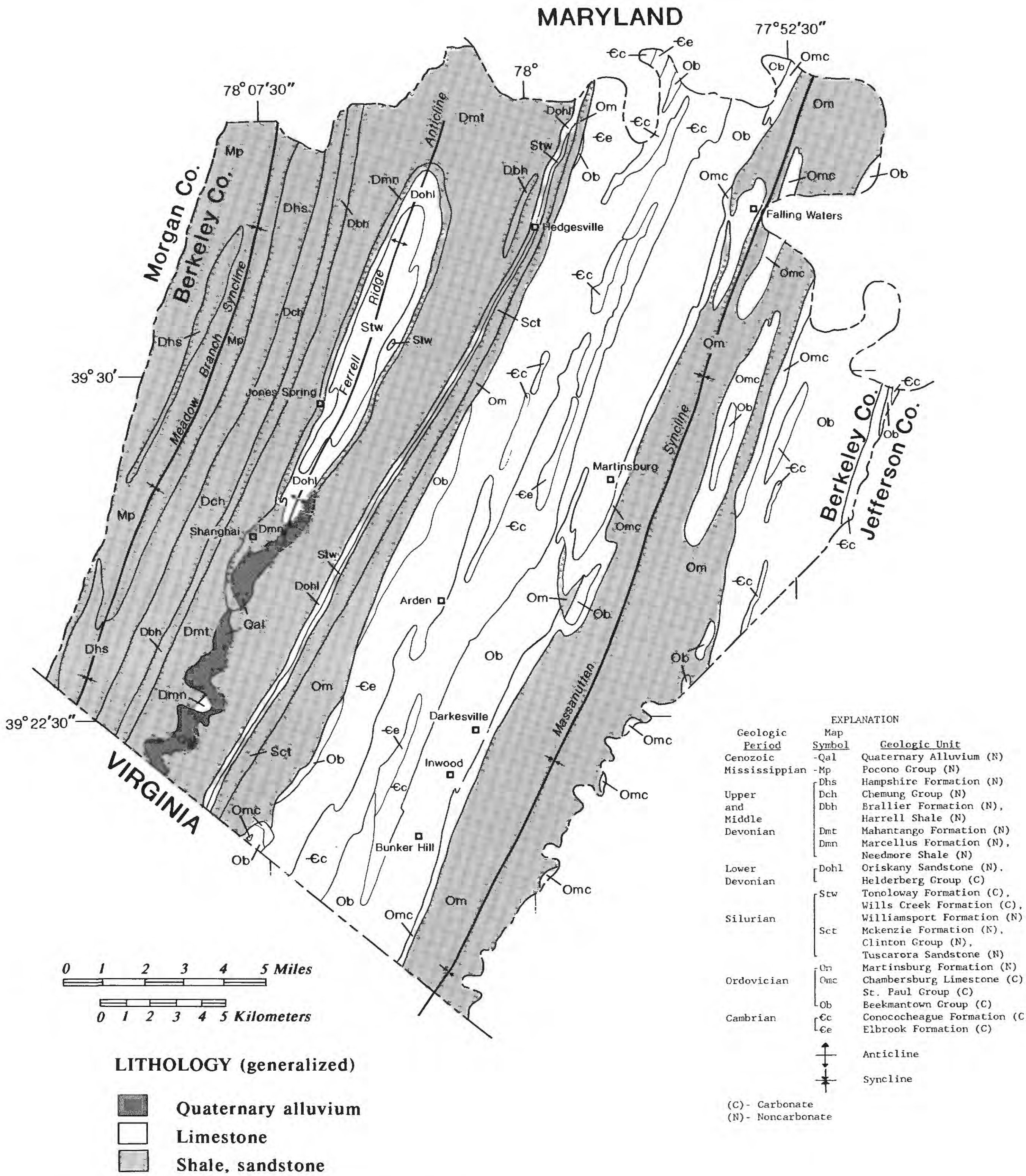


Figure 2. Geology of Berkeley County, West Virginia.

The dominant joint trend in the carbonate rocks north of Martinsburg is about N. 60° W. to N. 70° W., and is perpendicular to the strike of bedrock (Taylor, 1974). This dominant trend was present in both dolomite and limestone, but the range of orientations of the dolomite was wider than that of the limestone. Field observations by Taylor (1974) indicate that dolomite is more densely fractured than limestone, owing to the more brittle nature of dolomite. Graeff (1953) also reported a dominant joint trend perpendicular to the strike of bedrock in the southern part of the county near Inwood. The dominant joint trend for carbonate rock was N. 42° W. Graeff did not separate his data into dolomite and limestone trends.

Bedding planes are important ground-water-flow paths in the direction of the strike and dip of the beds. Fractures in the rocks create features called **lineaments** on land surface if the fractures extend great distances. Lineaments can include faults, dry-stream channels, aligned stream-meander bends, and aligned sinkholes. Lineaments have been mapped in Berkeley County by Hobba (1976), Taylor (1974), and Zewe (1991).

Ground-Water Flow

Ground water flows from a higher hydraulic **head** toward a lower hydraulic head. The main direction of flow is the path of highest horizontal **hydraulic conductivity**, usually along an open fracture or parting. Regionally, the **hydraulic gradient** is toward lower hydraulic heads along Opequon Creek and the Potomac River on the east side of North Mountain, and toward Back Creek on the west side of North Mountain. Locally, the hydraulic gradient is typically in the direction of the nearest pumping well, spring, or stream.

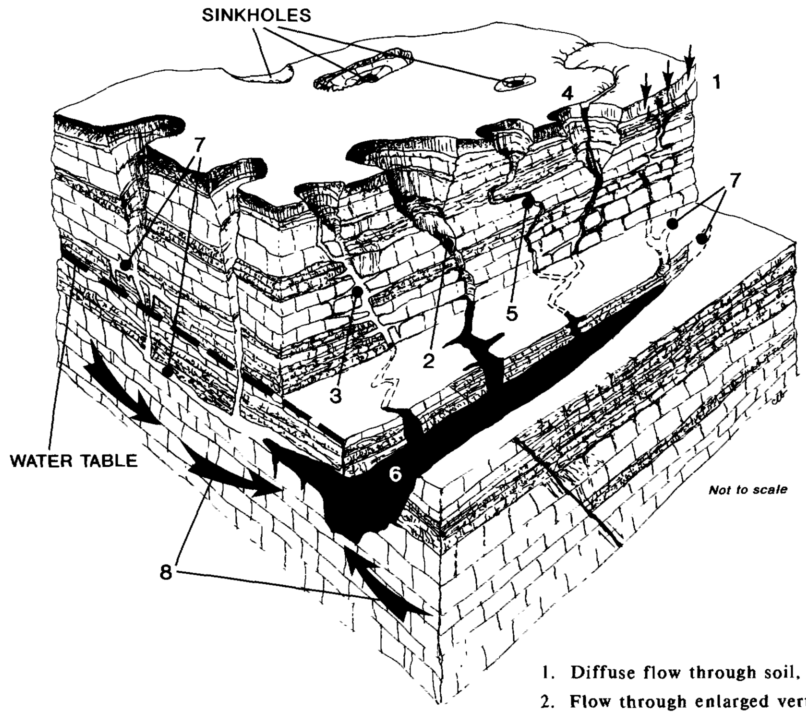
Horizontal hydraulic conductivity is highest in areas with many, interconnected, wide fractures, and lowest in areas of few, poorly connected, narrow fractures. Fault zones could be the main avenues of flow wherever they are present, because they are typically areas of increased fracturing. Faults act as drains, collecting water from tributary faults, bedding-plane separations, joints, and cavernous zones in the surrounding rock. Ground water entering a fault flows along the fault, toward a lower hydraulic head. Faults, however, also can close or act as barriers to flow if they are filled with sediment.

Carbonate rocks have diffuse and conduit flow (fig. 3). **Diffuse flow** occurs where fractures are small and the flow is slow and **laminar**. **Conduit flow** usually occurs in faults, beneath **losing streams**, in cavernous areas, and where fractures have been enlarged by **dissolution**. Mill Creek and Tuscarora Creek have losing sections based on flow measurements made during June 26-27, 1990. Torytown Run, Sylvan Run, Dry Run, Evans Run, and Harlan Run also have losing sections based on a ground-water-level map by Hobba (1976). There could be other streams that have losing sections. Conduits can range from less than one inch to tens of feet in width and height, and are generally the main flow paths for water wherever they are present. Ground water in conduits can move rapidly and is sometimes turbulent.

Generalized ground-water-flow patterns in the noncarbonate areas are shown in figure 4. The water table is a subdued replica of the topography. Ground water flows downhill, from hilltops to valleys, in response to gravity. Ground-water divides, which separate one recharge area from another, are usually ridgetops. Discharge points are springs and seeps along the flow path, on hillsides and in valley bottoms. Fractures in noncarbonate rocks are not enlarged by dissolution, and ground-water flow is diffuse.

Ground-Water Levels

Ground-water levels are affected by recharge from **precipitation** and infiltration from streams, and discharge to springs, streams, wells, quarries, and mines. Water levels in wells usually show a seasonal trend, as shown by the hydrograph for well 70 in figure 5. Water levels peak between April and mid-June and decline to the lowest levels between mid-October and November. This decline occurs even though June, July, and August are normally the third, fourth, and second wettest months, respectively (based on National Oceanic and Atmospheric Administration weather records for



EXPLANATION

1. Diffuse flow through soil, residuum, or unconsolidated surficial material
2. Flow through enlarged vertical conduits
3. Diffuse flow through joints, fractures, faults, and bedding planes
4. Surface streams draining into sinkholes
5. Horizontal and vertical flow to master conduit
6. Water-filled master conduit
7. Air-filled conduit
8. Flow lines of diffuse ground-water flow

Modified by D S Mull and others, 1988

Figure 3. The components of ground-water flow in a cavernous carbonate aquifer.

Martinsburg from 1891 to 1990). Much of the precipitation during this time is not available for recharge because of evapotranspiration.

Precipitation most effectively recharges the ground-water system after the leaves drop in the fall and temperatures decrease. Even though November through February are typically the driest months, ground-water levels usually rise slowly from December through February. Precipitation amounts increase from March through May, which is normally the wettest month. **Evapotranspiration** does not reach its maximum until summer, and, consequently, ground-water levels usually peak in April through mid-June. These trends are averages, and variations from the average occur during extreme wet and dry periods. The effect that a drought had on water levels in 1969 can be seen in figure 5. The lowest water level on record at well 70 in Martinsburg occurred on December 7, 1969. Precipitation was 10.62 in. below normal from December 1968 through June 1969, the time of year when water levels are normally recovering. Above-normal precipitation fell during July and August 1969, but this rainfall was mostly removed by evapotranspiration, and resulted in only a slight rise in water levels. Precipitation was below normal during September through November 1969, causing a continuing decline in water levels. Precipitation was 4.17 in. above normal during December 1969 through June 1970, causing the water level to recover.

Ground-water levels were studied using depth-to-water measurements for 342 wells in Berkeley County. These measurements were made over a number of years--290 measurements in 1973 (Hobba, 1976), 46 measurements in 1989-90 during

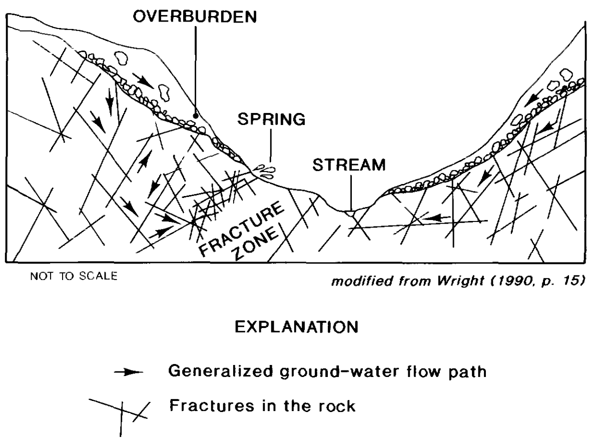


Figure 4. Generalized ground-water-flow patterns in noncarbonate rocks.

data collection for this study, and 2 measurements each in 1957, 1970, and 1985 (unpublished data in the files of the Charleston, W.Va., District office). No reported values were used. To minimize variances caused by extreme wet or dry conditions, measurements were used only when the water level at well 70 was between 39.77 and 45.50 ft below land surface. The locations of all wells inventoried during 1989-90 are shown in figure 6.

The configuration of the water table is a subdued reflection of the topography; the water table is shallow in valleys and deep under the surrounding hilltops.

Mean depth to water in wells tapping the carbonate rocks in the Shenandoah Valley was 41.47 ft below land surface. Ground-water levels in the noncarbonate Martinsburg Formation (east of North Mountain) averaged 23.40 ft below land surface--significantly shallower than the surrounding limestone. Mean depth to water in hilltop wells in the Martinsburg Formation was 30.61 ft, and mean depth to water in wells on hillsides and valleys was 14.43 ft. Mean depth to water in wells on and west of North Mountain was 33.81 ft. Mean depths to water in hilltop, hillside, and valley wells on or west of North Mountain were 37.34, 36.61, and 21.04 ft, respectively.

Some wells are **artesian**. Well 58 is a flowing artesian well. This well is 714 ft deep and is located in the valley near Back Creek at Shanghai. The discharge was measured about once a month between February 28, 1989, and May 3, 1990 (fig. 7). The discharge exhibits the same seasonal trends that ground-water levels exhibit.

Ground-water-level fluctuations were studied from measurements from 4 wells that were equipped with continuous recorders that measured water levels every hour, and from 27 other wells in which water levels were measured on a monthly basis (app. C). Ground-water levels fluctuated more in carbonate areas than in noncarbonate areas. The mean ground-water-level fluctuation was 19.37 ft for 17 wells in carbonate rocks and 8.07 ft for 14 wells in noncarbonate rocks. The minimum and maximum fluctuations in carbonate areas were 1.20 and 45.94 ft, respectively. The minimum and maximum fluctuations in the noncarbonate areas were 2.76 and 12.67 ft, respectively.

Ground-water-level fluctuation in a well depends on the location of the well within the ground-water system. A ground-water system on or near a ground-water divide generally receives water only from infiltration of precipitation. Farther from the divide, particularly near streams, the ground-water level is less responsive because the well responds to flows from a larger area. Declines in water level near discharge areas (streams and springs) are less during the summer and early fall months than declines near ground-water divides because of the sustaining inflow from surrounding areas. Consequently, ground-water levels generally fluctuate less in discharge areas than in recharge areas. Wells 21 and 73 (fig.6) are drilled in carbonate rocks and are located along streams. Ground-water-level fluctuations at these wells were 7.07 and 1.20 ft, respectively. The ground-water-level fluctuations at well 73 were less than those at any of the other wells.

Hydrologic Characteristics of the Carbonate Rocks

Recharge, specific yield, and transmissivity were estimated in a 60-mi^2 area that includes the

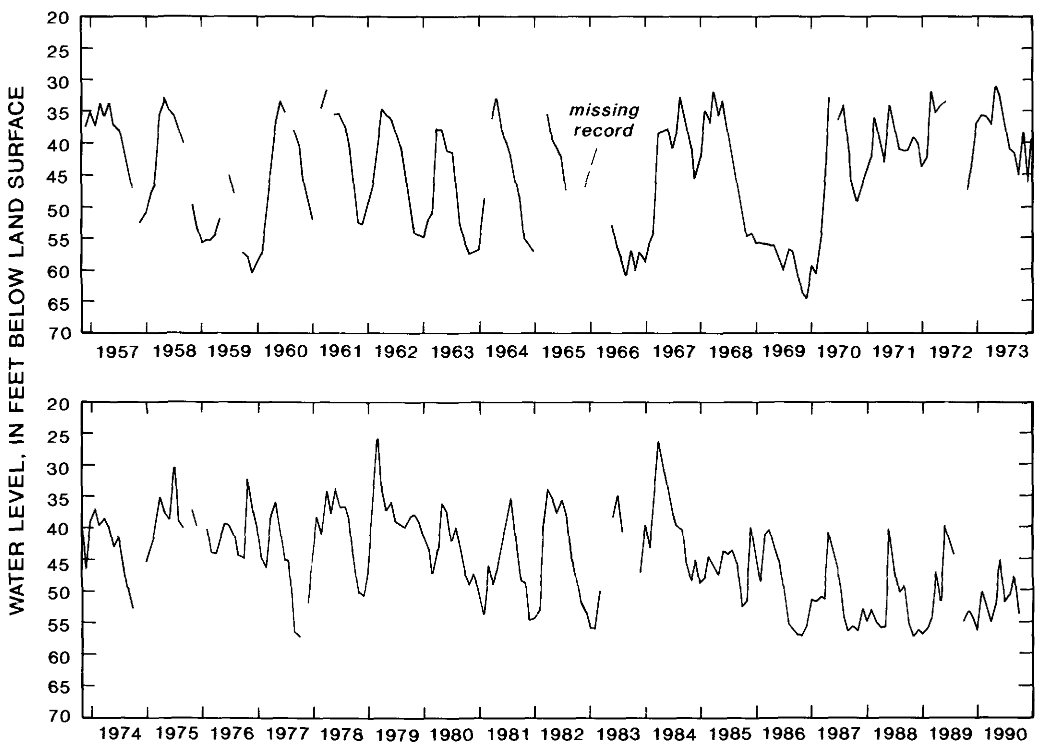


Figure 5. Water levels in well 70 in the Beekmantown Group at Martinsburg, West Virginia. (Well 70 is also numbered 20-5-7 in the U.S. Geological Survey computer data base. The hydrograph is plotted from end-of-month values).

parts of Mill Creek, Middle Creek, Evans Run, and Tuscarora Creek basins underlain by carbonate rock (fig. 8). The western and eastern hydrologic boundaries of this carbonate ground-water-flow system are delineated at the contact with the noncarbonate Martinsburg Formation. Little water flows from the shale into the carbonate aquifer from the west, and little water flows out of the carbonate aquifer and into the shale to the east. The easternmost shale acts as a barrier to ground water flowing to the east, causing springs to emanate from the carbonate rocks near the contact. The northern and southern hydrologic boundaries are less definite, and were estimated on the basis of the area topography and on a ground-water-level map by Hobba (1976). Recharge was estimated for Tuscarora Creek near Martinsburg, Opequon Creek near Martinsburg, and Back Creek near Jones Spring using hydrograph-separation techniques.

Recharge and Discharge

Recharge of the carbonate ground-water systems occurs by infiltration of precipitation, by seepage from losing streams, and by overland runoff into sinkholes. Natural discharge occurs at **gaining streams**, springs, and seeps. Ground water is also pumped from wells, springs, quarries, or mines.

Recharge for the 60-mi^2 area was estimated by calculating the discharge from the area. The discharge was calculated by adding the discharge of streams to the amount of water withdrawn from

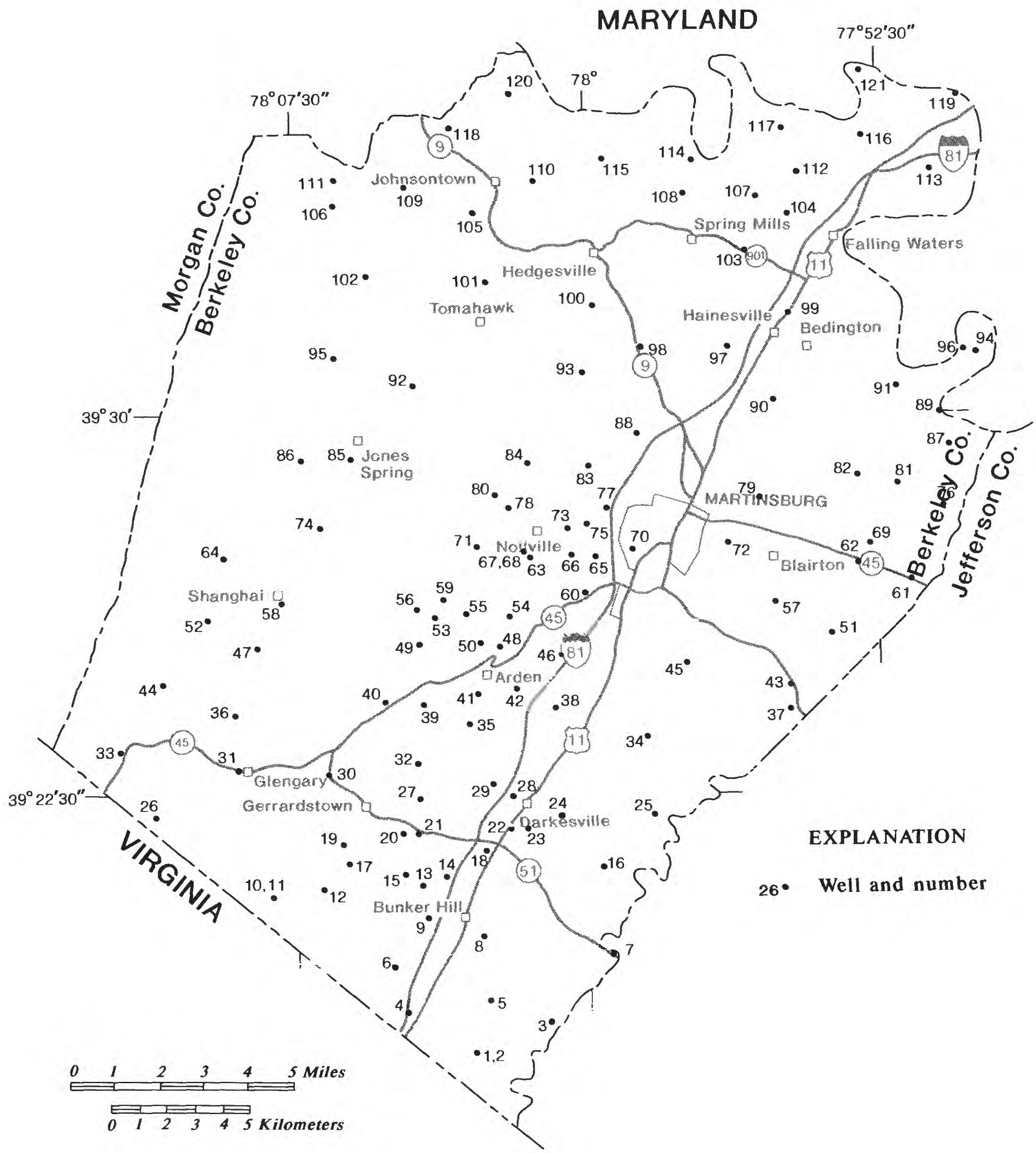


Figure 6. Location of wells inventoried during 1989-90 in Berkeley County, West Virginia.

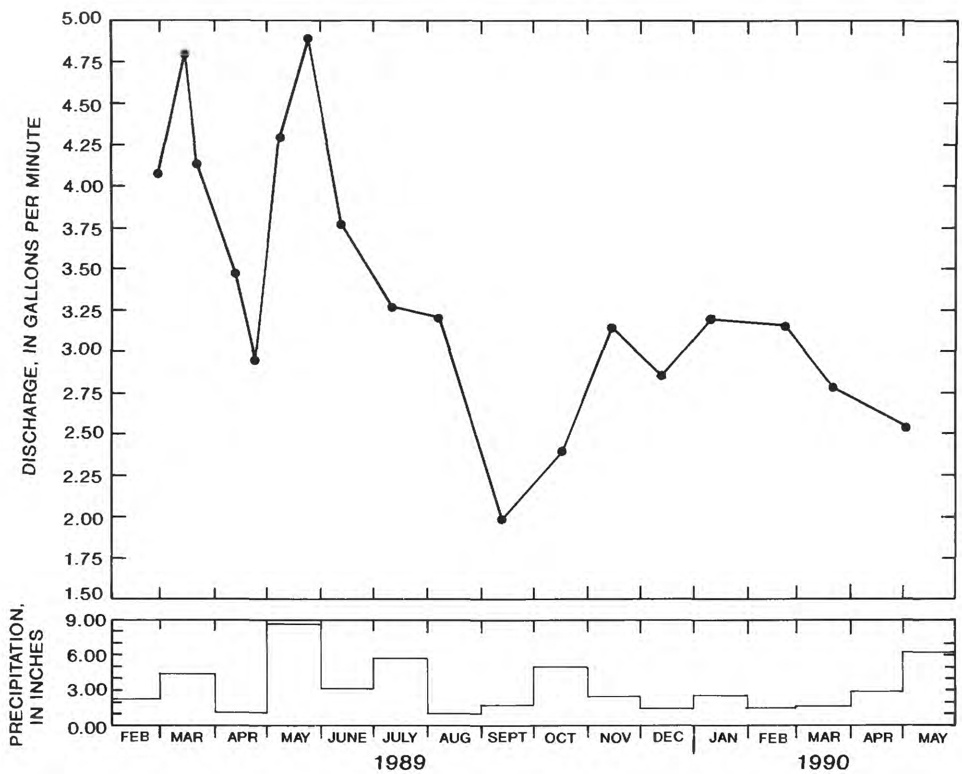


Figure 7. Discharge from artesian well 58 near Shanghai, West Virginia, and monthly precipitation at Martinsburg, West Virginia.

public supply wells and springs at a time when water levels were near their mean annual level. This discharge represents the mean discharge, assuming that the annual recharge equaled the annual discharge, and that the hydrologic boundaries of the area were accurately delineated. The discharge was 19,800 gal/min (table 1), which is equivalent to 330 (gal/min)/mi^2 for the 60-mi^2 area, or about 10 in. of recharge per year.

Discharges of the Mill Creek, Middle Creek, Evans Run, and Tuscarora Creek basins, located in the 60-mi^2 area, were estimated to check for differences within the area. The discharge from each basin then was divided by the drainage area of each basin. The discharges are as follows: Mill Creek, 405 (gal/min)/mi^2; Middle Creek, 260 (gal/min)/mi^2; Evans Run, 165 (gal/min)/mi^2; and Tuscarora Creek, 395 (gal/min)/mi^2. The differences in discharge are significant, assuming that recharge is equally spread over all four basins. The discharge of Middle Creek and Evans Run is extremely low when compared to Mill Creek and Tuscarora Creek. This probably indicates that part of the water entering the ground as recharge within the Middle Creek and Evans Run topographic basins is captured underground and discharged to springs in the Mill Creek or Tuscarora Creek basins. Dye-tracer test C (see subsection Flow Velocity) from near Darkesville to Dove Spring indicates that this occurred in at least one place in Middle Creek Basin.

Hydrograph separation was applied at three streamflow-gaging stations: Tuscarora Creek at Martinsburg (1949-62, 1968-76), Opequon Creek near Martinsburg (1949-89), and Back Creek near Jones Spring (1929-30, 1939-75). With hydrograph

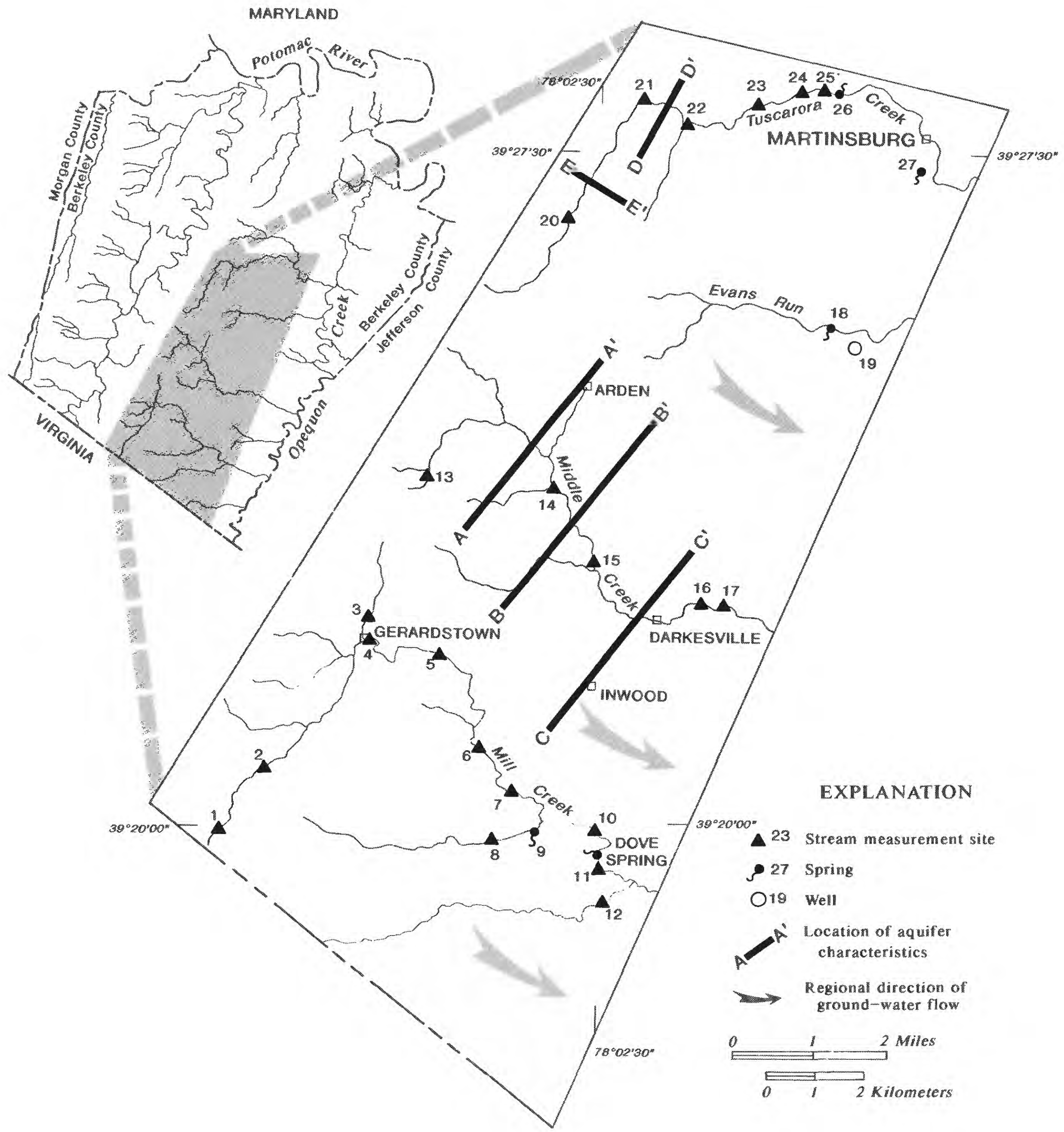


Figure 8. Location of streamflow-discharge measurement sites and location where estimates of aquifer characteristics were made.

Table 1.-- Discharge measurements and drainage areas for sites in the carbonate aquifer systems in the Mill Creek, Middle Creek, Evans Run, and Tuscarora Creek basins for June 26-27, 1990, Berkeley County, West Virginia

[gal/min, gallon per minute; mi^2, square mile]

Site No.	Name	Discharge (gal/min)	Drainage Area (mi^2)
	Mill Creek basin		
1	Mill Creek[1]	0	
2	Mill Creek[2]	240	
3	Unnamed tributary to Mill Creek[1]	0	
4	Mill Creek[2]	150	
5	Mill Creek[2]	835	
6	Mill Creek[2]	2,100	
7	Mill Creek[2]	2,100	
8	Torytown Run[2]	270	
9	Lefevre Spring[3]	2,200	
10	Mill Creek[2]	5,340	
11	Mill Creek[2]	6,060	
12	Sylvan Run[2]	900	
	Subtotal[4]	9,160	22.6
	Middle Creek basin		
13	Unnamed tributary to Middle Creek[2]	<1	
14	Middle Creek[2]	850	
15	Middle Creek[2]	1,490	
16	Middle Creek[2]	2,445	
17	Middle Creek[2]	2,670	
	Subtotal[5]	2,670	10.3
	Evans Run basin		
18	Big Spring[6]	1,000	
19	City and quarry wells[7]	1,500	
	Subtotal[8]	2,500	15.2
	Tuscarora Creek basin		
20	Tuscarora Creek[1]	0	
21	Tuscarora Creek[2]	810	
22	Tuscarora Creek[2]	1,265	
23	Tuscarora Creek[2]	1,680	
24	Tuscarora Creek[2]	1,430	
25	Tuscarora Creek[2]	1,550	
26	Tuscarora Creek[6]	2,900	
27	Martinsburg Water Supply Spring[6]	1,000	
	Subtotal[9]	5,450	13.8
	Total yield from all four basins[10]	19,800	61.9

[1] The discharge measurements made at sites 1, 3, and 20 are exact because these sites were dry.

[2] The discharge measurements made at sites 2, 4-8, 10-17, and 21-25 are accurate to within plus or minus 5 percent.

[3] Pumping rate reported by Berkeley County Public Service District at the time discharge measurements were made.

[4] The yield from Mill Creek basin is the sum of the discharge at the carbonate/noncarbonate rock contact (site 11), plus the discharge from Sylvan Run attributable to the carbonate rock (site 12), plus pumpage removed from the basin at Lefevre Spring (site 9).

[5] The yield from Middle Creek basin is the discharge at the carbonate/noncarbonate rock contact (site 17).

[6] Discharge estimated from measurements reported by Erskine (1948) and McColloch (1986).

[7] Discharge estimated from pumpage reported by Hobba and others (1972, p.75) and reported by the Martinsburg Public Service District.

[8] The yield from Evans Run basin is the sum of the discharge at Big Spring (site 18) and the city and quarry wells (site 19).

[9] The yield from Tuscarora Creek basin is the sum of the discharge at the carbonate/noncarbonate rock contact (site 25), plus the discharge of Kilmer Spring (site 26), and the discharge of the Martinsburg Water Supply Spring (site 27).

[10] These four basins compose the 60-mi^2 carbonate area, so that the total yield can be converted to about 475,000 (gal/d)/mi^2.

separation, streamflow is divided into overland runoff and ground-water-discharge components. Hydrograph separation was applied using the HYSEP2 computer program developed by Sloto (1988).

The median values of ground-water recharge for each method and an average of the three methods for each streamflow-gaging station are presented in table 2. The ground-water-recharge values are equal to discharge values, assuming that interbasin transfer and changes in storage are negligible. Recharge values differ significantly among the three drainage areas, although the amount of precipitation received by each basin is approximately the same. A greater percentage of precipitation enters the ground as recharge in drainage areas that have developed karst terrain than in drainage areas that have not developed karst terrain. Although the percentage of rock types for the three drainage areas was not determined, geologic maps indicate that Tuscarora Creek at Martinsburg drains only carbonate rocks, Opequon Creek near Martinsburg drains carbonate and noncarbonate rocks, and Back Creek near Jones Spring drains mostly noncarbonate rocks, but does include a small section of carbonate rocks. Correspondingly, the highest recharge values were for Tuscarora Creek, followed by Opequon Creek, and Back Creek.

Ground-water flow comprises a larger percentage of the streamflow in carbonate-rock areas than in noncarbonate-rock areas. At Tuscarora Creek, ground water averaged 86.5 percent of the streamflow. At Opequon Creek and Back Creek, ground water averaged 63.9 percent and 50.6 percent of the streamflow, respectively. Nutter (1973, p. 13) obtained similar results in nearby Hagerstown Valley, Md., which is underlain by carbonate rocks. Nutter used hydrograph separation, and estimated that ground-water discharge is 80 to 90 percent of the total discharge in the valley.

Specific Yield and Transmissivity

Specific yield was estimated for the 60-mi^2 area of carbonate rock from **base-flow** measurements and from changes in water levels. The annual discharge from the area is about 19,800 gal/min, or about 10.41 Ggal/yr as estimated from table 1. The annual fluctuation in ground-water levels represents the volume of rock dewatered in yielding this flow. The mean and median annual fluctuations in ground-water levels for carbonate rocks are 19 ft and 17.5 ft, respectively. The specific yield is 0.044 using the mean annual fluctuation, or 0.049 using the median annual fluctuation. These values agree with those of Trainer and Watkins (1975, p. 40), who did not calculate specific yield for carbonate rocks, but indicated that reasonable average **storage coefficients** (equivalent to specific yield in water-table aquifers) are 3 to 4 percent for carbonate rocks in the Potomac River Basin.

Transmissivity was estimated for three reaches in the Middle Creek drainage area and for two reaches in the Tuscarora Creek drainage area. The estimate was calculated by use of measurements of streams during a base-flow recession and the gradient of the water table. Transmissivity was estimated by the following formula (Trainer and Watkins, 1975, p. 30):

$$T = 2.29\,(10^{-4})\,W\left(\frac{ax}{h_o} - \frac{x^2}{2h_o}\right),$$

where:

T = transmissivity, in feet squared per day;

W = constant rate of recharge, in inches per year;

a = distance from stream to ground-water divide, in feet;

x = distance from stream to observation well, in feet; and

h_o = altitude of water table at observation well with respect to mean stream level at the lower end of the profile.

In this calculation, it is assumed that (1) the aquifer is bounded on two sides by streams of infinite length that fully penetrate the aquifer, (2) the **aquifer is homogeneous** and **isotropic**, and (3) recharge is at a constant rate of accretion with respect to time and space (Ferris and others, 1962, p. 130-132). Although the carbonate rocks of Berkeley County are not isotropic, the aquifer can be considered isotropic if only the directional flow par-

Table 2.--Hydrograph-separation results for three streamflow-gaging stations in Berkeley County, West Virginia

[median values for the period of record; percent, percentage of streamflow composed of ground water]

Streamflow-gaging station	Recharge values		
	Inches	Gallon per minute per square mile	Percent
Tuscarora Creek at Martinsburg	11.8	389	86.5
Opequon Creek near Martinsburg	7.02	232	63.9
Back Creek near Jones Spring	5.53	183	50.6

allel or perpendicular to strike is considered. If a large enough segment of the aquifer is considered, the aquifer can be considered homogeneous (Basmaci and Sendlein, 1977, p. 205). Trainer and Watkins (1975, p. 31) also used this technique and concluded that, "The transmissivity values estimated in this manner....compare fairly well with those determined from pumping-test data. This agreement leads us to believe that use of the gradient method is justified in the Appalachian Valley, despite the strong directional properties of the rock."

Ground-water levels that were measured during June 26-27, 1990, were used to determine values of h_0. These levels corresponded with the mean annual water level in nearby observation well 70. A map showing ground-water levels prepared by Hobba (1976) was used wherever measurement sites were unavailable.

Two estimates of transmissivity were calculated--one based on the estimated recharge in the reach and one based on the annual recharge of 10 in., as estimated from the area of carbonate rock (table 3). The recharge of each reach was estimated by dividing the base flow of each reach (calculated from the discharge measurements in table 1) by the drainage area of the reach. The values of recharge seem low for the reaches in Middle Creek and the E-E' section of Tuscarora Creek (fig. 8). The drainage areas supplying water to the streams in these reaches could be losing water to other drainage areas. Transmissivity values would be too low if estimated from recharge values that are too low. Therefore, transmissivity values also were estimated based on the annual recharge rate of 10 in. that was calculated earlier in this report. The estimates of transmissivity range from 730 to 9,140 ft^2/d, based on the annual recharge of 10 in. This wide range in transmissivity values demonstrates that there are variations in the degree of fracturing of the carbonate rock.

Flow Velocity

Qualitative dye-tracer tests can be used to determine point-to-point connections between injection and recovery points, to estimate traveltimes under existing hydrologic and meteorologic conditions, and to study the boundaries of the recharge area. During a qualitative dye-tracer test,

Table 3.--Estimates of annual recharge and transmissivity for carbonate rocks in the Middle Creek and Tuscarora Creek basins in Berkeley County, West Virginia

[gal/min, gallon per minute; in., inches; ft^2/d, feet squared per day; mi^2, square miles]

Stream section	Flow (gal/min)	Recharge: Calculated (in.)	Recharge: Previous estimate (in.)	Transmissivity: Calculated[1] (ft^2/d)	Transmissivity: Previous estimate[2] (ft^2/d)	Approximate contributing area (mi^2)	Geologic formation
Parallel to the strike of rocks							
A-A' (Upper part of Middle Creek)	850	6.0	10	440	730	4.29	Elbrook
B-B' (Middle part of Middle Creek)	640	7.5	10	6,860	9,140	2.58	Conococheague
C-C' (Lower part of Middle Creek)	955	6.5	10	665	1,020	4.41	Beekmantown-Chambersburg
D-D' (Upper part of Tuscarora Creek)	455	10.8	10	1,570	1,450	1.27	Elbrook
Perpendicular to the strike of rocks							
E-E' (Upper part of Tuscarora Creek)	810	7.8	10	620	800	1.58	Beekmantown-Elbrook

1 The calculated transmissivity was calculated using the calculated annual recharge.
2 The previous estimate of transmissivity was calculated from the previously estimated annual recharge of 10 in.

a discrete sample of water is "tagged" with an appropriate fluorescent dye tracer (for example, Rhodamine WT dye). Expected resurgence points are then monitored for traces of the dye by analyzing water samples or activated charcoal-dye traps (Mull and others, 1988). For more information on dye-tracing techniques, refer to Mull and others (1988).

Passive detectors were used to determine the presence or absence of dye in expected resurgence points of springs and streams. The detectors were 5- by 3-in. fiberglass-screen pouches filled with No. 10-mesh activated coconut charcoal and placed in selected springs and streams near the injection sinkholes. Fluorometric dye that reached the monitored resurgence points was adsorbed onto the charcoal. Detectors were installed before the dye was injected to determine levels of natural **background fluorescence**. Springs and streams were preferred monitoring points because they flow continuously, whereas flow from a well depends on pumping. Three wells were used as monitoring points in one area lacking springs or streams. These wells were used for domestic water supply and were pumped daily. Water samples were collected by letting the water run for a few minutes and then filling a bottle with 30 mL (milliliters) of water.

The dye-injection sinkhole sites were believed to be hydraulically connected to the ground-water-flow system. The sinkhole was flushed with approximately 1,000 gal of water before dye was injected to test the suitability of the sinkhole as an injection site, and to wash away any debris or sediment in the hole. The dye was then poured into the sinkhole, and an additional 1,000 gal of water was used to flush the dye into the ground-water-flow system.

The dye detectors were collected and replaced with a new set about once a week. All detectors were checked for dye. An **eluant** was used to remove the dye that was **adsorbed** onto the charcoal. The eluant's chemical composition was 50 percent 1-propanol, 25 percent ammonia hydroxide, and 25 percent distilled water. The charcoal was soaked for 30 minutes, and then the **eluate** was poured into a 6-mL cuvette. The cuvette was placed in a Turner Model-111[2] fluorometer equipped with a 546-nanometer (nm) primary filter and a 560-nm secondary filter. A photomultiplier inside the fluorometer measured the **fluorescence** of the eluate,

2. Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

read as a dimensionless number on the fluorometer dial. Raw well-water samples were poured into a cuvette and were analyzed directly for the presence of dye.

Determination of the presence of dye is somewhat arbitrary. A site through which the dye passed (positive) typically had a low range of natural background fluorescence, followed by a sharp increase in fluorescence with time during the sampling period, and a gradual return to the background fluorescence. Rainfall occasionally caused an additional resurgence of the dye. The sharp rise was caused by the passage of dye through the area. A site where no dye was present (negative) typically had no increases in fluorescence throughout the sampling period. At some sites (indeterminate), it was impossible to determine the presence or absence of dye because of high ranges of natural background fluorescence that could have masked low concentrations of dye resurgence.

Three fluorometric tracer tests were completed for this investigation (fig 9). Rhodamine WT dye was used in all three tests. The results of the tracer tests and the estimated ground-water-flow velocities are presented in table 4. The first tracer test (A) began on December 20, 1989. One gallon of 20-percent solution rhodamine WT dye was injected into a sinkhole in the Beekmantown Group near Files Crossroad in eastern Berkeley County (fig. 10). Eight sites were monitored for dye resurgence--three springs (sites A1, A2, and A3), two on Rocky Marsh Run (sites A4, A5), and three wells (sites A6, A7, and A8). Wells were used as monitoring points to the north of the injection point because of the lack of flowing springs and streams. All of the sites that were monitored were in carbonate rocks except for site A8, which was a well drilled in the Martinsburg shale and was about 700 ft from the shale-carbonate contact. Well sites A6 and A7 tested positive; sites A1, A2, A5, and A8 tested negative; and sites A3 and A4 tested indeterminate. The dye flowed to site A6 at a velocity of 53 to 55 ft/d, and to site A7 at a velocity of 32 to 33 ft/d. These velocities infer diffuse-flow conditions. These velocities are also probably underestimated under the given hydrologic conditions, because a straight-line distance was used to calculate the velocities, although flow is usually not in one direction. The result is given as a range and it is unknown where and when the dye entered the stream.

The second tracer test (B) also began on December 20, 1989. One gallon of 20-percent solution rhodamine WT was injected into a sinkhole 1.2 mi northeast of Jones Spring in the western part of Berkeley County. The sinkhole is on the boundary between the Tonoloway and Wills Creek Formations. Three springs (sites B1, B5, and B6) and four streams (sites B2, B3, B4, and B7) were monitored for dye resurgence (fig. 11). Sites B1, B4, B5, and B6 were located in carbonate rocks and the remaining sites were in noncarbonate rocks. Sites B1, B5, and B6 tested positive, site B7 tested negative, and sites B2, B3, and B4 had indeterminate results. The dye moved in opposite directions, probably through a fault that parallels the bedrock strike and passes near the injection point and sites B6 and B1. Site B1 is in the opposite direction from the injection point, as is site B6. The dye was injected on a hilltop, probably on a ground-water divide, which made it possible for the dye to move in opposite directions. Flow velocity at site B6 ranged from 703 ft/d to a possible maximum of 1,507 ft/d. The flow velocity at site B1 ranged from 131 to 155 ft/d, which was much slower than the flow at site B6. The slower velocity could be caused by a lower hydraulic head or by a fault pinching shut in the direction of site B1. Flow velocities at site B5 ranged from 877 ft/d to a possible maximum of 1,879 ft/d.

The third tracer test (C) began on April 27, 1990. One-half gallon of 20-percent solution rhodamine WT was injected in a sinkhole 0.75 mi north of Inwood in the southeastern part of Berkeley County. Four springs (sites C2, C5, C6, and C7) and four streams (sites C1, C3, C4, and C8) were monitored for dye resurgence (fig. 12). Sites C1 and C5 tested positive; sites C2, C6, and C7 tested negative; and sites C3, C4, and C8 were indeterminate. Flow velocity at site C1 ranged from 32 to 77 ft/d. There are no known faults between site C1 and the injection point. Flow velocity to site C5 ranged from 714 to 1,154 ft/d. This site is located along a fault, and the dye was probably in conduit-flow conditions.

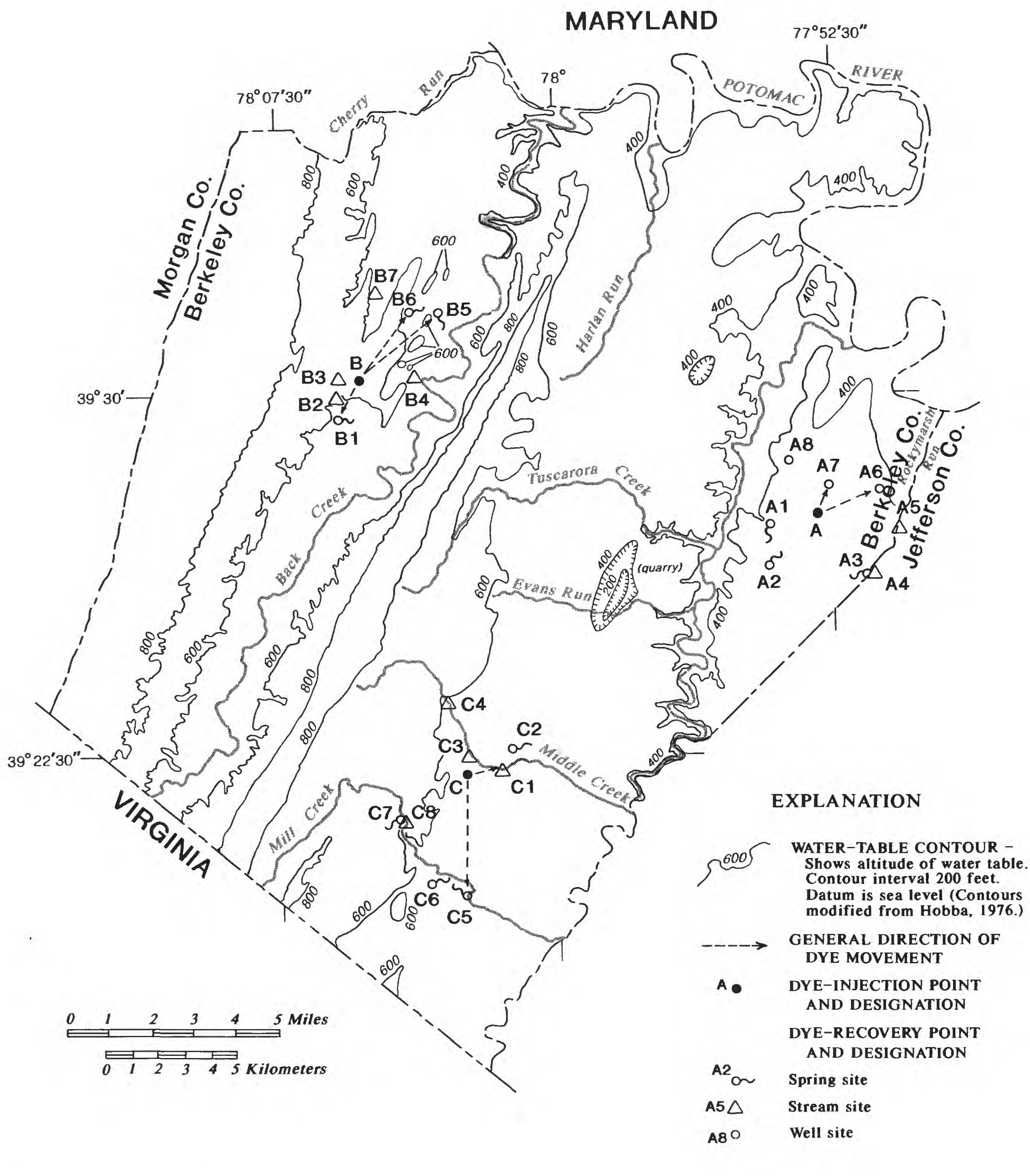


Figure 9. Location of dye-tracer tests and water-table contours.

Table 4.--Results of dye-tracer tests and estimated flow velocities in Berkeley County, West Virginia

[A and B refer to the first and second dye-tracer tests, respectively, which began on December 20, 1989; C refers to the third dye-tracer test, which began on April 27, 1990; ft, feet; ft/d, feet per day]

Site	Type of site	Straight-line distance from injection to recovery (ft)	Results of tracer tests	Dye travel-time from injection point to recovery point (d)	Estimated ground-water-flow velocity, (ft/d)	Orientation of recovery point with respect to strike of bedrock	Geologic unit of tracer test
A1	Spring	6,050	Negative	---	---	Not parallel	Chambersburg Limestone
A2	Spring	9,075	Negative	---	---	Not parallel	Beekmantown Group
A3	Spring	9,850	Indeterminate	---	---	Not parallel	Beekmantown Group
A4	Stream	9,900	Indeterminate	---	---	Not parallel	Beekmantown Group
A5	Stream	10,075	Negative	---	---	Not parallel	Beekmantown Group
A6	Well	7,875	Positive	142-149	53-55	Not parallel	Beekmantown Group
A7	Well	4,050	Positive	121-128	32-33	Parallel	Beekmantown Group
A8	Well	8,100	Negative	---	---	Not parallel	Martinsburg Shale
B1	Spring	5,750	Positive	37-44	131-155	Parallel	Tonoloway, Wills Creek and Williamsport Formations, Helderberg Group
B2	Stream	3,950	Indeterminate	---	---	Parallel	Mahantango and Marcellus Formations
B3	Stream	2,700	Indeterminate	---	---	Not parallel	Mahantango Formation
B4	Stream	9,475	Indeterminate	---	---	Not parallel	Tonoloway, Wills Creek and Williamsport Formations, Helderberg Group Oriskany sandstone
B5	Spring	13,150	Positive	7-15	877-1,879	Parallel	Tonoloway, Wills Creek and Williamsport Formations, Helderberg Group Oriskany sandstone
B6	Spring	[1]10,550	Positive	7-15	703-1,507	Parallel	Tonoloway, Wills Creek and Williamsport Formations, Helderberg Group
B7	Stream	11,000	Negative	---	---	Not parallel	Brallier, Mahantango, and Marcellus Formations
C1	Stream	2,000-4,260	Positive	55-63	32-77	Not parallel	Elbrook and Conococheague Formations Beekmantown Group
C2	Spring	6,450	Negative	---	---	Not parallel	Beekmantown Group
C3	Stream	2,600	Indeterminate	---	---	Parallel	
C4	Stream	9,375	Indeterminate	---	---	Not parallel	Elbrook and Conococheague Formations
C5	Spring	15,000	Positive	13-21	714-1,154	Not parallel	Beekmantown Group
C6	Spring	14,450	Negative	---	---	Parallel	Beekmantown Group
C7	Spring	10,350	Negative	---	---	Not parallel	Elbrook Formation
C8	Stream	10,150	Indeterminate	---	---	Not parallel	Elbrook and Conococheague Formations

[1] This is the distance to the spring where the dye emerged. Site B6 was about 900 ft downstream from the spring.

The results of the ground-water-tracer tests in Berkeley County were similar to those in Jefferson County (Kozar, Hobba, and Macy, 1991) in that ground-water flow is generally controlled by geologic structure within the aquifer. Ground-water velocities in Berkeley County ranged from 32 ft/d to a possible maximum of 1,879 ft/d. The slower velocities, attributed to diffuse flow, ranged from 32 to 155 ft/d, and had a mean velocity of 71 ft/d. The faster velocities, attributed to conduit flow, ranged from 703 to 1,879 ft/d, and had a mean velocity of 1,139 ft/d. The maximum ground-water velocity estimated for Berkeley County was almost twice the value determined for Jefferson County. This could have been due to steeper hydraulic gradients at the test sites in Berkeley County, or possibly higher hyraulic conductivity.

GROUND-WATER AVAILABILITY

About 9.7 Mgal/d of ground water was withdrawn in Berkeley County in 1990. The distribution of the withdrawals by types of use is as

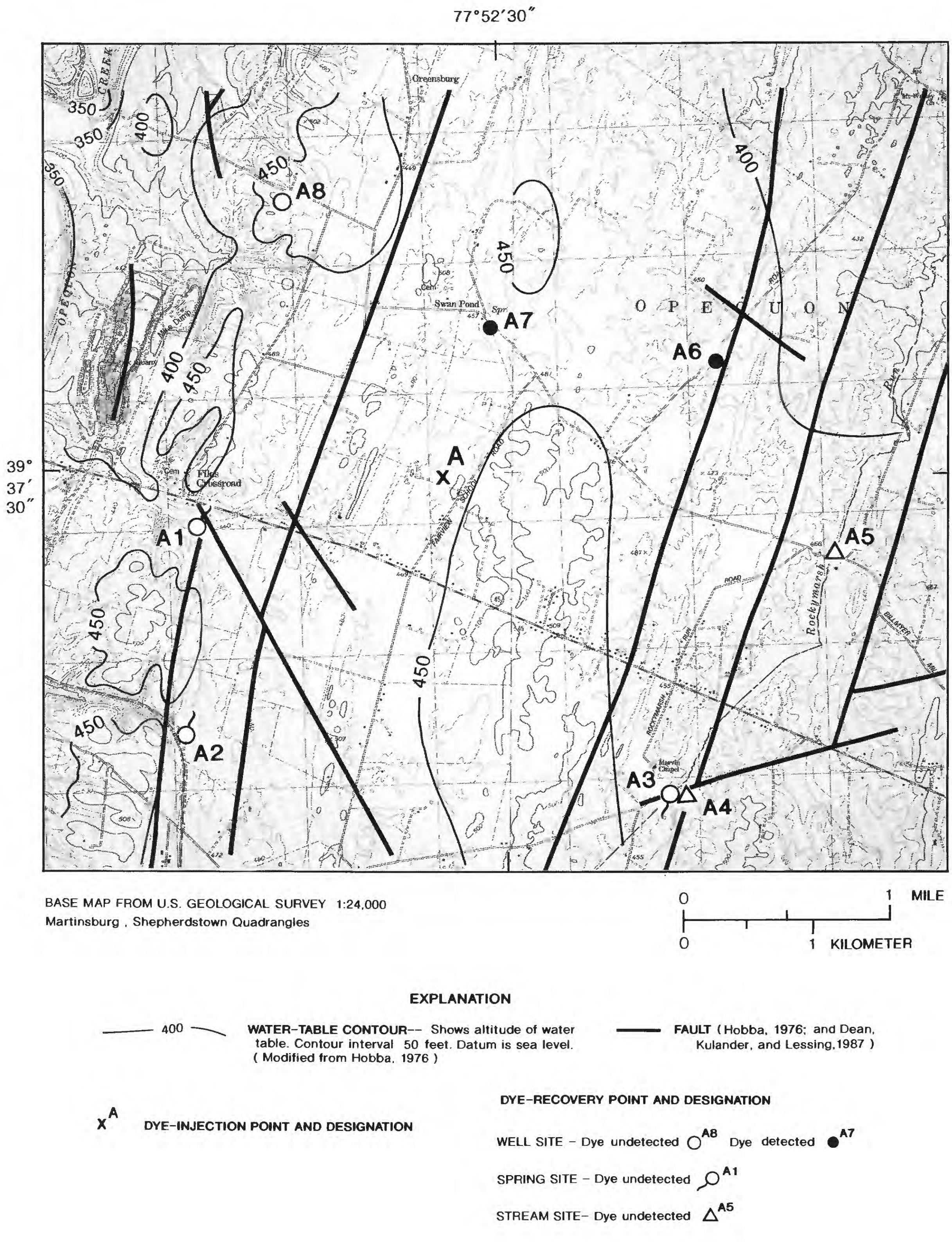


Figure 10. Location of sites for dye-tracer test A near Files Crossroads, West Virginia.

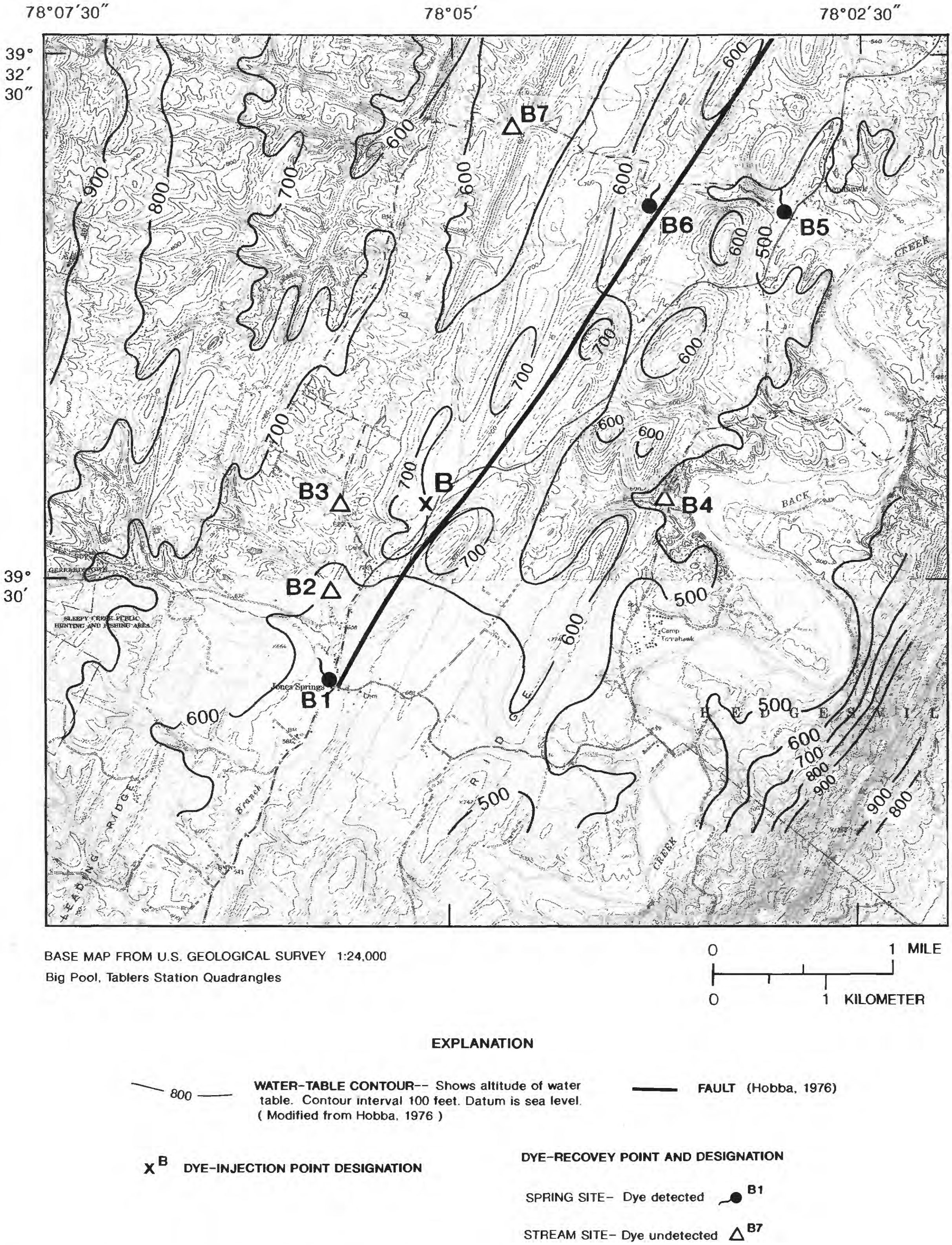
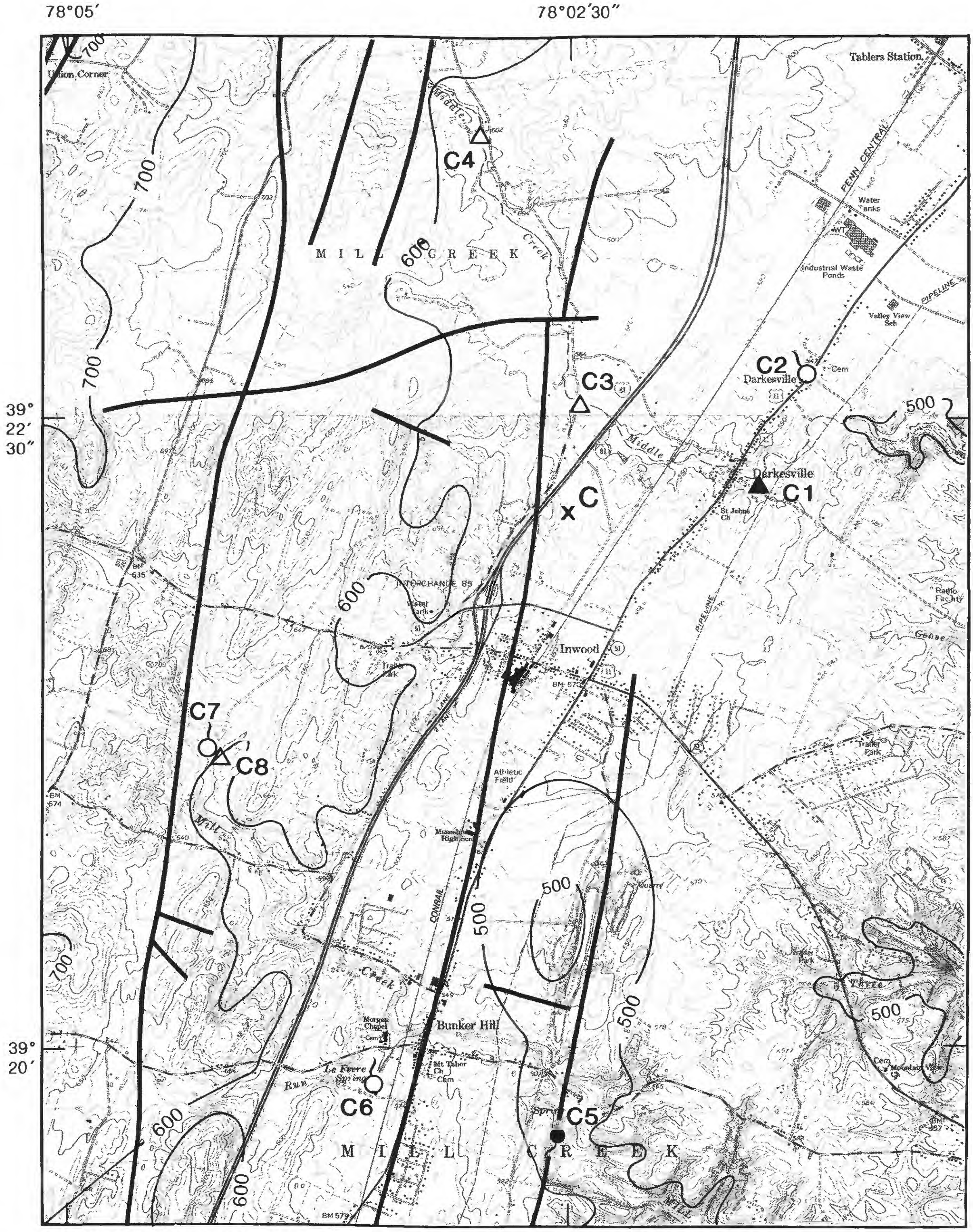


Figure 11. Location of sites for dye-tracer test B near Jones Spring, West Virginia.



BASE MAP FROM U.S. GEOLOGICAL SURVEY 1:24,000
Inwood, Tablers Station Quadrangles

0 — 1 MILE
0 — 1 KILOMETER

EXPLANATION

— 500 — WATER-TABLE CONTOUR-- Shows altitude of water table. Contour interval 100 feet. Datum is sea level. (Modified from Hobba, 1976)

— FAULT (Hobba, 1976)

x C DYE-INJECTION POINT AND DESIGNATION

DYE-RECOVERY POINT AND DESIGNATION

SPRING SITE - Dye detected C5 Dye undetected C2

STREAM SITE - Dye detected C1 Dye undetected C8

Figure 12. Location of sites for dye-tracer test C near Inwood, West Virginia.

follows: public water supply, 3.89 Mgal/d; mine or quarry dewatering, 2.98 Mgal/d; domestic, 1.49 Mgal/d; industrial, 1.24 Mgal/d; livestock, 0.07 Mgal/d; and commercial supply, 0.03 Mgal/d.

Well Yield

Well yield is a measurement of the rate of flow that a well produces. Well-yield data used in this report were obtained from Beiber (1961), Friel and others (1975), drillers' reports from the West Virginia State Department of Health, and from well inventories made during this project. Well-yield data from 445 wells were reported by well owners or by drillers. The locations of 121 wells inventoried by U.S. Geological Survey personnel during the project (1989-90) are shown in figure 6. Ground-water-site records from these wells are presented in appendix A-1. Records obtained from the West Virginia State Department of Health were used in the data analysis only if the well site could be plotted on a map based on the description of the location given in the driller's report. The locations of these wells are not shown in figure 6, and the records are not included in appendix A-1.

Well yield is affected by the size and number of water-bearing fractures intersected during drilling. Well yields become greater as the size and number of fractures intersected during drilling increases. Well yield is highly variable in Berkeley County. Reported yields ranged from 0.25 to 567 gal/min. Wells that were drilled as dry holes were not included in the data base. The frequency of dry holes is not known.

About 5 percent of the well-yield data were from wells other than 6-in. in diameter. The yields of wells with borehole diameters other than 6 in. were adjusted to that of a 6-in.-diameter borehole (water-table conditions) so that the data could be more accurately compared. The adjustments were made according to a table by Johnson Division (1975, p. 107) (table 5). For example, if a 6-in.-diameter well yields 15 gal/min, a 12-in.-diameter well under the same hydrologic conditions could likely yield 10 percent more water than the 6 in. well, or 16.5 gal/min. The percentage of increase in well yield resulting from increasing the well diameter is less for artesian conditions than for water-table conditions.

Well yields differ by geologic formation. The highest mean well yield (48 gal/min) was in the Beekmantown Group. Well yields higher than 100 gal/min were present in no other geologic unit, except at one well in the Chambersburg Limestone. Twelve such wells are present in the Beekmantown Group. The highest median well yield was in the Martinsburg Formation. The percentage of wells that equal or exceed a given yield value for each geologic unit are shown in figures 13 to 19. For example, 50 percent of the well yield in each geologic unit equaled or exceeded the following: Beekmantown Group, 15 gal/min; Martinsburg Formation, 20 gal/min; Chambersburg Limestone, 13 gal/min; Elbrook Formation, 15 gal/min; Conococheague Formation, 12 gal/min; Hampshire Formation, 18 gal/min; and Mahantango Formation, 10 gal/min.

The distance to a fault zone is an important consideration when wells are drilled. Fractures typically increase in number and size close to faults, increasing well yields. The distances to faults that were mapped by Dean and others (1987) and by Hobba (1976) were calculated by plotting the well locations on the maps and measuring the distance to the fault trace. The well-yield statistics for carbonate rocks in table 6 indicate that the mean, median, and maximum well yields decrease as the distance

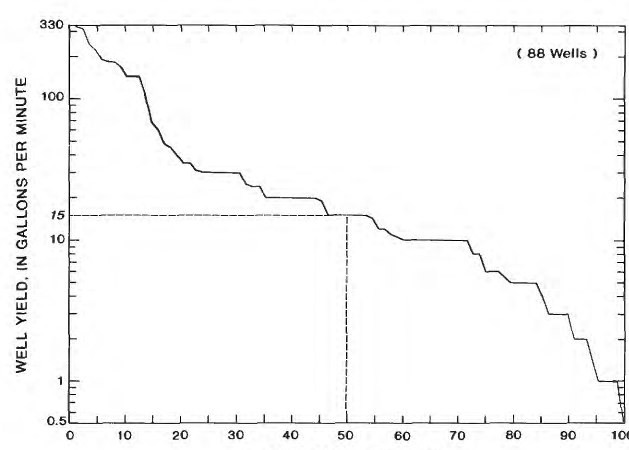


Figure 13. Well-yield frequencies for wells in the Beekmantown Group in Berkeley County, West Virginia.

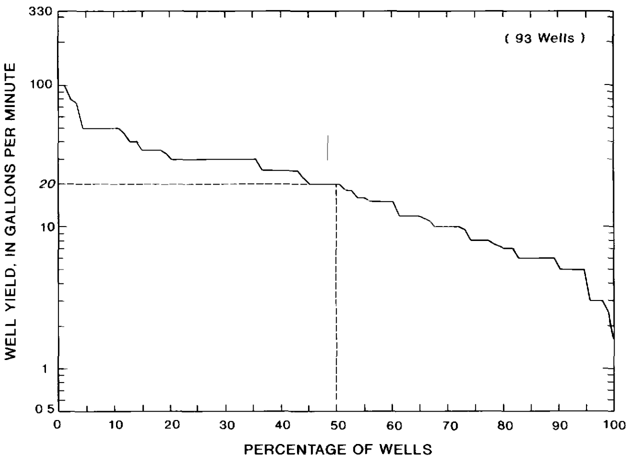


Figure 14. Martinsburg Formation

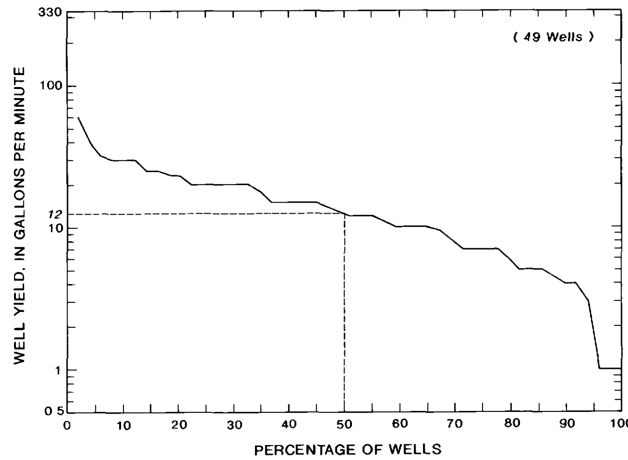


Figure 17. Conococheague Formation

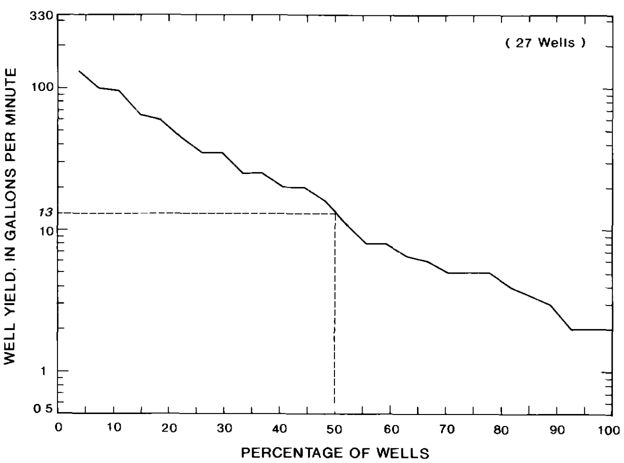


Figure 15. Chambersburg Limestone

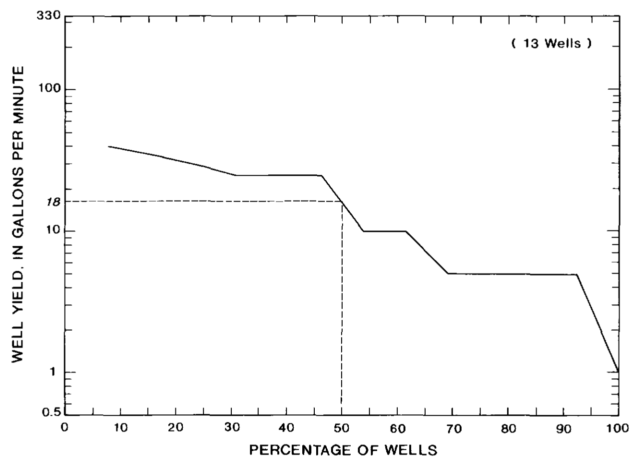


Figure 18. Hampshire Formation

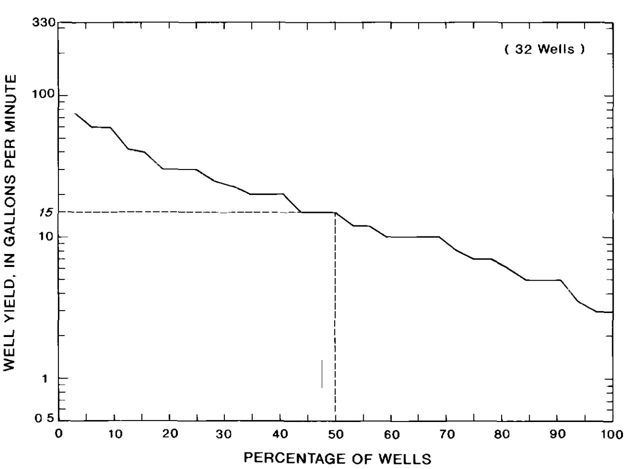


Figure 16. Elbrook Formation

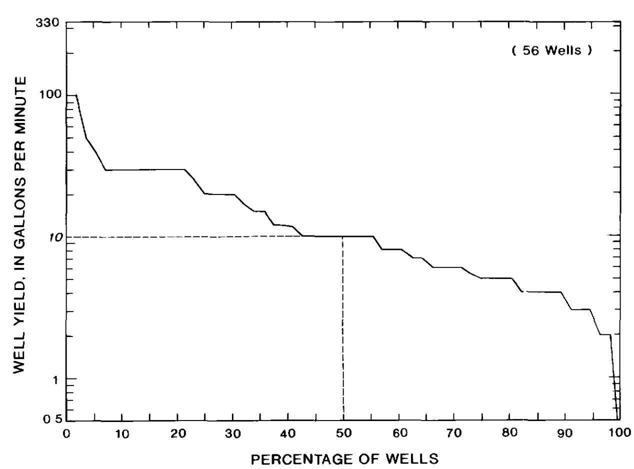


Figure 19. Mahantango Formation

Figures 14-19. Well-yield frequencies for wells in the: (Fig. 14) Martinsburg Formation, (Fig. 15) Chambersburg Limestone, (Fig. 16) Elbrook Formation, (Fig. 17) Conococheague Formation, (Fig. 18) Hampshire Formation, and (Fig. 19) Mahantango Formation in Berkeley County, West Virginia.

Table 5.--Relation of well diameter to well yield

[Modified from Johnson Division, 1975, p. 107. This table shows the theoretical percentage increase in yield that results from enlarging the well diameter. in., inches]

Original well diameter (in.)	Well yield increase, in percent						
	Enlarged well diameter, in inches						
	6	12	18	24	30	36	48
	Water-table conditions						
6	1	10	17	23	28	32	39
12	---	1	6	12	16	20	26
18	---	---	1	5	9	12	18
24	---	---	---	1	4	7	13
30	---	---	---	---	1	3	9
36	---	---	---	---	---	1	5
	Artesian conditions						
6	1	8	12	16	19	32	39
12	---	1	5	8	11	20	26
18	---	---	1	3	6	8	12
24	---	---	---	1	3	5	9
30	---	---	---	---	1	2	6
36	---	---	---	---	---	1	4

from a fault increases. All wells in carbonate formations with yields greater than 67 gal/min were 800 ft or closer to a fault. **Specific capacity** data also indicate a trend toward greater values closer to a fault. Median specific capacity is greater for wells closer than 700 ft to a fault than for wells more than 700 ft from a fault (table 7).

The area that a fault influences depends on the dip and width of the fault. Taylor (1974, p. 51) states that low-dip faults have a much greater area of fractured rock in the upper few hundred feet of bedrock than do vertical or near-vertical faults. Taylor (p. 51) also notes that:

"The width of the fault zones in the area is quite variable. The North Mountain fault has several mapped splays and appears to exert influence over a fairly large area, whereas many of the strike-slip faults have widths less than 50 feet in which effects on the bedrock can be observed. Traverses across a number of these strike-slip faults showed very little topographic expression and little evidence of fault-induced fracturing, indicating very narrow fault zones."

Rauch and Plitnik (1984) studied the effects of lineaments in the same geologic units in the Hagerstown Valley, Md. They stated (p. 8),

"Optimum well locations are within about 100 feet of a photolineament center line for carbonate rocks having predominantly diffuse-flow aquifer characteristics. Such wells produce about 5 times the rate of more distant wells, on average... Conduit-flow carbonate rocks, which are highly cavernous, do not represent good photolineaments for high well yields... Optimum well sites in the Martinsburg Formation are within 300 feet of the center line for a photolineament."

Table 6.--Well yield in carbonate rocks at various distances from a fault in Berkeley County, West Virginia

[<, less than; ≥, greater than or equal to]

Distance from fault (feet)	Well yield, in gallons per minute				Number of wells
	Mean	Median	Minimum	Maximum	
<400	128	33	1.4	567	18
400- 799	59	24	5.0	323	20
800-1,299	32	21	2.0	142	18
1,300-1,999	15	12	1.0	65	17
≥2,000	12	10	1.0	35	19

Table 7.--Specific capacity of wells drilled in carbonate rocks at various distances from a fault in Berkeley County, West Virginia

[<, less than; ≥, greater than or equal to]

Distance from fault (feet)	Specific capacity, in gallons per minute per foot				Number of wells
	Mean	Median	Minimum	Maximum	
<700	4.70	3.60	0.24	20	13
≥700	5.00	.26	.06	41	11

In general, less additional water is available as a well is deepened because of a decrease in the degree of fracturing. Beiber (1961, p. 18) reported for carbonate rocks that "...Solutional activity has been most vigorous at shallow depths and the largest openings generally occur at depths of less than 100 feet." Median well yields for various well-depth ranges decreased with increasing depth in carbonate rocks (table 8). Median well yields in the noncarbonate rocks also decreased with depth, with the exception of the 0- to 49-ft depth interval. It is possible that ground-water levels in this interval are not high enough to support high-yielding wells. Additionally, much of this interval commonly is cased.

Drilling a deeper hole does not necessarily mean that there would be less water. Deeper holes are drilled because the more productive shallow fracture zones are not always intersected, and it is sometimes necessary to drill deeper to find enough fractures to produce the desired amount of water.

Wells in carbonate rocks are usually drilled deeper than those in the noncarbonate rocks. The median well depths for carbonate and noncarbonate rocks were 225 and 150 ft, respectively (table 9). The deepest median well depth was 250 ft in the Conococheague Formation, and the shallowest median well depth was 125 ft in the Martinsburg Formation. The well-depth data used in this table are from drillers' reports that were completed from 1986 through 1989 and are on file with the West Virginia State Department of Health.

Springflow

Springs are natural discharge points for water draining from the ground-water system. Springs provide much of the base flow to streams in Berkeley County. The locations of 70 springs are shown in figure 20, and the latitiude, longitude, altitude, geologic formation, topographic setting, and discharge data from these springs are presented in appendix A-2.

Discharge from springs ranges from near zero at some sites to greater than 2,000 gal/min year-round at other sites. The number of springs in Ber-

Table 8.--Well yield for various well depth ranges in Berkeley County, West Virginia

[≥, greater than or equal to]

Depth range (feet)	Well yield, in gallons per minute				Number of sites
	Mean	Median	Minimum	Maximum	
	Carbonate rocks				
0- 49	26	30	10	35	7
50- 99	22	20	2	67	26
100-149	28	20	1	142	47
150-199	48	15	1	567	35
200-249	23	12	2	315	36
250-299	38	10	1	225	19
300-399	25	7	1	421	37
≥400	21	4.5	.5	323	34
	Noncarbonate rocks				
0- 49	18	8.8	0.25	100	10
50- 99	24	21	.25	100	46
100-149	18	16	2.5	50	64
150-199	20	10	4	100	39
200-299	16	8	2	80	23
300-399	5.1	5	1.5	10	14
≥400	3.9	3.2	1.5	10	8

Table 9.--Well depth by geologic unit in Berkeley County, West Virginia

Geologic unit	Well depth, in feet				Number of wells
	Mean	Median	Minimum	Maximum	
Carbonate rocks	264	225	65	875	104
Beekmantown Group	276	225	65	875	38
Chambersburg Limestone	274	208	125	600	18
Conococheague Formation	261	250	85	600	33
Elbrook Formation	226	227	75	350	15
Noncarbonate rocks	178	150	70	545	96
Martinsburg Shale	153	125	70	350	51
Mahantango Formation	207	172	75	545	40

keley County that are within given discharge ranges for carbonate and noncarbonate rocks is given in table 10.

The largest springs are in the carbonate rocks. The median discharge of 41 springs in carbonate rocks was 150 gal/min (calculated from the mean springflows of each site). The median discharge of 14 springs in noncarbonate rocks was 8.3 gal/min. Eleven of thirteen springs in the carbonate rocks with mean discharge 500 gal/min or greater were within 500 ft of a fault or the limestone-shale contact (fig. 21). Hobba and others (1972, p. 64) reported that, of 25 springs in Berkeley and Jefferson Counties that yield more than 1,000 gal/min, 16 are on or are near mapped faults. Faults are related to large springflows because they are often the main avenues of ground-water flow, provided they are not closed or filled with sediment. The limestone-shale contact is related to larger springflows because the shale is typically less permeable than the limestone, and acts as a dam, causing ground water to collect in the limestone adjacent to the shale. Also, dissolution of the limestone along the limestone-shale contact can promote conduit development.

Springflow typically follows the same seasonal pattern as that of ground-water levels in wells: lowest springflow is from mid-October through November and highest springflow is from April through mid-June. Hydrographs for five springs in carbonate rocks are shown in figures 22 through 26. The hydrographs of springs 213, 231, 234, and 268 indicate that springflow increases quickly in response to recharge from precipitation, and then decreases at a slower rate after the precipitation ends. This characteristic is not evident on the hydrograph of spring 205 because of the effects of pumping.

The size of recharge areas for springs can be estimated from the average spring discharge and the

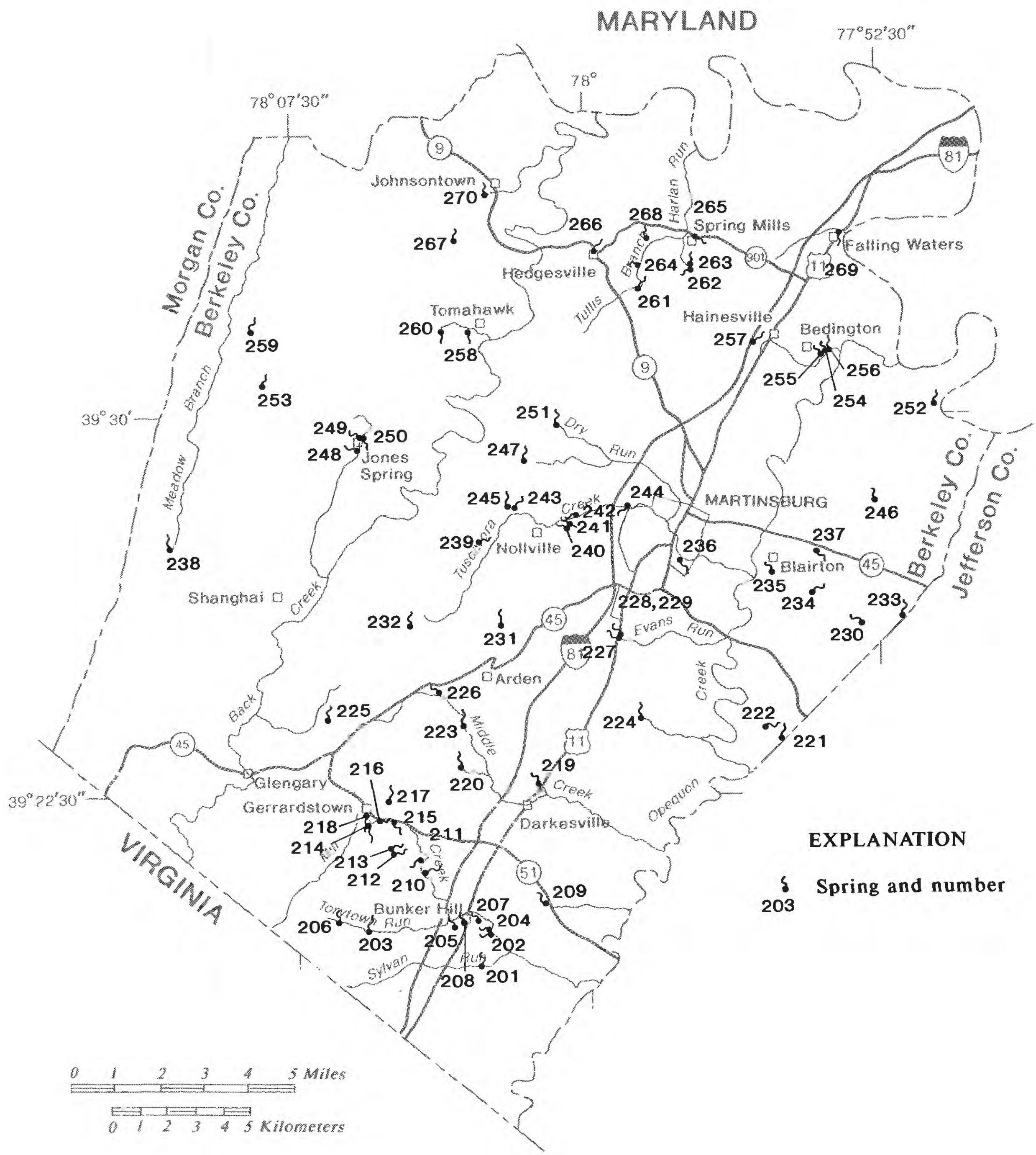


Figure 20. Location of springs in Berkeley County, West Virginia.

Table 10.--Number of carbonate and noncarbonate springs in given discharge ranges in Berkeley County, West Virginia

[Discharge range is the range into which the mean springflow falls. gal/min, gallon per minute; <, less than; ≥, greater than or equal to]

Discharge range (gal/min)	Number of carbonate-rock springs	Number of noncarbonate-rock springs
<10	2	7
10- 49	2	5
50- 99	11	1
100- 199	8	1
200- 499	5	0
500- 999	5	0
1,000-1,999	3	0
≥2,000	5	0

annual recharge rate according to the formula $A = \frac{Q}{R}$; where A = size of recharge area, in square miles; Q = average spring discharge, in gallons per minute; and R = annual recharge rate, in gallons per minute per square mile (Nutter, 1973). The annual recharge rate is about 10 in/yr, or 330 (gal/min)/mi^2 for the carbonate rocks. The estimated recharge areas for springs in the carbonate rocks are shown in table 11. The discharges used to calculate these recharge areas were the means of all available flow measurements for each spring.

The formula calculates the approximate size of the area that contributes to the flow of the spring; it does not define its shape or its boundaries. Recharge boundaries can often be estimated by outlining the topographic divides around a site. With this formula, it is assumed that all recharge comes from precipitation within a given recharge area. The formula is less accurate where losing streams are present. Losing streams allow water from another recharge area to re-enter (recharge) the ground-water-flow system, and discharge at a downgradient spring. Therefore, the formula would give a value that is higher than it should be because of the extra water added by the losing stream.

GROUND-WATER QUALITY

Ground-water quality in Berkeley County is affected by geology, topographic location, and land use. Geology affects ground-water quality because

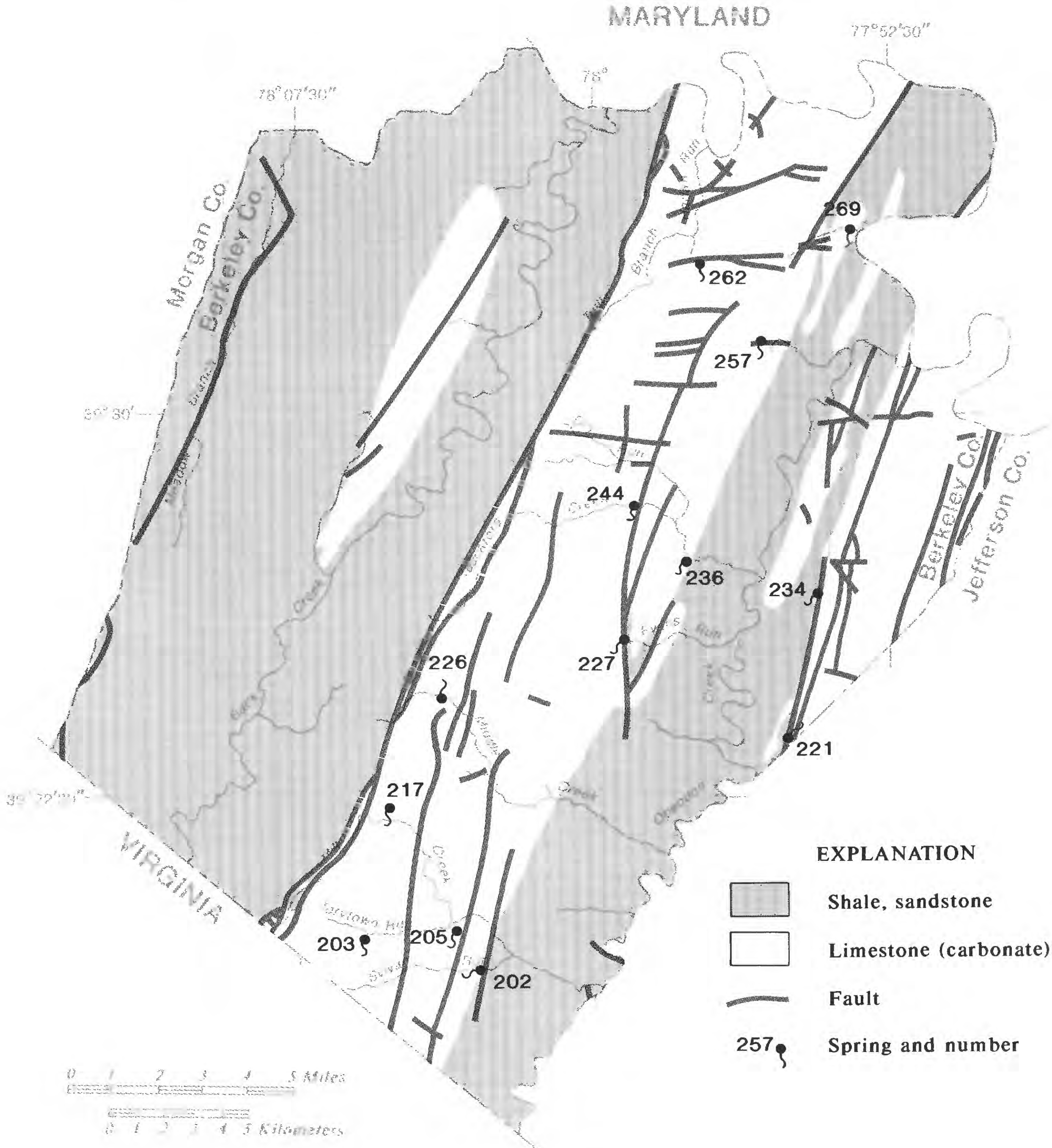


Figure 21. Location of springs with mean discharge greater than 500 gallons per minute, faults, and limestone contacts in Berkeley County, West Virginia.

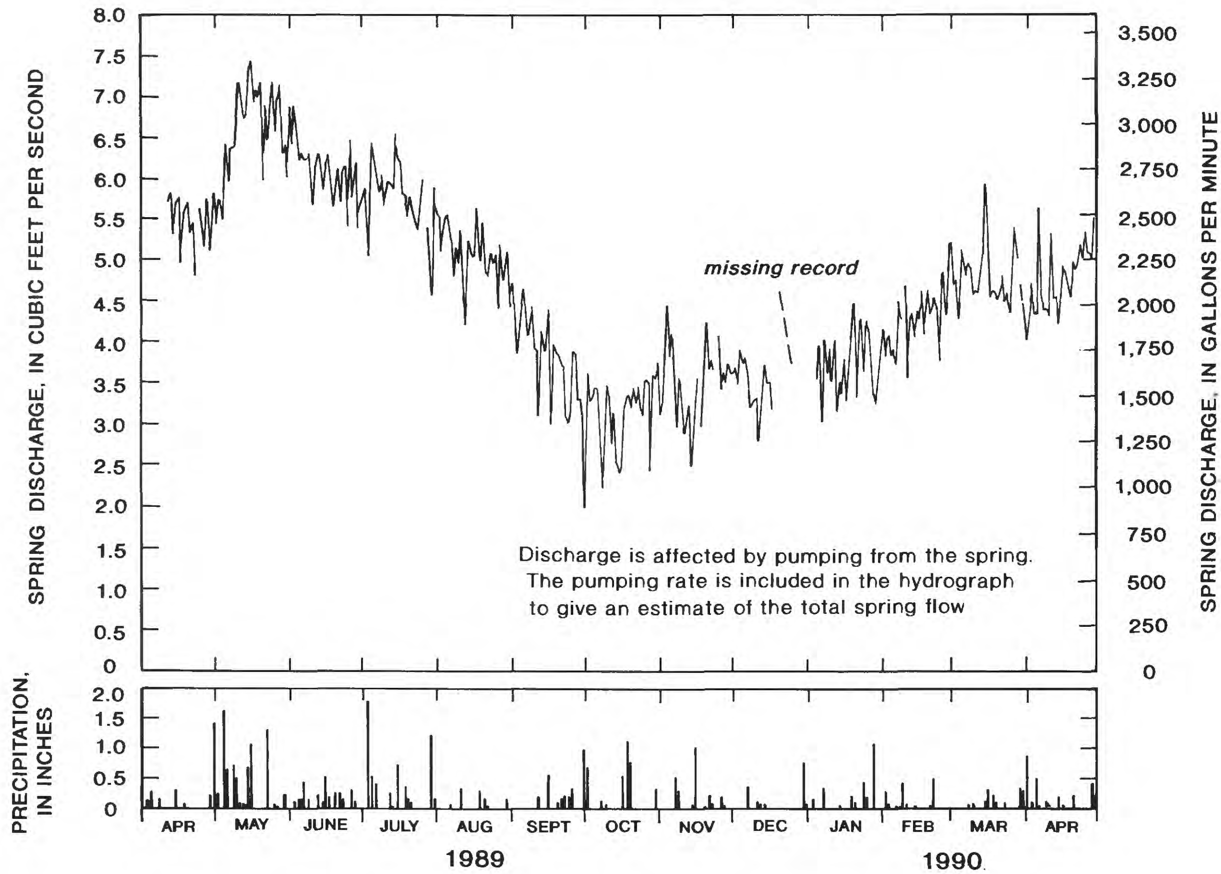


Figure 22. Discharge from spring 205 and daily precipitation at Martinsburg, West Virginia.

of the different types of rock that are present. Ground water also becomes more mineralized (increasing the amount of total dissolved solids) as it travels from mountaintops to valleys. Land use can affect ground-water quality because chemicals on the land surface, such as pesticides and fertilizers, can infiltrate into the underlying aquifers. Human and animal wastes also can contaminate ground water. The carbonate rocks are particularly susceptible to contamination because sinkholes often provide a direct connection between the land surface and the ground-water system. Contamination within the carbonate rocks can spread quickly because of potential rapid flow of ground water through conduits.

Collection and Analytical Methods

Water samples were collected from wells and springs for chemical analyses. Most of the ground-water-quality data were obtained from the analyses of water samples collected during two time intervals. Ground-water-quality samples were collected from a network of 46 wells and 14 springs August 21-24, 1989. These sites included 25 wells and 11 springs in the carbonate rocks and 21 wells and 3 springs in the noncarbonate rocks. Ground-water-quality samples were collected from a second network of 54 wells and 6 springs March 5-9, 1990. These sites included 33 wells and 5 springs in the carbonate rocks and 21 wells and 1 spring in the noncarbonate rocks. Water samples from seven

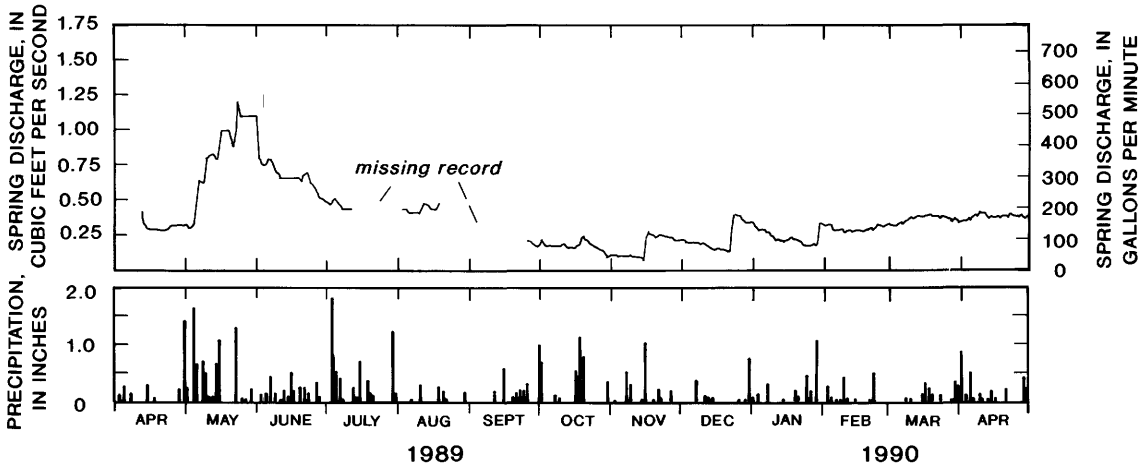


Figure 23. Discharge from spring 213 and daily precipitation at Martinsburg, West Virginia.

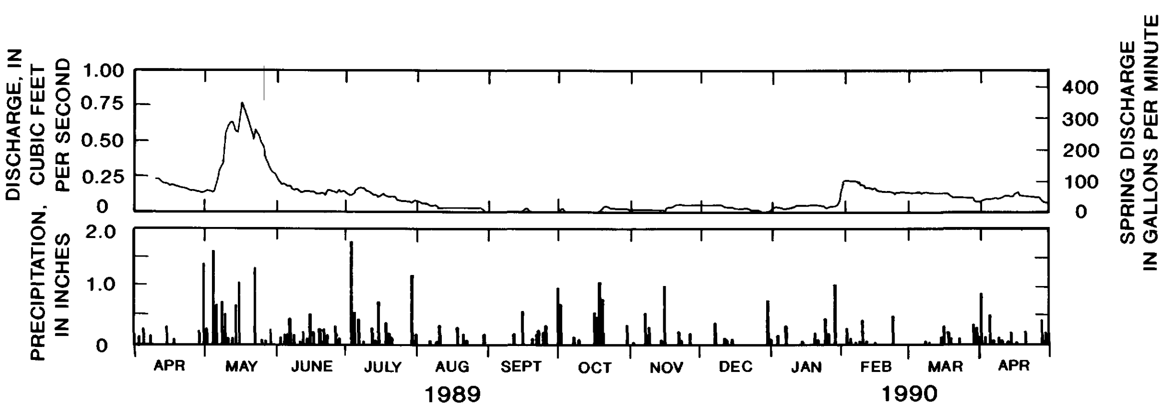


Figure 24. Discharge from spring 231 and daily precipitation at Martinsburg, West Virginia.

springs were collected quarterly (beginning in March 1989 and ending in March 1990) to document seasonal water-quality changes. Six of these springs discharge from carbonate rocks and one spring discharges from noncarbonate rock. Water-quality data for 91 wells and 26 springs are presented in appendix B-1. Chemical analyses for pesticides from 21 wells and 14 springs are presented in appendix B-2.

The wells that were sampled were domestic wells and were pumped daily by the homeowners. To ensure a representative ground-water sample, the wells were pumped until the water temperature and (or) **specific conductance** had stabilized. The springs were sampled at their point of emergence from the ground. Water temperature; specific conductance; pH; concentrations of dissolved oxygen, carbonate alkalinity, bicarbonate alkalinity, and total alkalinity; fecal coliform, and fecal streptococcal bacteria counts (Wood, 1976) were measured in the field. The bacteria samples were collected, incubated, and analyzed according to standard microbiological sampling techniques (Britton and Greeson, 1988). The U.S. Geological Survey Central Laboratory in Denver, Colo., analyzed the samples for concentrations of nutrients (nitrogen and phosphorus species), dissolved calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, silica, iron, manganese and total dissolved solids. Water samples collected from 35 sites were analyzed for pesticides. Analyses for volatile

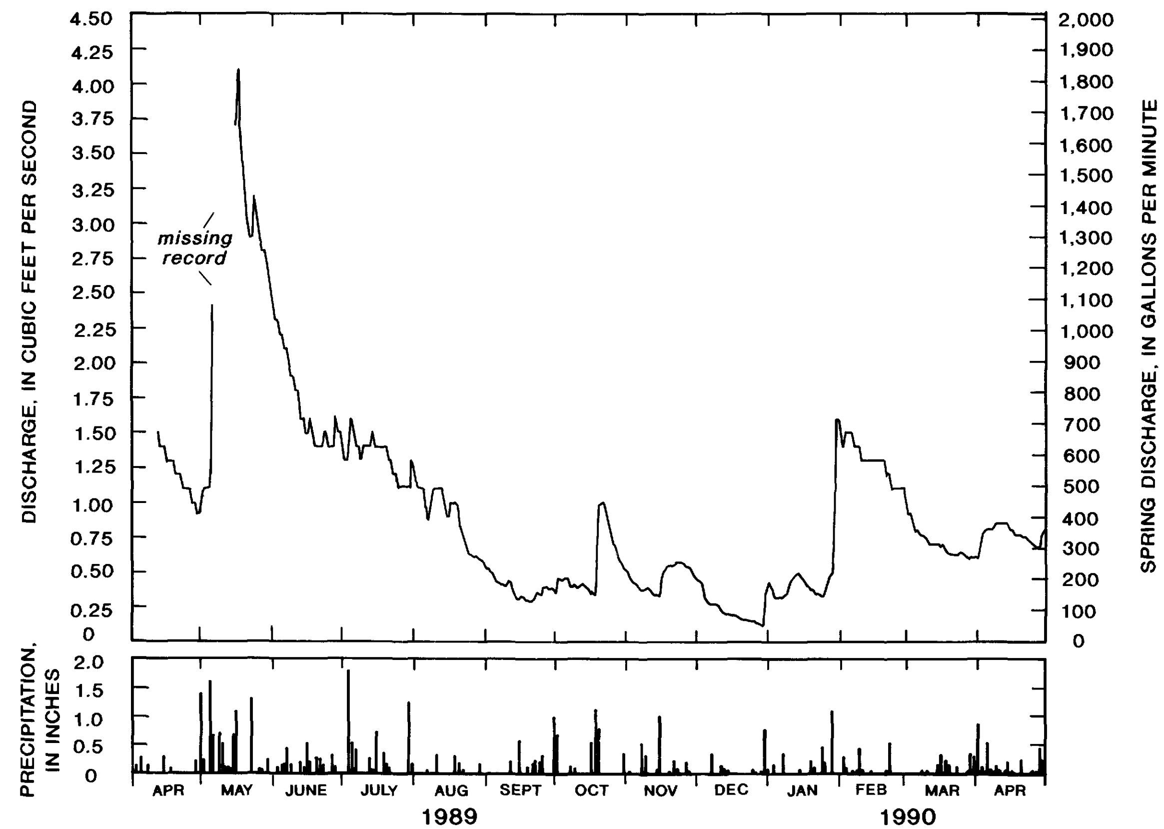


Figure 25. Discharge from spring 234 and daily precipitation at Martinsburg, West Virginia.

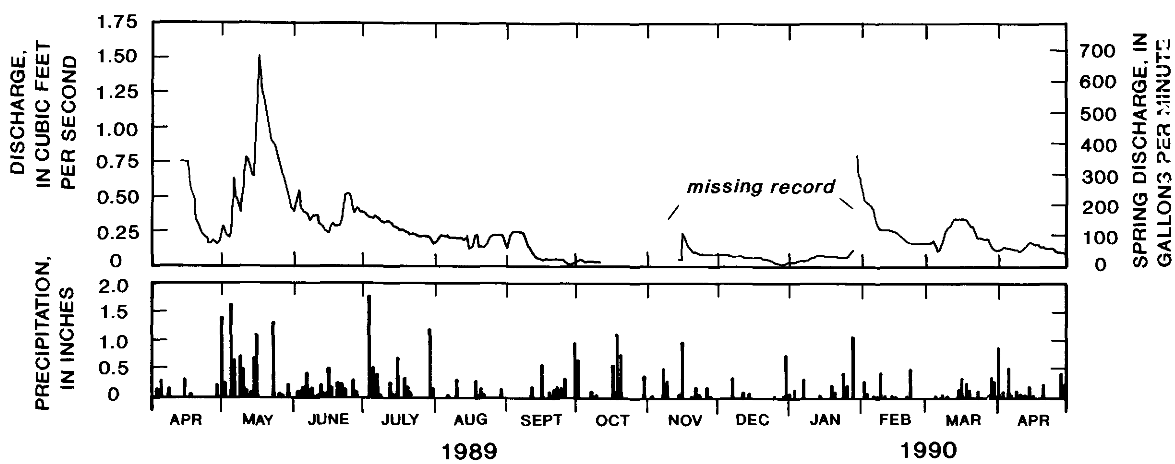


Figure 26. Discharge from spring 268 and daily precipitation at Martinsburg, West Virginia.

Table 11.--Estimated recharge areas for selected springs in Berkeley County, West Virginia

[mi^2, square mile; gal/min, gallon per minute; in., inch]

Spring no.	Mean discharge (gal/min)	Number of measurements	Estimated recharge areas (mi^2) Recharge of 8 in.	Recharge of 10 in.	Recharge of 12 in.
201	1	1	0.004	0.003	0.002
202	2,350	2	8.88	7.11	5.92
203	525	2	1.98	1.59	1.32
204	90	1	.34	.27	.23
205	2,140	31	8.09	6.47	5.39
206	61.5	18	.23	.19	.16
207	80	1	.30	.24	.20
208	80	1	.30	.24	.20
209	.5	1	.002	.002	.001
210	---	--	---	---	---
211	20	1	.08	.06	.05
212	148	2	.56	.45	.37
213	209	15	.79	.63	.53
214	40	1	.15	.12	.10
215	60	1	.23	.18	.15
216	80	1	.30	.24	.20
217	535	2	2.02	1.62	1.35
218	80	1	.30	.24	.20
219	493	11	1.86	1.49	1.24
220	150	1	.57	.45	.38
221	917	3	3.47	2.77	2.31
222	20	1	.08	.06	.05
223	---	--	---	---	---
224	3	1	.01	.009	.008
225	17.4	17	.06	.05	.04
226	500	1	1.89	1.51	1.26
227	1,420	4	5.37	4.29	3.58
228	---	--	---	---	---
229	---	--	---	---	---
230	130	1	.49	.39	.33
231	79.2	17	.30	.24	.20
232	---	--	---	---	---
233	130	1	.49	.39	.33
234	598	17	2.26	1.81	1.51
235	---	--	---	---	---
236	1,370	1	5.18	4.14	3.45
237	---	--	---	---	---
238	5.95	6	.02	.02	.01
239	---	--	---	---	---
240	200	1	.76	.60	.50
241	150	1	.57	.45	.38
242	---	--	---	---	---
243	233	3	.88	.70	.59
244	2,900	1	10.96	8.77	7.31
245	---	--	---	---	---
246	50	2	.19	.15	.13
247	72.8	1	.28	.22	.18
248	3	1	.01	.009	.008
249	76	5	.29	.23	.19
250	25	1	.09	.08	.06
251	100	1	.38	.30	.25
252	---	--	---	---	---
253	6.56	2	.02	.02	.02
254	.63	3	.002	.002	.002
255	.50	1	.002	.002	.001
256	101	17	.38	.30	.25
257	2,270	19	8.58	6.86	5.72
258	40	2	.15	.12	.10
259	---	--	---	---	---
260	50	1	.19	.15	.13
261	10	1	.04	.03	.02
262	2,160	4	8.17	6.53	5.44
263	---	--	---	---	---
264	435	3	1.64	1.32	1.10
265	277	3	1.05	.84	.70
266	3	1	.01	.009	.008
267	184	5	.70	.56	.46
268	118	17	.45	.36	.30
269	1,780	2	6.73	5.38	4.49
270	110	1	.42	.33	.28

organic compounds were performed on ground-water samples collected from four springs in June 1989. Analyses for radon-222 were performed on ground-water samples collected from 7 wells and 11 springs.

Calcium bicarbonate is the most common type of water as shown in figures 27-29. Ground-water analyses from the carbonate rocks plot in tight clusters with only a few scattered points, and those from the noncarbonate rocks have a greater range of percentages of ions. Generally, ground water from the carbonate rocks is harder and more mineralized than ground water from noncarbonate rocks.

In ground water from wells drilled in carbonate rocks, median concentrations of the following dissolved constituents were higher than in ground water from wells drilled in noncarbonate rocks: total dissolved solids, calcium, sulfate, magnesium, chloride, nitrate, potassium, and fluoride. In ground water from wells drilled in noncarbonate rocks, median concentrations of dissolved silica, sodium, iron, and manganese were higher than in ground water from wells drilled in carbonate rocks.

The water-quality data for seven different geologic formations that were sampled in at least five different locations are shown in figures 30 through 36. There are several important differences in the quality of water that is found in the various geologic formations. For example, within the carbonate rocks, the ratios of the median concentrations of magnesium to calcium increase with increasing geologic age as follows: Chambersburg Limestone of Middle Ordovician age, 0.09; Beekmantown Group of lower Ordovician age, 0.14; Conococheague Limestone of upper Cambrian age, 0.22; and Elbrook Formation of middle Cambrian age, 0.31. This trend indicates that these formations are more dolomitic with increasing geologic age.

Ground water from springs in the carbonate rocks is typically more diluted than ground water from wells in the carbonate rocks. Trilinear diagrams indicated no differences between the percentages of the major chemical ions in ground water from springs and those in ground water from wells in carbonate rocks (figs. 27 and 28). There were not enough samples from springs to compare the ground-water quality of wells and springs in the noncarbonate rocks.

Ground water discharged from near-mountaintop springs in noncarbonate rocks typically is chemically similar to precipitation, because the short residence time the water has is insufficient for the water to react with the rock. Ground water discharged from springs in noncarbonate rocks near the base of the mountains or in the valleys is more mineralized than ground water discharged from near-mountaintop springs because of the greater residence time that the water has before flowing from the hilltops to the valleys. The chemical analyses from springs 238, 253, and 259 are examples of the water quality from near-mountaintop springs. The maximum specific conductance in ground water from these springs was 65 μS/cm and the highest pH was 5.3. Chemical analyses from springs 225 and 258 are examples of the water quality from springs located closer to the base of the mountain or in the valley. The specific conductance from these two springs ranged from 335 to 610 μS/cm and the pH ranged from 7.0 to 7.5.

Water-Quality Constituents and Properties

The U.S. Environmental Protection Agency (USEPA) (1990) has established maximum allowable concentrations and values for many water-quality constituents. The Maximum Contaminant Level (**MCL**) is the maximum permissible concentration of a contaminant in water that is delivered to any user of a public water system. The Secondary Maximum Contaminant Level (**SMCL**) is a nonenforceable recommended standard for drinking water, based on aesthetic considerations such as taste, odor, and appearance. The Maximum Contaminant-Level Goal (**MCLG**) is a nonenforceable maximum concentration of a drinking-water contaminant, set at a level that would result in no adverse health effects over a lifetime of exposure. The following constituents and physical properties exceeded the MCL's or the SMCL's at least once during this study: iron, manganese, nitrate, fecal coliform and fecal streptococcal bacteria, pH, total dissolved solids, and chloride.

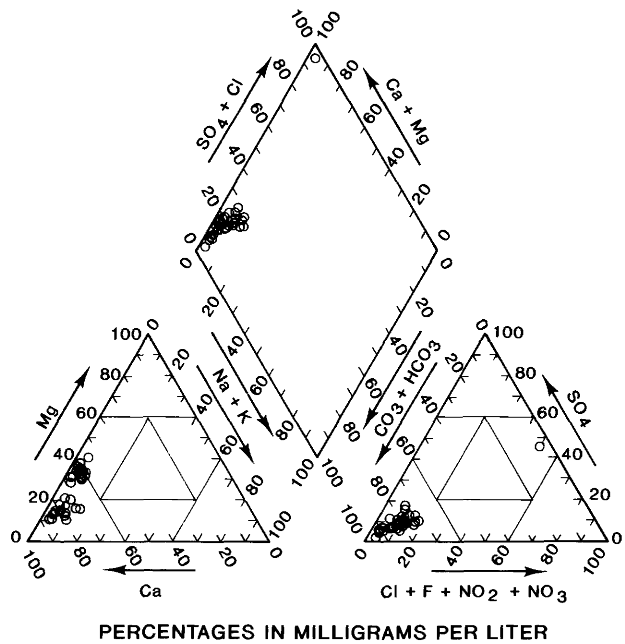


Figure 27. Ground-water-quality data from springs in carbonate rocks.

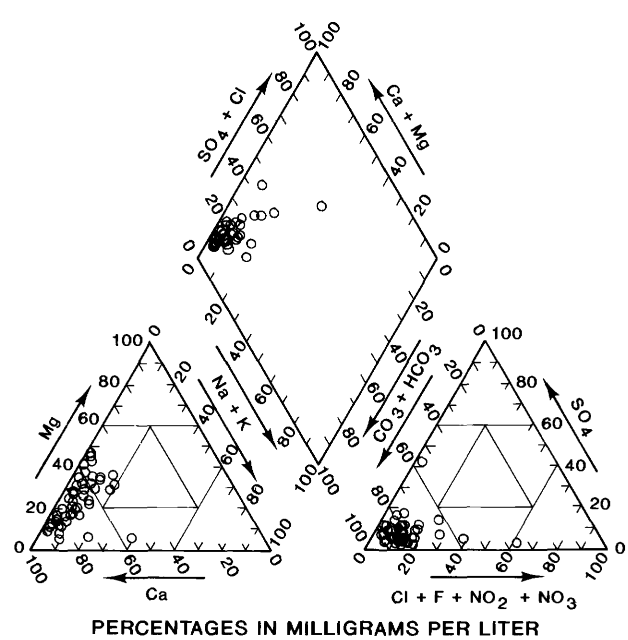


Figure 28. Ground-water-quality data from wells in carbonate rocks.

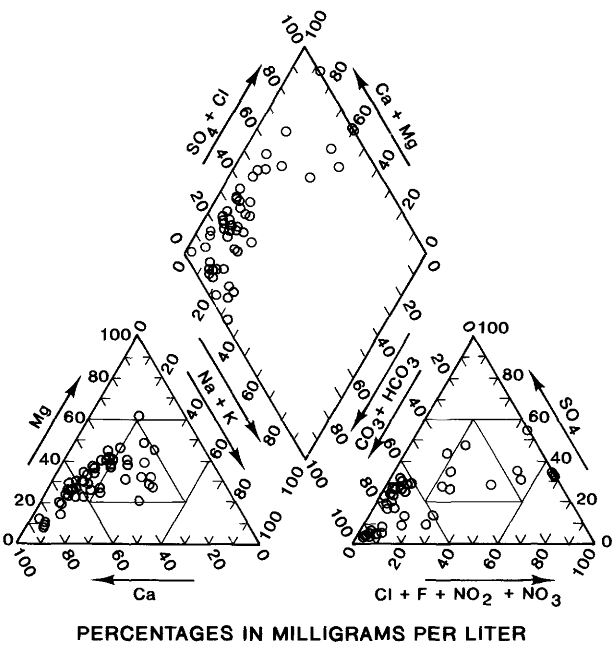


Figure 29. Ground-water-quality data from wells and springs in noncarbonate rocks.

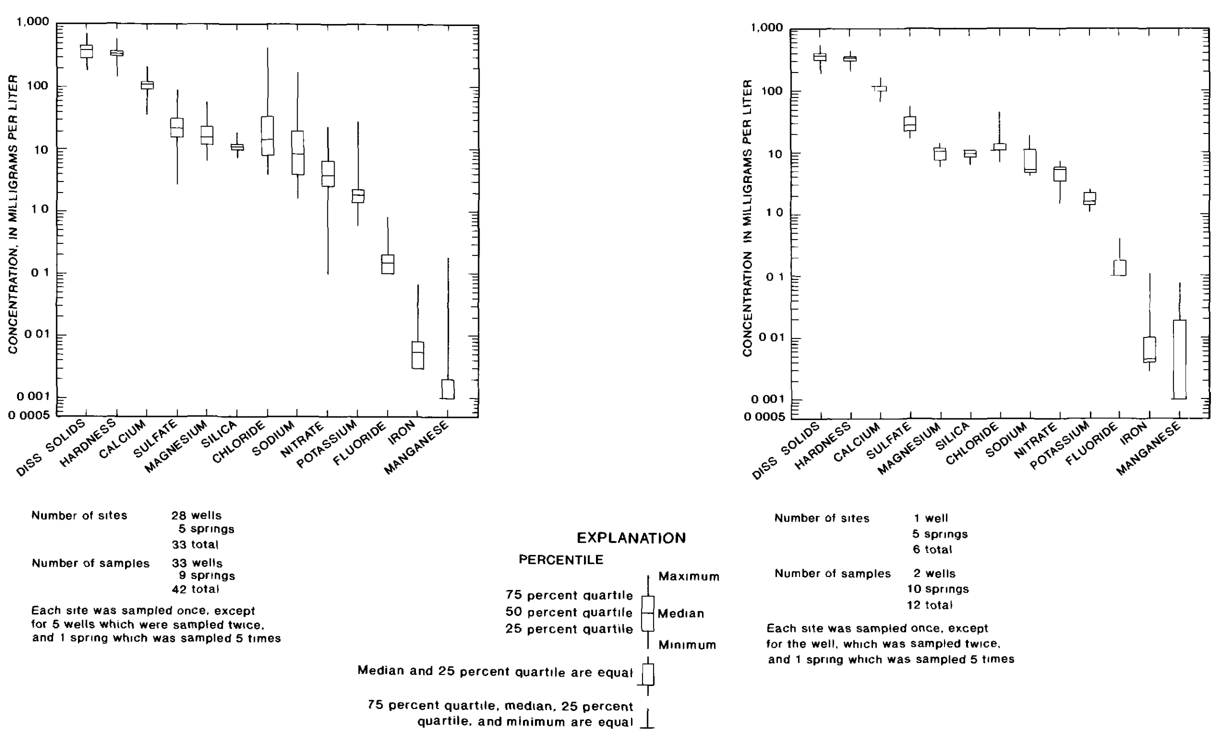
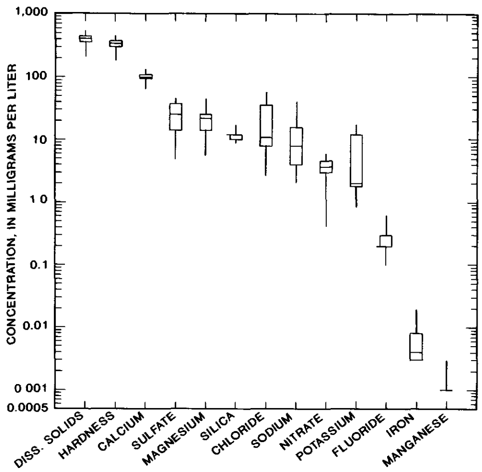


Figure 30. Beekmantown Group

Figure 31. Chambersburg Limestone

Figures 30-31. Distribution of concentrations for selected constituents in water samples from the Beekmantown Group and Chambersburg Limestone.

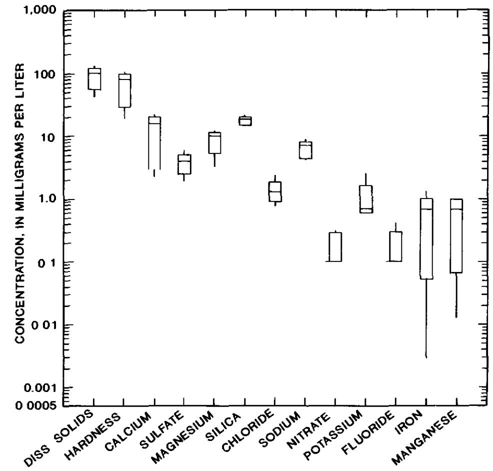


Number of sites 9 wells
1 spring
10 total

Number of samples 10 wells
1 spring
11 total

Each site was sampled once, except for 1 well which was sampled twice

Figure 32. Conococheague Formation

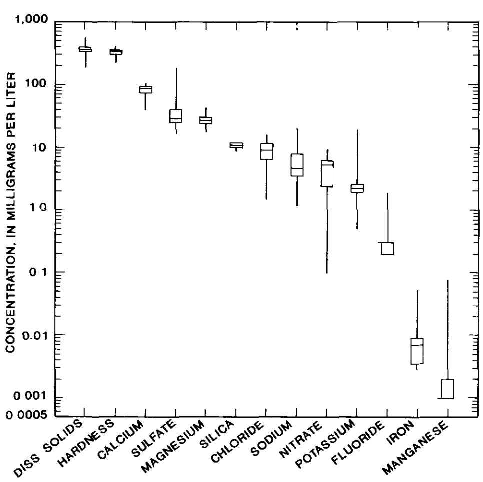


Number of sites 5 wells

Number of samples 5 wells

Each well was sampled once

Figure 34. Hampshire Formation



Number of sites 10 wells
9 springs
19 total

Number of samples 12 wells
21 springs
33 total

Each site was sampled once, except for 2 wells which were sampled twice, and 3 springs which were sampled 5 times

EXPLANATION

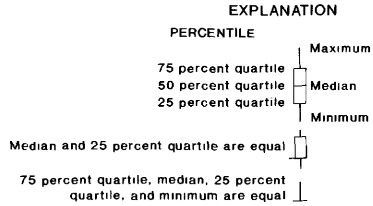
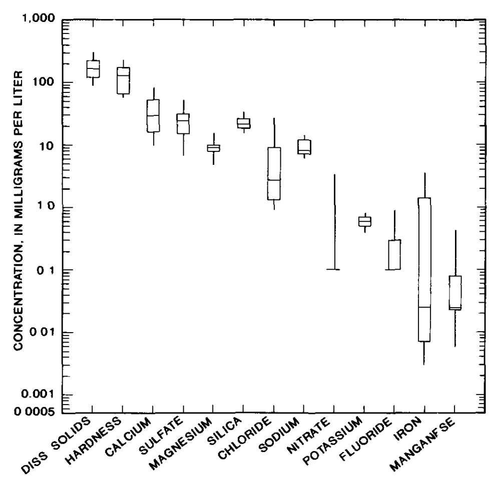


Figure 33. Elbrook Formation



Number of sites 11 wells

Number of samples 11 wells

Each well was sampled once

Figure 35. Mahantango Formation

Figures 32-35. Distribution of concentrations for selected constituents in water samples from the (Fig. 32) Conococheague Formation, (Fig. 33) Elbrook Formation, (Fig. 34) Hampshire Formation, and (Fig. 35) Mahantango Formation.

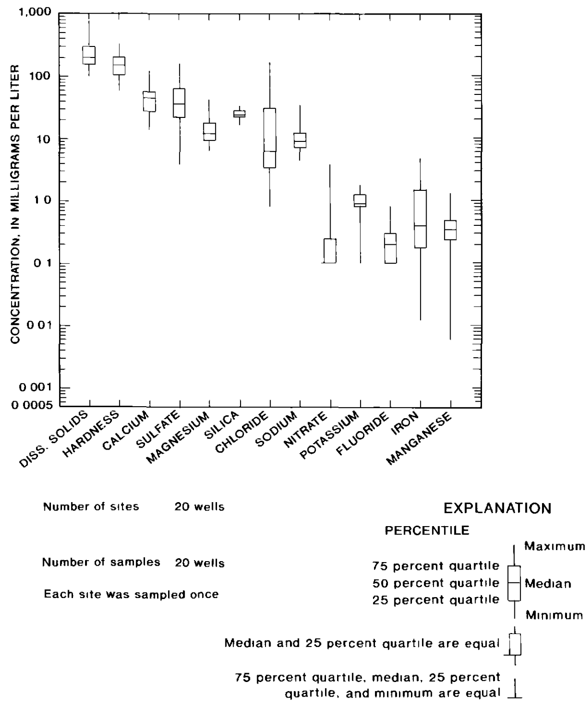


Figure 36. Distribution of concentrations for selected constituents in water samples from the Martinsburg Formation.

Bacteria

The USEPA MCLG for fecal streptococcal and fecal coliform bacteria is zero colonies per sample. Fecal streptococcal and fecal coliform bacteria are indicators of potential bacterial or viral contamination, because water that contains these bacteria also can contain pathogenic bacteria or viruses. A statistical summary of the bacteria data is presented in table 12.

Fecal streptococcal bacteria were present in all springs sampled during June, August, and October, but were present in only 69.2 percent of the springs sampled during December and March. These bacteria were less numerous in ground-water samples collected from wells but indicated the same seasonal decline in numbers. Fecal streptococcal bacteria were present in 54.3 percent of water samples from wells sampled during June, August, and October but in only 17 percent of water samples from wells sampled during December and March. Fecal streptococcal bacteria were only slightly more common in water from wells in carbonate-rock terrain (53.8 percent) than in noncarbonate-rock terrain (45.6 percent).

Fecal coliform bacteria were also present in a greater percentage of water samples from springs than water samples from wells, and they were more numerous during June, August, and October, than in December and March. Fecal coliform bacteria were present in 85.7 percent and 23.9 percent of the water samples from springs and wells, respectively, during June, August, and October. These bacteria were present in 61.5 percent and 7.4 percent of the water samples from springs and wells, respectively, during December and March. Fecal coliform bacteria were more commonly present in water from wells in carbonate-rock terrain (41.4 percent) than in noncarbonate-rock terrain (10.6 percent).

Physical Properties

Physical properties of water include **pH**, specific conductance, temperature, alkalinity, hardness, and total dissolved solids. Physical properties were measured at all sites from which water samples were collected.

pH

The USEPA SMCL indicates that pH should be between 6.5 to 8.5. A pH of 7.0 indicates a neutral solution. A pH higher than 7.0 is indicative of alkaline water, and pH lower than 7.0 is indicative of acidic water. The corrosiveness of water increases as pH decreases. Excessive alkalinity in water also can attack metals. The pH of water at 11 sites was lower than 6.5; 10 of the sites were in noncarbonate rocks. The pH of springs in the noncarbonate rocks near mountaintops typically was lower than 5.3. The maximum measured pH at all sites was 7.9.

Specific Conductance

Specific conductance is the ability of a substance to conduct an electric current, and is reported in units of **microsiemens per centimeter** at 25 degrees Celsius (μS/cm). Specific conductance of water increases as the concentrations of dissolved ions increases; therefore, the higher the specific

Table 12.--Statistical summary of bacteria data from wells and springs in Berkeley County, West Virginia

Date of sample	Wells: Number of positive sites[1]	Wells: Number of sites sampled	Wells: Percentage of positive sites[1]	Springs: Number of positive sites[1]	Springs: Number of sites sampled	Springs: Percentage of positive sites[1]
Fecal streptococcal bacteria						
June, August, October 1989	25	46	54.3	21	21	100
March, December 1989; March 1990	9	53	17.0	9	13	69.2
Fecal coliform bacteria						
June, August, October 1989	11	46	23.9	18	21	85.7
March, December 1989; March 1990	4	54	7.4	8	13	61.5

[1] A positive site contains at least 1 colony per 100 milliliters.

conductance, the more mineralized the water. Specific conductance values were higher in water samples from carbonate rocks than in water samples from noncarbonate rocks. Specific-conductance values in water samples from carbonate rocks ranged from 220 to 2,500 µS/cm, with a median of 645 µS/cm. Specific-conductance values in water samples from noncarbonate rocks ranged from 28 to 1,040 µS/cm, with a median of 268 µS/cm.

Temperature

The ground-water temperature of springs was measured five times at each of 7 springs, twice at 1 spring, and once at 18 springs. Three measurements of 16.0°C or higher were not included in the data analysis because they were affected by heat from the sun. The median ground-water temperature was 12.0°C. Ground-water temperatures of springs fluctuated seasonally. The minimum and maximum temperatures were 6.5°C and 14.5°C, respectively. In four springs, temperatures were below 10°C when measurements were made in December or March. In nine springs, temperatures ranged from 13.0 to 14.5°C when measurements were made in August or early October.

Alkalinity

The **alkalinity** in all of the ground-water samples collected was produced by the dissolved form of carbon dioxide called bicarbonate. Alkalinity is commonly expressed in terms of equivalent $CaCO_3$ (carbonate alkalinity), and does not include alkalinity produced by noncarbonate anions such as sulfate, phosphate, and nitrate. Carbonate rocks, such as limestone, consist primarily of calcium carbonate. Calcium carbonate is dissolved and forms calcium bicarbonate when acted upon by ground water containing carbon dioxide, which derives from the atmosphere and soil. The ground-water samples from the carbonate rocks contained higher concentrations of bicarbonate (median concentration of 354 mg/L) than the water samples from noncarbonate rocks (median concentration of 128 mg/L).

Water Hardness

Water hardness is caused primarily by calcium and magnesium ions, and, therefore, the hardness values were calculated from the measured concentrations of calcium and magnesium. Hardness is commonly classified as follows: soft (0 to 60 mg/L); moderately hard (61 to120 mg/L); hard (121 to180 mg/L); and very hard (greater than 180 mg/L)

(Hem, 1985, p. 159). Hardness in all water samples from the carbonate rocks was equal to or greater than 147 mg/L; the median concentration was 358 mg/L. Water from noncarbonate rocks was not as hard as water from carbonate rocks. Hardness in 25 percent of the ground-water samples from noncarbonate rocks was equal to or less than 59 mg/L, and the minimum hardness value was 6 mg/L.

Total Dissolved Solids

The dissolved solids concentration is a measurement of the mineral content of the water. The USEPA SMCL for total dissolved solids is 500 mg/L. Ground water from the carbonate rocks is more mineralized and has a higher dissolved solids concentration than ground water from noncarbonate rocks. The dissolved solids concentration in water from 12 wells drilled in carbonate rocks exceeded 500 mg/L (residue on evaporation at 180°C), with a maximum of 705 mg/L at well 4 (app. B-1). The maximum dissolved solids concentration from springs in the carbonate rocks was 472 mg/L at spring 257. The median dissolved solids concentration for all samples from carbonate rocks was 367 mg/L. Median dissolved solids concentration in ground water from noncarbonate rocks was158 mg/L; the maximum was 729 mg/L at well 5.

Inorganic Constituents

Inorganic constituents are those that do not contain carbon. The following inorganic constituents exceeded the USEPA MCL or SMCL in water in at least one site; selected constituents--chloride, iron, manganese, and nitrate--are discussed below. Radon also is discussed, because no definite limit has been set for this constituent.

Chloride

The USEPA SMCL for chloride is 250 mg/L. Sources of chloride in ground water include road salt, sewage, organic nitrogen fertilizers, industrial wastes, and naturally occurring brines. A dissolved chloride concentration higher than 250 mg/L can increase the corrosiveness of the water and can give water a salty taste. Chloride concentration in water from well 89 was 420 mg/L (app. B-1). Well 89 is the only site that contains water with a chloride concentration that exceeds the SMCL.

Chloride concentration was higher in water in carbonate rocks than in water in noncarbonate rocks. The median chloride concentrations for carbonate and noncarbonate rocks were 10 and 3.8 mg/L, respectively. Chloride concentrations in water at 41 of the carbonate rock sites and 10 of the noncarbonate rock sites were at least 10 mg/L.

Iron and Manganese

The USEPA SMCL for iron is 300 µg/L. Dissolved iron concentrations that are higher than 300 µg/L typically precipitate on exposure to air. This causes problems such as turbidity, staining, and objectionable taste and color. Iron dissolves from most rocks and soils and can be corroded from pipes, pumps, and other equipment. Ground water with dissolved iron concentrations higher than 300 µg/L is found only in the noncarbonate rocks. Twenty-two wells (52 percent) in the noncarbonate rocks contained water with dissolved iron concentrations of at least 300 µg/L (app. B-1). The maximum dissolved iron concentration in all ground-water samples was 4,700 µg/L. The maximum dissolved iron concentration in water from five springs in noncarbonate rocks was 45 µg/L, indicating that the presence of iron may be restricted to wells. The lower dissolved iron concentrations in noncarbonate springs also could be caused by precipitation of iron at the spring emergence before sampling.

The USEPA SMCL for manganese is 50 µg/L. Dissolved manganese concentrations higher than 50 µg/L typically have the same objectionable features as iron, but produce dark-brown or black stains. Manganese is dissolved from rocks and soils. Ground water that contained a dissolved iron concentration of 300 µg/L or higher typically contained a dissolved manganese concentration of 50 µg/L or higher. In water samples from 21 of the 22 wells with dissolved iron concentrations higher than 300 µg/L, dissolved manganese concentrations exceeded 50 µg/L. Dissolved manganese concentrations were at least 50 µg/L in water from

37 (32 percent) of 117 sites, but only 4 (3 percent) of the sites were in carbonate rocks. Concentrations of dissolved manganese were lower in carbonate rocks than in noncarbonate rocks; the maximum concentration was 180 µg/L.

Nitrate

The USEPA MCL for nitrate as nitrogen is 10 mg/L. Sources of nitrate include decaying organic matter, sewage, and fertilizers. Nitrate concentrations above 10 mg/L encourage the growth of algae and other organisms, which produce an undesirable taste and odor, and can cause methemoglobinemia (blue-baby syndrome) in infants. Land use and geology can have a major effect on nitrate concentrations. Contaminants from land surface can enter the ground-water system quickly through carbonate rocks because of the secondary porosity typical of carbonate rocks, such as large sinkholes, and because of the presence of losing streams. Contaminants from land surface cannot enter the ground-water system as quickly through noncarbonate rocks as through carbonate rocks because sinkholes and losing streams are absent. Fractures in the noncarbonate rocks also are much tighter than in the carbonate rocks, so that contaminants in the noncarbonate rocks move more slowly than in the carbonate rocks.

Nitrate concentrations are usually calculated by subtracting the concentration of nitrite from the total concentration of nitrite plus nitrate. Because nitrate concentration in water at only one site was higher than the coefficient of variation (8-14 percent) for the determination of the nitrite plus nitrate concentration (Skougstad and others, 1979, p. 439), the concentrations of nitrite plus nitrate are considered equal to the concentrations of nitrate in this report. Nitrite concentrations of at least 0.01 mg/L were detectable in water at only eight sites. The maximum nitrite concentration was 0.06 mg/L.

Median nitrate concentrations in water from the carbonate and noncarbonate rocks were 4.0 and 0.62 mg/L, respectively. Concentrations in water from three wells (sites 4, 38, and 62) exceeded 10 mg/L. All three wells tap the carbonate rocks. The highest nitrate concentration that was detected was 23 mg/L at well 38 on August 23, 1989. In a second water sample collected from this well on March 6, 1990, nitrate concentration was 14 mg/L, indicating that the concentration is variable but still exceeds the USEPA MCL. Kozar and others (1991), in a study of neighboring Jefferson County, concluded that the nitrate concentration in ground water could differ in relation to recharge events and to the amount of fresh manure on the land surface.

Radon

An MCL of 300 pCi/L (picocuries per liter) for radon-222 in ground water was proposed by the USEPA in July 1991 (Jeff Hass, U.S. Environmental Protection Agency, oral commun., 1992). The concentration of radon was analyzed in water from 7 wells and 11 springs. The minimum and maximum concentrations were 92 and 1,600 pCi/L, respectively. The median concentration was 505 pCi/L. Differences in radon concentration between carbonate and noncarbonate ground-water samples, or between spring and well samples, were not significant.

Organic Compounds

Organic compounds are those that contain carbon. Sampling for organic compounds included pesticides and volatile organic compounds.

Pesticides

Organochlorine and organophosphate insecticide analyses were performed on ground-water samples collected at six springs during March, June, October, and December 1989 and March 1990. Additional organochlorine and organophosphate insecticide analyses were performed on ground-water samples from 18 wells and 5 springs during August 21-24, 1989. Analyses for triazine herbicides were performed on ground-water samples from four wells and five springs during this period. The analyses are shown in appendix B-2.

The USEPA and the U.S. Public Health Service (written commun., 1971) limit the allowable concentrations in drinking water of many of the pesticides that were sampled for during this study.

No **insecticides** or **herbicides** in any ground-water samples collected throughout this study exceeded these limits. However, the following pesticides were present in detectable concentrations in at least one sample: atrazine, chlordane, cyanazine, DDE, DDT, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, malathion, and simazine. Atrazine, cyanazine, and simazine are triazine herbicides. The remaining pesticides that were detected were organochlorine and organophosphate insecticides. The pesticides listed above were detected in ground water from wells and springs in or near orchards or crop fields. Ground-water samples were analyzed for the following organochlorine and organophosphate insecticides that were not present in detectable concentrations: Aldrin, DDD, disyston, ethion, lindane, methoxychlor, methylparathion, methyltrithion, mirex, parathion, perthane, phorate, trithion, and toxaphene. Triazine herbicides that were not present in detectable concentrations included: alachlor, ametryne, prometone, prometryne, propazine, simetryne, and trifluralin.

Volatile Organic Compounds

Ground-water samples were collected at springs 213, 232, 257, and 268 in June 1989 and were analyzed for volatile organic compounds. These springs were in carbonate rocks. The detection limit for each compound was 3.0 µg/L, with the exception of vinyl chloride, which had a detection limit of 1.0 µg/L. None of the following compounds were present in detectable concentrations:

benzene
bromoform
carbon tetrachloride
chlorobenzene
chlorodibromomethane
chloroethane
2-chloroethyl vinyl ether
chloroform
1,2-dibromoethane
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
dichlorobromomethane
dichlorodifluoromethane
1,1-dichloroethane
1,2-dichloroethane
1,1-dichloroethylene
1,2-*trans*-dichloroethene
1,2-dichloropropane
1,3-dichloropropene
cis-1,3-dichloropropene
trans-1,3-dichloropropene
ethyl benzene
methyl bromide
methyl chloride
methylene chloride
styrene
1,1,2,2-tetrachloroethane
tetrachloroethylene
toluene
1,1,1-trichloroethane
1,1,2-trichloroethane
trichloroethylene
trichlorofluoromethane
vinyl chloride
xylene

Changes in Water Quality

Changes in water quality can be caused by changes in the ground-water conditions and land-use practices. Recharge to the ground-water system can have a diluting effect on the ground-water quality. For example, Hobba (1985, p. 17) described an inverse relation between springflow and specific conductance. The specific conductance decreased with increasing flow, and increased with decreasing flow.

Land-use practices that change during the year can cause changes in water quality. For example, the concentration of dissolved nitrate in ground water is related to rainfall and the amount of fresh manure on the land surface (Kozar and others, 1991). Recharge to the ground-water system can contain higher concentrations of dissolved nitrate when fresh manure is present than when it is not present.

Seasonal Changes

Seasonal changes were studied by collecting samples at various times of the year. Water samples were collected quarterly from seven springs, beginning March 28, 1989 and ending March 9, 1990. Six of those springs (213, 231, 234, 257, 267, and 268) discharged from carbonate rocks; one spring (238) discharged from noncarbonate rock. Springflow measurements were made at the same time the water samples were collected. The concentrations of most of the chemical constituents changed over the period of sample collection, but no trends were evident that could be related to discharge or time of year. Analysis of quarterly water-quality data provided some information, however, on the range of concentrations (minimum to maximum) that could be expected during the year. The minimum and maximum concentrations for these seven springs are summarized in table 13.

Changes in water quality also were studied by comparing the water samples collected August 21-24, 1989, with those collected March 5-9, 1990. Ground-water levels during August 21-24, 1989, were similar to ground-water levels during March 5-9, 1990. The mean ground-water level of four wells with hourly measurements was 47.78 ft below land surface during August 21-24, 1989, and 46.46 ft below land surface during March 5-9, 1990. Springflow also was similar between the two sampling periods. The mean springflow from five springs was 570 gal/min during August 21-24, 1989, and 574 gal/min during March 5-9, 1990.

Table 13.--Minimum and maximum values for ground-water quality for seven springs sampled on a quarterly basis between March 1989 and March 1990, Berkeley County, West Virginia

[mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than]

Site	Number of samples	Specific conductance (µS/cm)	pH	Temperature (°C)	Oxygen, dissolved (mg/L)	Hardness (mg/L as CaCO3)	Alkalinity (mg/L as CaCO3)
213	5	578-670	6.8-7.3	11.5-12.5	7.2-8.0	350-360	290-314
232	5	645-750	7.0-7.4	9.0-14.5	6.6-8.8	310-360	253-301
234	5	660-750	6.4-7.2	11.0-13.0	5.9-8.0	340-350	270-316
238	5	37- 51	4.4-5.1	8.0-11.5	4.8-7.8	7- 12	0-0
257	5	745-930	6.7-7.2	11.0-12.5	5.8-8.2	360-370	300-312
267	5	395-436	6.8-7.4	11.5-12.5	6.1-7.8	200-230	190-212
268	5	460-570	6.9-7.4	11.5-12.5	5.1-7.9	230-270	207-230

Site	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Sodium (mg/L as Na)	Potassium (mg/L as K)	Sulfate (mg/L as So4)	Chloride (mg/L as Cl
213	91 - 93	29 -31	3.2- 4.0	2.1-2.4	25 -26	6.3- 7.4
232	81 - 97	25 -28	9.3-12	2.1-3.5	33 -40	10 -16
234	120 -120	10 -13	4.8- 5.3	1.4-2.4	22 -29	7.0-12
238	1.4- 3.0	0.84- 1.1	1.8- 3.2	.8-1.0	3.9- 5.5	3.4- 6.7
257	120 -120	15 -16	21 -26	1.4-2.1	31 -37	35 -44
267	70 - 80	5.8 - 6.2	2.8- 3.1	.2-1.1	<1.0-15	3.3- 4.2
268	61 - 68	19 -24	4.7- 7.9	1.6-3.5	22 -31	8.1-13

Site	Fluoride (mg/L as F)	Silica (mg/L as SiO2)	Dissolved solids, residue at 180 °C (mg/L)	Nitrite + nitrate (mg/L as N)	Iron (µg/L as Fe)	Manganese (µg/L as Mn)
213	0.3-0.4	12 -12	344-392	5.7 -6.1	<3-12	<1- 4
232	.2- .3	9.5-12	336-408	5.5 -9.3	<3- 8	<1- 5
234	.1- .4	10 -11	364-410	5.4 -7.3	<3-11	<1- 2
238	<.1- .4	4.8- 5.9	11- 32	.55- .70	12-45	48-64
257	.1- .2	11 -11	410-472	2.7 -3.5	<3- 6	<1-<1
267	.1- .3	7.4- 8.2	186-241	.56- .81	<3-10	<1- 3
268	.2- .3	9.7-11	263-299	2.2 -4.1	8-39	1- 4

The following ten sites were sampled during both periods: spring 256 and wells 21, 32, 38, 51, 57, 82, 88, 96, and 98. The dissolved solids concentrations in ground water from 9 of the 10 sites were higher in March 1990 than in August 1989. The median values for ground-water quality from all sites sampled during August 21-24, 1989, and during March 5-9, 1990, are summarized in table 14. The table is separated into wells and springs in carbonate rock, and wells and springs in noncarbonate rock, so that a comparison can be made. The median concentrations of hardness, magnesium, sodium, iron, and dissolved solids for sites sampled in March 1990 were higher than the median concentrations for the same sites sampled in August 1989. This trend was evident for carbonate rock wells, carbonate rock springs, and noncarbonate wells sampled. Data for noncarbonate springs sampled did not exhibit this trend. It is uncertain at present what factors are responsible for this trend. The remaining constituents in table 14 did not indicate any networkwide upward or downward trends.

Long-Term Changes

Ground-water samples from wells and springs in Berkeley County were previously collected from July 30 through August 10, 1973 by Hobba (1976). These samples were analyzed for hardness and for concentrations of iron, chloride, and nitrate. Water samples with iron concentrations of 300 µg/L or

Table 14.--Median values for ground-water quality for August 21-24, 1989, and March 5-9, 1990, in Berkeley County, West Virginia

[mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius]

Site	Date	Specific conductance (µS/cm)	pH	Oxygen, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Wells, carbonate rock, 25 sites	Aug 21-24, 1989	450	6.9	6.5	326	295
Wells, carbonate rock, 33 sites	Mar 5- 9, 1990	730	7.0	7.1	346	300
Springs, carbonate rock, 11 sites	Aug 21-24, 1989	605	7.0	7.3	317	276
Springs, carbonate rock, 11 sites	Mar 5- 9, 1990	640	7.0	7.2	336	270
Wells, noncarbonate rock, 21 sites	Aug 21-24, 1989	275	6.9	1.0	105	101
Wells, noncarbonate rock, 21 sites	Mar 5- 9, 1990	270	6.9	1.0	150	124
Springs, noncarbonate rock, 3 sites	Aug 21-24, 1989	335	7.2	4.9	169	166
Springs, noncarbonate rock, 2 sites	Mar 5- 9, 1990	52	4.8	7.2	13	0

Site	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Sodium (mg/L as Na)	Potassium (mg/L as K)	Sulfate (mg/L as SO_4)	Chloride (mg/L as Cl)
Wells, carbonate rock, 25 sites	92	20	4.8	2.2	28	9.7
Wells, carbonate rock, 33 sites	100	21	7.9	1.6	25	13
Springs, carbonate rock, 11 sites	99	14	5.2	1.9	22	11
Springs, carbonate rock, 11 sites	92	19	5.3	1.4	27	10
Wells, noncarbonate rock, 21 sites	31	8.5	7.6	.8	14	2.3
Wells, noncarbonate rock, 21 sites	42	11	8.9	.8	31	4.3
Springs, noncarbonate rock, 3 sites	59	5.3	1.8	.7	5.0	1.3
Springs, noncarbonate rock, 2 sites	2.8	1.4	1.3	.8	8.4	2.9

Site	Fluoride (mg/L as F)	Silica (mg/L as SiO_2)	Dissolved solids, residue at 180°C (mg/L)	Nitrite + nitrate (mg/L as N)	Iron (mg/L as Fe)	Manganese (mg/L as Mn)
Wells, carbonate rock, 25 sites	0.2	10	356	4.0	5.0	1.0
Wells, carbonate rock, 33 sites	.2	12	404	3.0	7.0	1.0
Springs, carbonate rock, 11 sites	.2	10	339	4.0	4.0	1.0
Springs, carbonate rock, 11 sites	.3	10	392	5.2	5.0	1.0
Wells, noncarbonate rock, 21 sites	.1	20	156	.1	220	230
Wells, noncarbonate rock, 21 sites	.3	23	170	.1	590	330
Springs, noncarbonate rock, 3 sites	.1	8.7	183	.2	3.0	1.0
Springs, noncarbonate rock, 2 sites	.2	5.5	30	1.5	34	56

higher were present at 90 of 262 sites (34 percent). Iron concentrations of 300 µg/L or higher were also present in 52 percent of the ground-water samples collected from wells in noncarbonate rock during 1989-90 (see Iron and Manganese section). Chloride concentrations of 250 mg/L or higher were found in water samples from 2 out of 335 sites, indicating that chloride concentrations that exceeded the USEPA SMCL were not common in 1973. Only one site sampled during 1989-90 contained ground water with a chloride concentration of 250 mg/L or higher, indicating that high chloride concentrations are not yet common. In 1973, ground-water samples with a nitrate concentration of 45 mg/L or higher (equal to the current USEPA MCL of 10 mg/L) were found at 8 of 339 sites. Nitrate concentrations in ground water from 3 of 117 sites sampled during 1989-90 were higher than 10 mg/L. Hobba also collected water samples for fecal coliform and fecal streptococci analysis samples during January 12-14, 1974. Fecal coliform colonies were present in the 3 springs that were sampled and in water from 8 of 12 wells. Fecal streptococci colonies were present in 3 springs that were sampled and in water from 7 of 12 wells. During 1989-90, fecal coliform colonies were present in ground water from 26 of 44 springs and in water from 15 of 100 wells. Fecal streptococci bacteria were present in water from 30 of 44 springs and in water from 34 of 99 wells.

SUMMARY

Aquifers of Berkeley County are comprised of both carbonate and noncarbonate rocks. Karst topography has developed in the carbonate areas. The carbonate and noncarbonate aquifers have different water quality and quantity concerns.

Ground-water levels tend to follow seasonal trends; the lowest levels typically occur from mid-October through November, and the highest levels occur from April through mid-June. In the carbonate rocks east of North Mountain, mean depth to water was 41.47 ft. In the noncarbonate rocks of the Martinsburg Formation, mean depth to water was 23.40 ft--a shallower depth than in the surrounding limestone. In wells on and west of North Mountain, mean depth to water was 33.81 ft. Ground-water levels fluctuate more in carbonate areas than in noncarbonate areas. The mean ground-water-level fluctuation was 19.37 ft in 17 wells in carbonate rock and 8.07 ft in 14 wells in noncarbonate rock.

Recharge was estimated to be about 10 in/yr for a 60-mi^2 area of carbonate rocks. Specific yield for carbonate rocks ranged from 0.044 to 0.049 of rock by volume. Estimated transmissivity values ranged from 730 to 9,140 ft^2/d for four sections that are parallel to the strike of the rocks in Middle Creek and Tuscarora Creek. Estimated transmissivity was 800 ft^2/d for one section perpendicular to the strike of rocks in Tuscarora Creek.

Ground-water flow in the carbonate rocks is controlled by geologic structure within the aquifer. Ground-water velocities ranged from 32 to 1,879 ft/d. Mean flow velocities ranged from 71 ft/d under diffuse-flow conditions to 1,139 ft/d under conduit-flow conditions. In general, ground water flows from beneath hilltops to beneath valleys in noncarbonate rocks.

The highest mean well yield (48 gal/min) was in the Beekmantown Group . Well yields higher than 100 gal/min were present in wells in no other geologic unit, except in one well in the Chambersburg Limestone. Twelve such wells are present in the Beekmantown Group. The highest median well yield, 20 gal/min, however, was in the Martinsburg Formation.

The mean, median, and maximum well yields decrease with increasing distance from a fault. The median yield was 33 gal/min in wells less than 400 ft from a fault. The median specific capacity was 3.6 (gal/min)/ft in wells less than 700 ft from a fault and was 0.26 (gal/min)/ft in wells greater than or equal to 700 ft from a fault.

Well yield decreased with increasing well depth. The highest median well yield (30 gal/min) for carbonate rocks was in wells that were less than 50 ft deep. The highest median well yield (21 gal/min) for noncarbonate rocks was in wells that were 50 to 99 ft deep.

The largest springs are in the carbonate rocks and are typically on or near faults or the limestone-shale contacts. Springflow typically follows the same seasonal pattern as that of ground-water levels in wells. Lowest springflow is from mid-October through November, and highest springflow is from April through mid-June.

In ground water from wells drilled in carbonate rocks, hardness values and median concentrations of the following dissolved constituents were typically higher than in water from wells drilled in noncarbonate rocks: total dissolved solids, calcium, sulfate, magnesium, chloride, nitrate, potassium, and fluoride. In ground water from noncarbonate rocks, dissolved concentrations of silica, sodium, iron, and manganese were higher than in water from wells drilled in carbonate rocks. Water from springs in the carbonate rocks is more diluted than water from wells in the carbonate rocks.

Ground water near the tops of the mountains has lower pH and specific conductance than ground water from other topographic settings. The maximum specific conductance in water from three near-mountaintop springs was 65 μS/cm and the maximum pH was 5.3. In water from two noncarbonate springs near the base of the mountain or in the valley, specific conductance ranged from 335 to 610 μS/cm and pH ranged from 7.0 to 7.5.

Concentrations of the following constituents exceeded the MCL's or SMCL's promulgated by the USEPA (1990) in ground water from at least one site: iron, manganese, nitrate, fecal coliform and fecal streptococcal bacteria, pH, total dissolved solids, and chloride. The concentrations of the constituents in ground water from seven springs that were sampled quarterly differed, but no trends were evident that related to discharge or time of year.

Analyses of ground water for organochlorine and organophosphate insecticides and triazine herbicides, indicated that no concentrations exceeded USEPA MCL's and U.S. Public Health Service standards. The following organochlorine and organophosphate pesticides were present in detectable concentrations: chlordane, DDE, DDT, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, and malathion. Triazine herbicides that were present in detectable concentrations were atrazine, cyanazine, and simazine.

Radon concentrations ranged from 92 to 1,600 pCi/L. Water from four springs in the carbonate rocks was analyzed for 36 volatile organic compounds. None of the compounds were present in detectable concentrations.

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GLOSSARY

Hydrology, like most branches of science, has its own terminology. An understanding of certain terms is essential when reading this report. The definitions here have been simplified and shortened as much as possible. Further definitions can be found in reports by Heath (1983), Nutter (1973, p. 40-41), American Geological Institute (1984), and Lohman and others (1972).

Adsorb--The adhesion of molecules in solution to the surface of solid bodies with which they are in contact.

Alkalinity--The capacity of a solution (generally water) to neutralize acid.

Anticline--An upward fold in the rocks with stratigraphically older rocks in the center.

Artesian well-- An artesian well is a well deriving its water from an artesian or confined water body. The water level in an artesian well stands above the top of the artesian water body it taps.

Aquifer--A rock formation that contains sufficient saturated permeable material to yield significant amounts of water to wells or springs.

Background fluorescence--Existing fluorescence measured in water samples before a dye tracer test is conducted.

Base flow--The flow of a stream when all water in the channel is derived from ground water.

Bedding plane--The division plane that separates each successive layer or bed from the one above or below.

Carbonate rocks--Rocks that are composed principally of calcium carbonate (limestone) or calcium-magnesium carbonate (dolomite).

Cross fault--A fault that strikes diagonally or perpendicularly to the strike of the associated strata or to the general structural trend.

Dendritic drainage pattern--A surface drainage pattern in which streams branch at almost any angle, resembling the branching of trees.

Dip of rock strata--The angle between the horizontal and the bedding plane; dip is measured in a vertical plane at right angles to the strike of the bedding. (See *strike of rock strata.*)

Dissolution--The act or process of dissolving rock.

Dye tracer test--A test in which a fluorescent dye is injected into any aquifer and then springs and streams downgradient from the injection point are monitored for dye with activated charcoal dye detectors. The dye detectors generally are exchanged weekly and analyzed for the presence of dye, using a fluorometer and/or visual tests.

Eluant--A liquid used to extract one material from another.

Eluate--The solution that results from the eluation process.

Evapotranspiration--Evaporation from water surfaces plus transpiration from plants.

Fault--A fracture in the Earth's crust accompanied by displacement of one side of the fracture with respect to the other.

Fecal coliform bacteria--A bacteria found in human and other warm-blooded animal intestines.

Fecal streptococcal bacteria--A bacteria found in human and other warm-blooded animal intestines.

Flow, conduit--The flow of ground water along bedding planes, faults, and joints that have been enlarged into cavities or caverns by dissolution of the carbonate rocks.

Flow, diffuse--The flow of ground water along bedding planes, faults, and joints that have not been significantly enlarged by dissolution.

Flow, laminar--A flow of water in which the velocity at a given point is constant in magnitude and direction.

Fluorescence--Emission of visible light by a substance exposed to ultraviolet light.

Fracture--A break in rock that may be caused by compressional or tensional forces.

Gaining stream--A stream, or segment of a stream, that receives water from an aquifer. (See *losing stream.*)

Ground water--Water contained in the zone of saturation in the rock. (See *surface water.*)

Head--Pressure, expressed as the height of a column of water that can be supported by the pressure.

Herbicide--A type of pesticide used to control unwanted plants.

Homogenous--An aquifer with identical properties throughout.

Hydraulic conductivity--The capacity of a rock to transmit water.

Hydraulic gradient--The change of pressure head per unit distance from one point to another in an aquifer.

Insecticide--A type of pesticide used to control insects.

Isotropic--An aquifer that exhibits the same properties with the same values when measured along axes in all directions.

Joints--System of fractures in rocks along which there has been no movement parallel to the fracture surface. In coal, joints and fractures may be termed "cleats."

Karst--A geologic area having topographic features that develop as a result of underground solution of the carbonate rocks and diversion of surface water underground.

Laminar flow--(See *flow, laminar.*)

Lineaments--Linear features observed on aerial photographs or imagery (formed by the alignment of stream channels or tonal features in soil, vegetation, or topography) that can represent subsurface fracture zones.

Losing stream--A stream, or segment of a stream, that contributes water to an underlying aquifer. (See *gaining stream.*)

MCL (Maximum contaminant level)--An enforceable maximum permissible concentration of a contaminant in water that is delivered to any user of a public water system.

MCLG (Maximum contaminant level goal)--A non-enforceable maximum permissible concentration of a contaminant in drinking water. It is set at the level that would result in no adverse health effects over a lifetime of exposure.

Microsiemens--The unit used in reporting specific conductance of water per centimeter at 25° Celsius.

Noncarbonate rocks--In this report, rocks that are composed principally of shales and sandstones (in Berkeley County, West Virginia).

Pesticide--A chemical used to destroy pests such as insects and weeds.

pH--The negative logarithm of the hydrogen-ion concentration in the water.

Precipitation--Water that falls to the Earth's surface in the form of hail, mist, rain, sleet, or snow.

Primary porosity--Openings in the rock, such as pores, that were created at the time the rocks were formed.

Recharge--That part of precipitation or surface water that penetrates the Earth's surface and eventually reaches the water table.

Secondary porosity--Openings in the rock, such as fractures or solution channels, which formed after the rock was deposited.

Sinkhole--An undrained closed depression formed by the collapse of soil into a solution cavity in the underlying carbonate rocks.

SMCL (Secondary maximum contaminant level)--A non-enforceable recommended standard set by the U.S. Environmental Protection Agency for drinking water, based on aesthetic considerations such as taste, odor, and appearance.

Specific capacity--The rate of discharge of a well divided by the drawdown of the water level in the well.

Specific conductance--The measured electrical conductance of a unit length and cross section of water, reported in microsiemens per centimeter (μS/cm) at 25° Celsius. Often referred to as "conductivity."

Specific yield--The ratio of (1) the volume of water that the rock or soil, after saturation, will yield by gravity to (2) the volume of the rock or soil. The definition implies that gravity drainage is complete. In the natural environment, specific yield is generally observed as the change that occurs in the amount of water in storage per unit area of unconfined aquifer as the result of a unit change in head.

Storage coefficient--The volume of water an aquifer releases or takes into storage per unit surface area of the aquifer, per unit change in head.

Strike of rock strata--The direction of a line formed by the intersection of the bedding and a horizontal plane. (See *dip of rock strata.*)

Subsequent stream--A tributary that has developed its valley along a belt of underlying weak rock and is therefore adjusted to the regional structure.

Syncline--A downward fold in the rocks with stratigraphically younger rocks in the center.

Transmissivity--The rate at which water of a prevailing viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient.

Trellis drainage pattern--An arrangement of surface drainage characterized by parallel main streams with right-angle tributaries, which in turn are fed by elongated secondary tributaries parallel to the main streams.

Water table--The surface in an unconfined water body at which pressure is atmospheric; generally the top of the saturated zone.

APPENDIXES

Appendix A: Records of inventoried wells and springs in Berkeley County, West Virginia, 1989-90

Explanation

Topographic setting

- C- stream channel
- F- flood plain
- H- hilltop
- S- hillside
- U- undulating
- V- valley

Aquifer code

337POCN-	Pocono Group	- (noncarbonate)
341HMPR-	Hampshire Formation	- (noncarbonate)
341CMNG-	Chemung Group	- (noncarbonate)
341MRCL-	Marcellus Formation	- (noncarbonate)
344MNNG-	Mahantango Formation	- (noncarbonate)
344MNMR-	Mahantango and Marcellus Formations	- (noncarbonate)
347ORSK-	Oriskany Sandstone	- (noncarbonate)
351TNWL-	Tonoloway Formation	- (carbonate)
361MRBG-	Martinsburg Formation	- (noncarbonate)
364CBBG-	Chambersburg Limestone	- (carbonate)
364STPL-	St. Paul Group	- (carbonate)
367BKMN-	Beekmantown Group	- (carbonate)
371CCCG-	Conococheague Formation	- (carbonate)
374ELBK-	Elbrook Formation	- (carbonate)

Other abbreviations used in the appendix

ft	- feet
in.	- inches
gal/min	- gallon per minute
°	- degrees of latitude or longitude
'	- minutes of latitude or longitude
"	- seconds of latitude or longitude

NOTE: Site numbers less than 200 pertain to wells.
Site numbers greater than 200 pertain to springs.

Appendix A-1: Records of wells

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Well depth (ft)	Length of casing (ft)	Year of con-struction	Altitude above sea level (ft)	Water level (ft)	Date water level measured	Aquifer code	Topo-graphic setting	Yield (gal/min)
1	391720078025901	391720	0780259	100	27	1983	590	43.08	01-18-1990	361MRBG	U	30
2	391720078025902	391720	0780259	340	34	1983	590	39.99	01-18-1990	361MRBG	U	6
3	391757078010601	391757	0780106	80	40	1979	560	44.02	07-10-1989	361MRBG	H	46
4	391809078044301(20-6-081)	391809	0780443	300	-	-	630	-	-	367BKMN	U	-
5	391822078023701(20-6-094)	391822	0780237	70	20	1965	585	18.41	02-15-1990	361MRBG	U	40
6	391903078050401	391903	0780504	187	25	1973	635	-	-	367BKMN	U	19
7	391919077592401	391919	0775924	90	8.5	1972	460	30.99	02-01-1990	361MRBG	V	9.5
8	391940078024701	391940	0780247	110	75	1988	530	44.65	05-24-1990	367BKMN	U	40
9	392002078041101	392002	0780411	330	118	1985	685	105.81	05-31-1990	371CCCG	U	30
10	392028078080701	392028	0780807	37	-	-	780	-	-	361MRBG	V	5
11	392028078080702	392028	0780807	186	-	1987	780	-	-	361MRBG	V	35
12	392037078064701	392037	0780647	478	20	1981	505	53.47	05-31-1990	374ELBK	S	.5
13	392041078041801	392041	0780418	165	-	1973	655	35.55	02-01-1990	371CCCG	U	-
14	392052078034301	392052	0780343	84	-	-	630	55.73	05-31-1990	371CCCG	U	-
15	392054078044401	392054	0780444	323	21	1979	715	117.95	06-20-1990	371CCCG	H	12
16	392101077594101	392101	0775941	120	21	1970	560	25.46	03-22-1989	361MRBG	H	-
17	392107078060901(20-4-072)	392107	0780609	118	-	1935	720	15	-	374ELBK	S	-
18	392122078024001	392122	0780240	-	-	1954	570	34.55	05-09-1989	367BKMN	U	-
19	392129078061701	392129	0780617	190	40	1986	680	11.21	02-15-1990	367BKMN	V	90
20	392143078044801	392143	0780448	320	-	1980	680	49.55	05-31-1990	371CCCG	U	25
21	392144078042401	392144	0780424	55	-	-	615	25.70	03-21-1989	371CCCG	U	-
22	392151078020401	392151	0780204	>250	-	1970	575	120	- -1985	367BKMN	U	-
23	392152078013801	392152	0780138	206	8	1969	570	18.81	06-20-1990	367BKMN	U	.3
24	392202078004501	392202	0780045	80	20	1986	555	12.83	03-29-1990	361MRBG	U	50
25	392203077582201	392203	0775822	228	45	1971	540	77.80	02-15-1990	361MRBG	H	-
26	392204078110501	392204	0781105	160	-	1979	640	46.44	07-26-1989	344MNNG	S	4
27	392225078042201	392225	0780422	405	20	1974	700	105.50	05-31-1990	371CCCG	U	1
28	392227078020001	392227	0780200	80	20	1986	565	15.49	06-20-1990	367BKMN	U	-
29	392242078023001	392242	0780230	160	30	1974	560	-	-	367BKMN	U	45
30	392254078063901	392254	0780639	52.5	11	-	800	10.93	03-21-1989	361MRBG	S	-
31	392259078085801	392259	0780858	125	-	1957	540	28.36	02-15-1990	344MNNG	V	6
32	392306078042401	392306	0780424	380	42	1986	700	-	-	374ELBK	U	3
33	392323078115701	392323	0781157	305	20.5	1987	960	48.13	01-17-1990	341HMPR	S	10
34	392336077583401	392336	0775834	80	20	1970	545	-	-	361MRBG	U	-
35	392353078030601	392353	0780306	80	21	1969	620	10	- -1969	371CCCG	U	-
36	392406078090301	392406	0780903	107	42	1977	560	32.98	03-22-1989	344MNNG	S	15
37	392407077545201	392407	0775452	-	-	-	490	37.54	04-25-1989	364CBBG	U	-
38	392412078005401(20-5-116)	392412	0780054	300	-	1966	560	-	-	367BKMN	U	-
39	392416078041501	392416	0780415	100	20	1972	730	39.41	06-18-1990	374ELBK	U	-
40	392423078051401	392423	0780514	85	35	1977	800	8.17	02-14-1990	361MRBG	S	-
41	392430078025101	392430	0780251	101	30	1980	660	58.93	06-20-1990	374ELBK	U	54
42	392436078015301(20-5-071)	392436	0780153	185	-	-	660	86.67	02-14-1990	371CCCG	U	30
43	392437077545201	392437	0775452	127	-	1960	500	-	-	367BKMN	U	-
44	392444078105301	392444	0781053	160	16	1983	835	28.61	03-22-1989	341HMPR	S	30
45	392505077573101	392505	0775731	110	5	-	500	47.18	07-11-1989	361MRBG	H	-
46	392514078002701	392514	0780027	140	-	1976	570	73.95	02-13-1990	367BKMN	U	-
47	392526078082601	392526	0780826	164	20	1962	580	33.49	01-18-1990	344MNNG	S	5
48	392527078021801	392527	0780218	500	16.5	1982	675	42.87	04-25-1989	374ELBK	U	-
49	392529078041901	392529	0780419	300	20	1980	735	-	-	367BKMN	V	11
50	392531078024701	392531	0780247	150	100	1988	730	84.40	04-20-1989	374ELBK	U	42
51	392539077534601	392539	0775346	136	-	1974	500	42.89	04-19-1989	367BKMN	U	-
52	392601078094201	392601	0780942	125	40	1981	800	54.73	01-18-1990	341HMPR	S	25
53	392602078035401	392602	0780354	60	10	-	700	13.90	04-20-1989	367BKMN	V	-
54	392603078020201	392603	0780202	200	20	1976	660	28.01	04-20-1989	371CCCG	U	-
55	392605078030601	392605	0780306	480	60	1974	800	176.61	04-20-1989	374ELBK	H	-
56	392612078042201	392612	0780422	-	24	1976	870	32.01	04-20-1989	361MRBG	H	-
57	392617077551301	392617	0775513	125	-	1960	445	29.25	03-22-1989	364CBBG	S	-
58	392621078074900(20-4-079)	392626	0780746	714	-	1899	500	FLOWS	02-28-1989	341MRCL	V	4.1
59	392624078034301	392624	0780343	140	-	1977	700	21.70	04-20-1989	367BKMN	U	-
60	392630078000601	392630	0780006	136	25	1973	544	-	-	371CCCG	S	-
61	392642077514501	392642	0775145	110	-	1953	480	-	-	367BKMN	U	-
62	392704077530701	392704	0775307	425	17	1989	470	19.32	02-21-1990	367BKMN	U	10
63	392713078012901	392713	0780129	115	-	-	600	60.11	02-13-1990	371CCCG	U	5
64	392713078091801	392713	0780918	140	80	1978	800	45.75	07-26-1989	341HMPR	S	40
65	392714077595001	392714	0775950	144	-	1989	560	80.42	02-14-1990	371CCCG	U	10
66	392717078002601	392717	0780026	176	70	1988	620	121.80	06-18-1990	371CCCG	U	80
67	392721078013901	392721	0780139	450	20	1988	600	51.74	06-18-1990	374ELBK	U	8
68	392721078013902	392721	0780139	550	20	1988	600	31.74	06-18-1990	374ELBK	U	1
69	392725077524701	392725	0775247	320	-	1968	500	-	-	367BKMN	U	-

Appendix A-1: Records of wells--Continued

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Well depth (ft)	Length of casing (ft)	Year of con-struction	Altitude above sea level (ft)	Water level (ft)	Date water level measured	Aquifer code	Topo-graphic setting	Yield (gal/min)
70	392725077582401(20-5-007)	392725	0775824	154	10	1920	465	49.47	04-19-1989	367BKMN	S	-
71	392726078025001	392726	0780250	140	25	1977	640	31.64	01-18-1990	367BKMN	V	10
72	392728077562501	392728	0775625	100	-	1988	490	11.04	02-23-1990	361MRBG	U	-
73	392748078003201	392748	0780032	30	23	1965	520	3.00	03-22-1989	374ELBK	V	-
74	392748078065101	392748	0780651	90	16	1981	540	26.50	01-17-1990	344MNNG	V	20
75	392753078000201	392753	0780002	-	42	-	520	37.02	06-20-1990	371CCCG	U	7
76	392806077505501(20-3-076)	392806	0775055	-	21	-	420	35.80	04-19-1989	367BKMN	U	-
77	392812077593101	392812	0775931	125	-	1951	520	39.25	02-14-1990	371CCCG	U	-
78	392814078020001	392814	0780200	35	-	1935	580	5.28	02-13-1990	374ELBK	V	-
79	392823077553601	392823	0775536	110	-	1962	480	-	-	361MRBG	H	-
80	392827078022201	392827	0780222	86	21	1979	680	7.38	03-22-1989	361MRBG	S	11.6
81	392837077520401	392837	0775204	78	-	-	480	-	-	367BKMN	U	-
82	392848077530601	392848	0775306	170	15	-	450	35.35	04-20-1989	367BKMN	U	-
83	392902077595901	392902	0775959	400	12	1976	540	80.09	07-11-1989	374ELBK	U	7
84	392906078013101	392906	0780131	60	6	1955	620	30.43	02-13-1990	374ELBK	U	25
85	392911078060101	392911	0780601	130	42	1984	585	21.81	03-22-1989	344MNNG	V	10
86	392911078071801	392911	0780718	153	20	1983	730	72.55	04-20-1989	341CMNG	S	6
87	392924077504401	392924	0775044	-	-	-	410	49.93	07-11-1989	367BKMN	U	-
88	392942077584301	392942	0775843	120	12	1987	585	-	-	367BKMN	U	10
89	393004077505601	393004	0775056	230	19	1973	400	79.43	02-21-1990	367BKMN	H	-
90	393021077551201	393021	0775512	60	-	1967	465	12.41	04-19-1989	361MRBG	S	-
91	393034077520301	393034	0775201	-	-	1961	425	-	-	367BKMN	U	-
92	393040078042601	393040	0780426	320	-	-	690	60.51	01-17-1990	351TNWL	S	-
93	393055078000601	393055	0780006	75	30	1934	610	-	-	374ELBK	U	-
94	393111077500101	393111	0775001	300	35	1961	460	96.07	07-25-1989	367BKMN	U	-
95	393113078062501	393113	0780625	165	21	1975	780	70.31	01-17-1990	341CMNG	S	-
96	393116077502401	393116	0775024	410	30	1986	450	-	-	367BKMN	H	1
97	393123077562201	393123	0775622	450	100	1988	490	-	-	367BKMN	U	10
98	393125077583401	393125	0775834	485	150	1976	525	77.54	03-23-1989	374ELBK	U	>15
99	393201077544701	393201	0775447	85	21	1972	460	18.30	02-23-1990	361MRBG	U	-
100	393213077594801	393213	0775948	80	-	1974	585	5.57	02-21-1990	374ELBK	U	-
101	393242078023201	393242	0780232	200	80	1978	565	95.47	03-23-1989	341MRCL	S	4
102	393250078053301	393250	0780533	220	-	1977	690	47.27	07-26-1989	341CMNG	H	-
103	393315077555601	393315	0775556	123	40	1970	490	55.81	03-23-1989	367BKMN	U	15
104	393358077544801	393358	0775448	130	-	1973	440	41.54	02-20-1990	367BKMN	U	35
105	393405078024901(20-1-024)	393405	0780249	90	-	1957	520	83.62	07-25-1989	344MRCL	S	-
106	393413078062301	393413	0780623	406	122	1987	885	56.95	03-23-1989	341HMPR	S	10
107	393419077553601	393419	0775536	162	-	1981	500	-	-	367BKMN	U	-
108	393424077572801	393424	0775728	84	50	1976	430	51.50	02-21-1990	374ELBK	U	10
109	393434078043401	393434	0780434	71	41	1974	590	12.59	01-17-1990	344MNNG	S	-
110	393440078011601	393440	0780116	140	-	1972	550	64.53	02-22-1990	344MNNG	H	-
111	393443078062101	393443	0780621	-	-	-	880	-	-	341HMPR	S	-
112	393448077543301	393448	0775433	85	-	1965	460	53.63	03-08-1990	367BKMN	U	-
113	393450077510801	393450	0775108	120	-	1979	510	32.43	04-20-1989	361MRBG	H	-
114	393505077571201	393505	0775712	150	-	1964	410	54.57	07-13-1989	374ELBK	S	-
115	393507077593201(20-1-140)	393507	0775932	83	-	1970	455	21.39	03-23-1989	344MNNG	S	-
116	393531077525201(20-2-105)	393531	0775252	50	-	-	510	20.61	02-21-1990	361MRBG	U	-
117	393542077545401	393542	0775454	254	40	1973	470	84.27	03-23-1989	371CCCG	H	-
118	393546078032401	393546	0780324	160	40	1982	590	68.12	02-22-1990	344MNNG	H	30
119	393621077502401	393621	0775024	105	-	1950	375	30	- -1978	361MRBG	V	2.5
120	393626078015101	393626	0780151	157	-	-	580	54.18	03-23-1989	344MNNG	H	-
121	393649077525201	393649	0775252	605	-	1988	380	59.52	07-13-1989	367BKMN	V	10.5

Appendix A-2: Records of springs

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Altitude above sea level (ft)	Aquifer code	Topo-graphic setting	Discharge (gal/min)	Date discharge measured
201	391903078024901(20-6-057)	391903	0780249	490	364CBBG	S	1	07-01-1969
202	391940078023400(20-6-056)	391940	0780234	470	364CBBG	C	1,660	07-14-1945
							3,040	10-07-1945
203	391945078054000(20-6-051)	391945	0780550	690	371CCCG	U	400	07-13-1945
							650	10-07-1945
204	391947078023900(20-6-055)	391947	0780238	485	364STPL	U	90	07-14-1945
205	391950078032900(20-6-052)	391953	0780331	555	367BKMN	U	500	12-17-1935
							2,680	07-13-1945
							2,940	10-07-1945
							2,967	03-21-1968
							3,133	04-11-1968
							3,115	05-28-1968
							2,801	06-03-1968
							2,554	06-18-1968
							2,877	06-27-1968
							2,361	08-08-1968
							1,495	09-24-1968
							1,252	11-15-1968
							1,436	12-17-1968
							992	01-29-1969
							1,580	03-11-1969
							696	10-15-1969
							2,069	01-13-1974
							2,204	04-24-1989
							2,715	05-08-1989
							2,997	05-11-1989
							2,895	05-24-1989
							2,708	06-12-1989
							2,532	07-10-1989
							2,283	08-07-1989
							1,797	09-14-1989
							1,638	10-20-1989
							1,505	11-16-1989
							1,681	12-13-1989
							1,703	01-16-1990
							2,073	03-21-1990
							2,101	05-02-1990
206	391956078062600(20-4-077)	391954	0780622	740	371CCCG	U	60	08-23-1956
							99	03-15-1989
							114	03-24-1989
							79.5	04-13-1989
							55.6	04-25-1989
							121	05-09-1989
							190	05-25-1989
							123	06-13-1989
							51.2	07-12-1989
							26.3	08-08-1989
							12.7	09-13-1989
							10.1	10-18-1989
							5.51	11-15-1989
							8.44	12-14-1989
							21.8	01-11-1990
							55.9	02-22-1990
							41.2	03-22-1990
							31.7	05-03-1990
207	391958078025300(20-6-054)	391958	0780253	530	367BKMN	C	80	07-14-1945
208	392001078031100(20-6-053)	392001	0780311	560	367BKMN	C	80	07-14-1945
209	392017078011200(20-6-026)	392017	0780112	520	361MRBG	C	.50	07-26-1956
210	392054078041301	392054	0780413	600	374ELBK	C	-	-
211	392059078042300(20-6-025)	392112	0780420	610	374ELBK	U	20	08-23-1956
212	392118078050300(20-4-073)	392118	0780503	635	374ELBK	U	220	07-13-1945
							75	08-23-1956

Appendix A-2: Records of springs--Continued

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Altitude above sea level (ft)	Aquifer code	Topo-graphic setting	Discharge (gal/min)	Date discharge measured
213	392124078050501	392124	0780505	635	374ELBK	U	234	03-29-1989
							136	04-24-1989
							278	05-08-1989
							371	05-11-1989
							507	05-24-1989
							302	06-12-1989
							273	06-20-1989
							199	07-25-1989
							128	09-13-1989
							78.1	10-17-1989
							115	11-16-1989
							70.0	12-19-1989
							100	01-16-1990
							174	03-21-1990
							167	05-02-1990
214	392151078054000(20-4-084)	392151	0780540	680	374ELBK	C	40	07-13-1945
215	392156078050000(20-4-086)	392202	0780504	640	374ELBK	C	60	07-13-1945
216	392157078052300(20-4-085)	392201	0780523	640	374ELBK	C	80	07-13-1945
217	392203078050000(20-4-082)	392218	0780510	695	374ELBK	U	350	07-13-1945
							720	10-07-1945
218	392205078054300(20-4-083)	392205	0780543	680	367BKMN	U	80	07-13-1945
219	392241078011901(20-5-058)	392241	0780119	520	367BKMN	U	500	07-13-1945
							1,870	10-07-1945
							1,284	04-25-1968
							1,180	05-28-1968
							6.73	05-28-1969
							0	06-25-1969
							11.7	07-23-1969
							476	08-20-1969
							94.2	09-17-1969
							1.35	10-28-1969
							0	12-09-1969
220	392301078031801	392301	0780318	595	371CCCG	U	150	06-20-1990
221	392333077550500(20-5-060)	392336	0775506	420	364CBBG	U	350	12-17-1935
							320	07-22-1945
							2,080	10-06-1945
222	392346077553000(20-5-059)	392346	0775530	400	361MRBG	U	20	07-22-1945
223	392351078031301	392351	0780313	600	374ELBK	C	-	-
224	392359077584200(20-5-057)	392359	0775842	520	361MRBG	S	3	07-14-1945
225	392359078063901	392359	0780639	820	344MRCL	S	28.3	03-15-1989
							22.0	03-22-1989
							19.4	04-13-1989
							19.8	04-25-1989
							27.2	05-09-1989
							31.1	05-25-1989
							18.1	06-13-1989
							16.5	07-12-1989
							12.3	08-08-1989
							8.91	09-13-1989
							11.3	10-18-1989
							11.4	11-15-1989
							10.2	12-14-1989
							14.1	01-11-1990
							15.2	02-22-1990
							16.9	03-22-1990
							12.9	05-03-1990
226	392431078035101	392431	0780351	650	374ELBK	U	500	- -1961
227	392531077590900(20-5-056)	392535	0775913	480	367BKMN	U	1,000	05-21-1935
							1,000	09-13-1935
							980	07-14-1945
							2,700	10-06-1945

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Altitude above sea level (ft)	Aquifer code	Topo-graphic setting	Discharge (gal/min)	Date discharge measured
228	392534077591401	392534	0775914	480	367BKMN	U	-	-
229	392536077591301	392536	0775913	480	367BKMN	U	-	-
230	392547077530000(20-3-052)	392547	0775300	480	367BKMN	U	130	07-21-1945
231	392550078021300(20-4-081)	392553	0780213	640	374ELBK	U	60	07-13-1945
							193	03-28-1989
							77.0	04-21-1989
							152	05-08-1989
							268	05-11-1989
							237	05-24-1989
							66.0	06-12-1989
							53.4	06-21-1989
							38.1	07-25-1989
							3.59	09-14-1989
							1.06	10-17-1989
							3.49	11-14-1989
							12.1	12-19-1989
							19.7	01-10-1990
							75.8	02-15-1990
							61.5	03-05-1990
							25.6	05-02-1990
232	392550078043301(20-4-092)	392550	0780433	-	361MRBG	S	-	-
233	392554077520000(20-3-053)	392554	0775200	480	367BKMN	U	130	07-21-1945
234	392619077541200(20-3-051)	392625	0775417	445	364CBBG	U	280	07-22-1945
							1,130	10-06-1945
							925	03-30-1989
							548	04-21-1989
							1,095	05-09-1989
							1,328	05-12-1989
							1,441	05-24-1989
							803	06-12-1989
							637	07-10-1989
							425	08-07-1989
							194	09-12-1989
							190	10-17-1989
							154	11-14-1989
							84.8	12-18-1989
							205	01-10-1990
							360	03-05-1990
							376	05-01-1990
235	392650077551800(20-3-050)	392650	0775518	380	364CBBG	U	-	-
236	392704077573900(20-5-055)	392704	0775739	400	364CBBG	U	1,370	10-06-1945
237	392717077540901	392717	0775409	410	364CBBG	U	-	-
238	392723078103900	392723	0781039	1590	337POCN	S	2.5	02-28-1989
							10.1	03-29-1989
							3.14	06-21-1989
							4.49	10-03-1989
							12.6	12-19-1989
							2.88	03-07-1990
239	392729078024601(20-4-091)	392729	0780246	-	367BKMN	U	-	-
240	392746078003301	392746	0780033	520	374ELBK	C	200	03-21-1989
241	392748078003202	392748	0780032	520	374ELBK	C	150	03-21-1989
242	392800078001901(20-5-134)	392800	0780019	-	374ELBK	C	-	-
243	392806078024700(20-4-080)	392811	0780156	570	367BKMN	U	100	12-17-1935
							280	07-13-1945
							320	10-07-1945
244	392812077585900(20-1-085)	392814	0775901	480	367BKMN	C	2,900	10-06-1945
245	392812078020201	392812	0780202	580	367BKMN	U	-	-

Appendix A-2: Records of springs--Continued

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Altitude above sea level (ft)	Aquifer code	Topo-graphic setting	Discharge (gal/min)	Date discharge measured
246	392815077524000(20-3-054)	392810	0775238	460	367BKMN	U	100	07-21-1945
							0	12-13-1989
247	392907078013501	392907	0780135	610	374ELBK	U	72.8	03-07-1990
248	392920078055001	392920	0780550	560	344MNNG	C	3	12-18-1935
249	392935078054200(20-4-005)	392932	0780544	570	347ORSK	C	70	05-21-1935
							40	07-20-1945
							100	10-15-1969
							40	- -1975
							130	05-27-1983
250	392935078054501	392935	0780545	580	344MNNG	C	25	12-18-1935
251	392950078004601	392950	0780046	580	374ELBK	U	100	02-21-1990
252	393011077510701(20-3-081)	393011	0775107	-	367BKMN	-	-	-
253	393038078081601	393038	0780816	1450	337POCN	S	9.26	01-18-1990
							3.85	03-06-1990
254	393112077535501(20-2-049)	393112	0775355	340	361MRBG	C	1	05-21-1935
							.90	10-15-1969
							0	03-01-1989
255	393112077535801(20-2-050)	393112	0775358	340	364CBBG	C	.50	05-21-1935
256	393116077535201	393116	0775352	340	364CBBG	U	99	03-01-1989
							132	03-16-1989
							102	04-19-1989
							92.5	04-25-1989
							206	05-09-1989
							161	05-25-1989
							99.5	06-13-1989
							75.9	07-12-1989
							40.6	08-08-1989
							24.3	09-13-1989
							28.3	10-18-1989
							89.6	11-15-1989
							86.1	12-14-1989
							150	01-11-1990
							129	02-22-1990
							100	03-22-1990
							94.3	05-03-1990
257	393128077554700(20-2-048)	393126	0775544	400	367BKMN	U	1,000	12-18-1935
							1,960	07-21-1945
							3,020	10-06-1945
							2,796	03-30-1989
							2,379	04-21-1989
							2,379	04-26-1989
							2,831	05-08-1989
							3,064	05-11-1989
							2,827	05-24-1989
							2,842	06-12-1989
							3,355	06-22-1989
							2,858	07-24-1989
							2,181	09-12-1989
							1,814	10-16-1989
							1,535	11-14-1989
							1,418	12-19-1989
							1,315	01-10-1990
							1,970	03-05-1990
							1,599	05-01-1990
258	393138078031600(20-1-091)	393145	0780258	460	347ORSK	V	40	06-15-1933
							40	07-20-1945
259	393143078083101(20-1-149)	393143	0780831	1180	337POCN	S	-	-
260	393145078033700(20-1-047)	393146	0780347	530	351TNWL	S	50	08-28-1956
261	393234077583900(20-1-090)	393229	0775842	500	374ELBK	C	10	07-20-1945

Site number	Site identification	Latitude (° ' ")	Longitude (° ' ")	Altitude above sea level (ft)	Aquifer code	Topo-graphic setting	Discharge (gal/min)	Date discharge measured
262	393252077572000(20-2-046)	393258	0775718	435	374ELBK	U	400	12-18-1935
							1,170	07-14-1945
							3,200	10-06-1945
							3,867	01-13-1974
263	393300077571800(20-2-034)	393300	0775718	430	371CCCG	C	-	-
264	393302077582900(20-1-089)	393258	0775838	470	374ELBK	U	330	07-20-1945
							560	10-06-1945
							415	07-25-1989
265	393325077571300(20-2-045)	393334	0775716	415	374ELBK	C	200	06-15-1933
							270	07-20-1945
							360	10-06-1945
266	393326077593500(20-1-087)	393316	0775944	630	344MNNG	S	3	12-18-1935
267	393334078031800	393334	0780318	490	351TNWL	C	224	03-29-1989
							250	06-21-1989
							148	10-03-1989
							130	12-20-1989
							168	03-05-1990
268	393335077582200(20-1-088)	393331	0775826	470	374ELBK	U	30	12-18-1935
							100	07-20-1945
							154	03-30-1989
							88	04-24-1989
							192	05-08-1989
							359	05-11-1989
							392	05-24-1989
							138	06-12-1989
							171	06-22-1989
							97.4	07-24-1989
							44.0	09-12-1989
							22.4	10-17-1989
							26.0	11-14-1989
							31.9	12-18-1989
							28.3	01-10-1990
							82.1	03-05-1990
							44.4	05-02-1990
269	393337077532900(20-2-047)	393337	0775332	370	364CBBG	V	1,010	07-21-1945
							2,550	10-06-1945
270	393428078022900(20-1-086)	393428	0780229	440	347ORSK	C	110	07-21-1945

Appendix B: Ground-water-quality data for selected wells and springs in Berkeley County, West Virginia, 1989-90

Explanation

Abbreviations used in the appendix

ft	- feet
°	- degrees of latitude or longitude
′	- minutes of latitude or longitude
″	- seconds of latitude or longitude
°C	- degrees Celsius
mm of Hg	- millimeters of mercury
μS/cm	- microsiemens per centimeter at 25 degrees Celsius
mg/L	- milligrams per liter
μg/L	- micrograms per liter
mL	- milliliter
cols	- colonies
pC/L	- picocuries per liter
K	- estimated bacteria count based on nonideal colony count
<	- less than

NOTE: Site numbers less than 200 pertain to wells.
Site numbers greater than 200 pertain to springs.

Appendix B-1: Water-quality data values

STATION NUMBER	DATE	TEMPERATURE WATER (DEG °C)	SPECIFIC CONDUCTANCE (µS/CM)	PH WATER WHOLE FIELD (STANDARD UNITS)	OXYGEN, DISSOLVED (MG/L)	BICARBONATE WATER DIS IT FIELD MG/L AS HCO3	CARBONATE WATER DIS IT FIELD MG/L AS CO3	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)
391720078025901	03-06-90	12.5	640	7.2	0.4	232	0	0.030	0.04	--	<0.010
391757078010601	08-24-89	13.5	235	7.3	4.5	110	0	0.020	0.03	--	<0.010
391809078044301	08-24-89	13.0	1180	7.0	2.5	502	0	0.020	0.03	--	<0.010
391822078023701	03-06-90	14.0	1040	6.9	0	177	0	0.030	0.04	--	<0.010
391903078050401	03-06-90	10.0	590	7.4	7.1	341	0	<0.010	--	--	<0.010
391919077592401	03-06-90	12.5	390	6.9	0.3	171	0	0.030	0.04	--	<0.010
392028078080701	03-08-90	12.0	650	7.5	3.5	307	0	0.030	0.04	--	<0.010
392041078041801	03-06-90	12.5	750	7.0	8.4	451	0	<0.010	--	--	<0.010
392101077594101	08-24-89	14.0	508	7.0	2.0	148	0	0.030	0.04	--	<0.010
392129078061701	03-08-90	12.0	420	7.9	1.2	212	0	0.120	0.15	--	<0.010
392144078042401	08-23-89	14.0	795	6.8	2.5	416	0	0.030	0.04	--	<0.010
	03-06-90	11.5	830	6.8	1.2	500	0	<0.010	--	--	<0.010
392151078020401	03-06-90	13.0	925	7.0	1.4	500	0	<0.010	--	--	<0.010
392203077582201	03-07-90	12.5	648	7.4	0.8	171	0	0.110	0.14	--	<0.010
392204078110501	08-23-89	12.5	157	6.4	1.6	73	0	0.010	0.01	--	<0.010
392242078023001	03-07-90	8.5	535	7.3	9.6	305	0	0.010	0.01	--	<0.010
392254078063901	08-24-89	14.5	288	7.1	0.7	163	0	0.050	0.06	--	<0.010
392259078085801	03-08-90	13.0	4	7.7	0.7	171	0	0.030	--	--	<0.010
392306078042401	08-24-89	17.0	650	7.4	7.7	379	0	0.020	0.03	--	<0.010
	03-08-90	12.0	635	7.4	4.6	373	0	<0.010	--	--	<0.010
392323078115701	03-08-90	13.0	224	7.3	3.8	151	0	<0.010	--	--	<0.010
392336077583401	03-07-90	12.0	268	6.7	1.0	119	0	<0.010	--	--	<0.010
392353078030601	03-08-90	12.5	697	7.4	5.8	356	0	<0.010	--	--	<0.010
392406078090301	08-23-89	14.5	387	6.5	0.9	134	0	0.020	0.03	--	<0.010
392412078005401	08-23-89	13.5	865	6.9	3.7	371	0	0.020	0.03	--	<0.010
	03-07-90	12.5	780	6.8	5.5	402	0	<0.010	--	--	<0.010
392423078051401	03-07-90	13.0	252	7.4	0.5	149	0	0.050	0.06	--	<0.010
392436078015301	03-07-90	12.0	610	7.0	8.9	329	0	<0.010	--	--	<0.010
392437077545201	03-08-90	11.5	615	7.1	8.7	329	0	0.060	0.08	--	<0.010
392444078105301	08-23-89	13.5	230	6.8	0.3	123	0	0.050	0.06	--	<0.010
392505077573101	08-23-89	15.0	502	6.9	2.5	139	0	0.020	0.03	--	<0.010
392514078002701	03-08-90	13.5	1180	7.1	8.8	354	0	<0.010	--	--	<0.010
392526078082601	03-07-90	12.0	310	6.7	1.7	133	0	0.070	0.09	--	<0.010
392527078021801	08-22-89	13.5	695	7.4	2.5	401	0	<0.010	--	--	<0.010
392529078041901	03-07-90	12.0	332	7.6	1.6	180	0	0.100	0.13	0.540	0.030
392539077534601	08-23-89	13.5	520	7.3	7.9	268	0	0.020	0.03	--	<0.010
	03-08-90	10.0	555	7.2	8.2	317	0	<0.010	--	--	<0.010
392601078094201	03-07-90	12.0	97	6.3	2.1	43	0	<0.010	--	--	<0.010
392605078030601	08-22-89	13.0	520	7.2	4.4	341	0	0.010	0.01	--	<0.010
392612078042201	08-22-89	13.0	208	7.0	0.2	115	0	<0.010	--	--	<0.010
392617077551301	08-23-89	12.5	865	6.7	0.6	417	0	0.040	0.05	--	<0.010
	03-08-90	12.0	845	6.9	0.2	427	0	<0.010	--	--	0.020
392621078074900	08-22-89	--	440	7.5	0	168	0	0.090	0.12	--	<0.010
392630078000601	08-22-89	15.0	575	7.2	7.2	329	0	0.010	0.01	--	<0.010
392642077514501	03-06-90	12.0	800	6.8	8.4	378	0	<0.010	--	--	<0.010

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	PHOSPHORUS ORTHO, DISSOLVED (MG/L AS P)	HARDNESS TOTAL (MG/L AS CACO3)	HARDNESS NONCARB DISSOLV FLD. AS CACO3 (MG/L)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	SULFATE DISSOLVED (MG/L AS SO4)
391720078025901	03-06-90	<0.100	<0.010	320	130	91	22	17	0.70	160
391757078010601	08-24-89	<0.100	<0.010	100	14	31	6.6	5.0	0.50	26
391809078044301	08-24-89	17.0	<0.010	530	120	120	56	33	25	89
391822078023701	03-06-90	<0.100	<0.010	--	--	120	41	33	1.4	140
391903078050401	03-06-90	0.590	<0.010	330	52	85	29	2.7	1.6	30
391919077592401	03-06-90	0.100	0.010	180	42	53	12	16	0.60	63
392028078080701	03-08-90	<0.100	<0.010	320	67	88	24	12	1.7	45
392041078041801	03-06-90	2.60	<0.010	430	58	99	44	2.1	1.4	29
392101077594101	08-24-89	0.650	<0.010	220	100	55	21	12	1.0	66
392129078061701	03-08-90	<0.100	0.020	--	--	49	19	12	0.80	34
392144078042401	08-23-89	4.00	<0.010	340	3	110	17	9.3	12	37
	03-06-90	3.30	<0.010	420	5	130	22	12	17	38
392151078020401	03-06-90	8.50	<0.010	480	72	150	26	22	2.6	29
392203077582201	03-07-90	<0.100	<0.010	170	29	48	12	8.7	1.0	39
392204078110501	08-23-89	<0.100	<0.010	59	0	10	8.3	6.4	0.80	14
392242078023001	03-07-90	4.20	<0.010	290	39	86	18	4.8	1.4	20
392254078063901	08-24-89	<0.100	0.020	130	0	32	12	7.7	1.7	4.0
392259078085801	03-08-90	0.410	0.020	--	--	52	11	12	0.70	31
392306078042401	08-24-89	0.210	<0.010	340	34	72	40	1.3	2.1	39
	03-08-90	0.210	<0.010	--	--	75	41	1.2	1.4	35
392323078115701	03-08-90	0.300	0.020	100	0	22	12	7.2	2.5	4.2
392336077583401	03-07-90	<0.100	<0.010	--	--	22	15	9.7	1.0	31
392353078030601	03-08-90	4.10	<0.010	350	54	99	24	16	0.90	34
392406078090301	08-23-89	3.40	<0.010	150	42	36	15	12	0.60	24
392412078005401	08-23-89	23.0	0.060	400	98	120	25	13	28	31
	03-07-90	14.0	0.060	370	40	110	23	8.4	4.8	25
392423078051401	03-07-90	<0.100	0.030	120	0	31	10	9.6	1.3	3.9
392436078015301	03-07-90	3.60	<0.010	310	42	110	9.1	7.9	2.1	9.5
392437077545201	03-08-90	1.30	<0.010	330	62	110	14	11	1.0	60
392444078105301	08-23-89	0.280	0.020	93	0	19	11	8.6	0.70	6.0
392505077573101	08-23-89	3.70	0.020	210	100	56	18	15	1.3	62
392514078002701	03-08-90	2.30	<0.010	320	25	110	9.8	1.6	1.6	14
392526078082601	03-07-90	<0.100	<0.010	160	46	46	9.8	6.6	0.40	51
392527078021801	08-22-89	<0.100	<0.010	380	46	81	42	3.5	2.4	42
392529078041901	03-07-90	0.570	0.010	150	0	36	14	16	1.3	2.7
392539077534601	08-23-89	8.40	<0.010	260	41	91	8.2	4.0	2.0	10
	03-08-90	7.10	<0.010	290	31	100	10	4.4	2.0	9.8
392601078094201	03-07-90	<0.100	<0.010	39	4	3.5	7.4	4.3	0.60	2.0
392605078030601	08-22-89	3.20	<0.010	310	32	92	20	3.6	1.9	28
392612078042201	08-22-89	<0.100	<0.010	87	0	20	9.1	6.1	1.1	4.0
392617077551301	08-23-89	3.50	0.010	420	83	160	6.1	19	1.1	54
	03-08-90	2.10	<0.010	430	83	160	8.3	17	2.5	46
392621078074900	08-22-89	<0.100	<0.010	170	36	48	13	18	0.90	60
392630078000601	08-22-89	5.70	0.010	310	38	100	14	4.0	15	23
392642077514501	03-06-90	8.60	<0.010	380	72	140	7.9	3.5	1.1	22

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	IRON, DISSOLVED (μG/L AS FE)	MANGANESE, DISSOLVED (μG/L AS MN)	COLIFORM, FECAL, 0.7 UM-MF (COLS./ 100 ML)	STREPTOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	RADON 222 TOTAL (PCI/L)
391720078025901	03-06-90	2.6	0.30	24	1500	570	<1	<1	444	--
391757078010601	08-24-89	0.80	0.10	22	410	230	<1	K1	148	--
391809078044301	08-24-89	69	0.10	9.2	4	<1	<1	K3	705	--
391822078023701	03-06-90	160	<0.10	26	4700	1300	<1	<1	729	--
391903078050401	03-06-90	7.3	0.30	8.7	<3	1	<1	<1	342	--
391919077592401	03-06-90	7.8	0.20	28	710	220	<1	<1	276	--
392028078080701	03-08-90	36	0.10	21	1500	520	<1	K3	395	--
392041078041801	03-06-90	2.7	0.20	12	<3	<1	<1	<1	446	--
392101077594101	08-24-89	40	0.20	27	240	470	<1	<1	306	92
392129078061701	03-08-90	6.1	0.80	18	35	97	<1	<1	250	--
392144078042401	08-23-89	10	0.20	10	8	<1	150	<1	415	--
	03-06-90	15	0.30	11	8	3	<1	<1	490	--
392151078020401	03-06-90	45	<0.10	8.4	18	18	K4	K8	595	--
392203077582201	03-07-90	7.0	0.40	22	33	150	<1	<1	230	--
392204078110501	08-23-89	1.4	0.10	21	11	25	<1	K3	88	480
392242078023001	03-07-90	7.7	0.30	9.6	6	<1	K7	K12	330	--
392254078063901	08-24-89	5.6	0.10	23	160	310	<1	<1	164	--
392259078085801	03-08-90	9.0	0.90	19	<3	25	<1	--	237	--
392306078042401	08-24-89	1.5	1.9	9.5	4	1	<1	<1	350	--
	03-08-90	3.9	1.0	9.6	11	1	<1	<1	369	--
392323078115701	03-08-90	1.0	<0.10	15	<3	13	<1	<1	125	--
392336077583401	03-07-90	4.2	0.30	29	1300	330	<1	<1	170	--
392353078030601	03-08-90	35	0.20	11	4	<1	<1	<1	420	--
392406078090301	08-23-89	25	0.10	18	5	23	<1	K1	202	--
392412078005401	08-23-89	33	0.10	12	5	<1	K2	K12	497	--
	03-07-90	15	0.20	13	6	<1	<1	<1	518	--
392423078051401	03-07-90	3.2	0.30	23	160	440	<1	<1	155	--
392436078015301	03-07-90	17	0.30	17	5	<1	<1	1	376	--
392437077545201	03-08-90	14	0.80	17	<3	12	<1	<1	412	--
392444078105301	08-23-89	2.3	0.10	19	100	690	<1	K1	118	--
392505077573101	08-23-89	40	<0.10	17	13	61	<1	K1	290	--
392514078002701	03-08-90	7.1	<0.10	14	6	<1	<1	<1	355	--
392526078082601	03-07-90	4.3	<0.10	32	3600	120	<1	<1	222	--
392527078021801	08-22-89	5.9	1.1	10	9	<1	K2	<1	380	--
392529078041901	03-07-90	23	0.30	15	4	16	<1	<1	185	--
392539077534601	08-23-89	7.9	0.10	10	7	<1	K1	K2	285	--
	03-08-90	15	<0.10	11	8	4	<1	<1	354	--
392601078094201	03-07-90	1.3	0.40	21	1300	1000	<1	<1	67	--
392605078030601	08-22-89	9.1	0.40	11	4	3	<1	K1	343	--
392612078042201	08-22-89	1.1	0.20	28	1400	470	<1	K2	118	--
392617077551301	08-23-89	47	0.10	8.5	4	<1	K430	160	537	--
	03-08-90	26	<0.10	8.8	110	33	K3	120	552	--
392621078074900	08-22-89	12	0.20	9.7	9	7	<1	<1	243	210
392630078000601	08-22-89	11	0.20	12	<3	<1	K2	K1	361	--
392642077514501	03-06-90	12	<0.10	13	16	3	<1	<1	440	--

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	TEMPERATURE WATER (DEG °C)	SPECIFIC CONDUCTANCE (µS/CM)	PH WATER WHOLE FIELD (STANDARD UNITS)	OXYGEN, DISSOLVED (MG/L)	BICARBONATE WATER DIS IT FIELD MG/L AS HCO3	CARBONATE WATER DIS IT FIELD MG/L AS CO3	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4)	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	NITROGEN, NITRITE DISSOLVED (MG/L AS N)
392704077530701	03-06-90	10.0	1050	6.7	1.0	475	0	<0.010	--	--	<0.010
392713078012901	03-09-90	11.0	1100	7.3	3.0	439	0	<0.010	--	0.410	0.020
392713078091801	08-23-89	13.0	68	5.7	0.7	337	0	0.020	0.03	--	<0.010
392714077595001	03-07-90	11.5	645	7.1	8.7	402	0	<0.010	--	--	<0.610
392725077524701	08-21-89	17.0	360	7.0	5.8	256	0	0.010	0.01	--	<0.010
392726078025001	03-06-90	12.0	440	7.7	7.4	229	0	<0.010	--	--	<0.010
392728077562501	03-06-90	12.0	340	7.0	0.8	158	0	0.010	0.01	--	<0.010
392748078065101	03-06-90	13.0	460	6.9	0.1	217	0	0.020	0.03	--	<0.010
392806077505501	08-22-89	14.5	410	6.8	6.5	360	0	0.020	0.03	--	<0.010
392812077593101	03-08-90	9.5	690	7.2	8.2	366	0	<0.010	--	--	<0.010
392814078020001	03-06-90	13.0	650	7.4	5.7	332	0	<0.010	--	--	<0.010
392823077553601	03-07-90	14.0	440	6.8	3.7	122	0	0.010	0.01	--	0.030
392827078022201	08-23-89	17.0	297	6.9	0.6	157	0	0.020	0.03	--	<0.010
392837077520401	03-07-90	9.0	650	7.0	5.5	329	0	<0.010	--	--	<0.010
392848077530601	08-22-89	16.0	450	6.8	6.0	372	0	<0.010	--	--	<0.010
	03-08-90	12.0	870	6.8	7.6	402	0	<0.010	--	--	<0.010
392902077595901	08-22-89	13.0	600	7.2	1.5	366	0	0.010	0.01	--	<0.010
392911078060101	08-22-89	14.0	390	7.4	4.6	177	0	0.170	0.22	--	<0.010
392911078071801	08-22-89	13.0	141	6.4	0.6	79	0	<0.010	--	--	<0.010
392924077504401	08-22-89	15.0	450	6.8	8.8	372	0	0.020	0.03	--	<0.010
392942077584301	08-23-89	14.0	450	6.8	8.5	415	0	0.020	0.03	--	<0.010
	03-08-90	12.0	730	7.0	8.7	390	0	<0.010	--	--	<0.010
393004077505601	03-06-90	10.5	2500	6.8	8.1	415	0	<0.010	--	--	<0.010
393021077551201	08-21-89	15.5	305	6.7	2.3	165	0	0.050	0.06	--	<0.010
393034077520301	08-22-89	15.0	420	6.4	8.7	341	0	0.020	0.03	--	<0.010
393040078042601	03-06-90	12.0	350	6.8	2.9	183	0	<0.010	--	--	<0.010
393055078000601	08-23-89	17.0	270	7.1	5.0	354	0	0.020	0.03	--	<0.010
393113078062501	03-06-90	12.0	264	7.1	0.2	158	0	0.030	0.04	--	<0.010
393116077502401	08-24-89	14.0	923	6.9	3.0	495	0	0.030	0.04	--	<0.010
	03-06-90	10.0	1300	6.7	1.0	536	0	<0.010	--	--	<0.010
393123077562201	08-23-89	14.0	350	6.9	8.7	311	0	0.010	0.01	--	<0.010
393125077583401	08-23-89	14.0	220	6.7	6.5	360	0	0.010	0.01	--	<0.010
	03-06-90	12.0	740	7.0	7.1	354	0	<0.010	--	--	<0.010
393201077544701	03-08-90	12.0	430	6.7	0.9	158	0	0.010	0.01	--	0.010
393213077594801	03-06-90	12.0	790	7.2	1.4	297	0	<0.010	--	--	<0.010
393242078023201	08-21-89	13.0	382	7.2	8.0	201	0	0.010	0.01	--	<0.010
393250078053301	08-22-89	13.0	122	6.7	0.6	60	0	<0.010	--	--	<0.010
393315077555601	08-23-89	16.0	500	6.9	7.5	299	0	0.020	0.03	--	<0.010
393358077544801	03-08-90	11.5	740	7.0	7.8	402	0	<0.010	--	--	<0.010
393405078024901	08-22-89	14.5	340	7.0	3.3	117	0	0.030	0.04	--	<0.010
393419077553601	08-22-89	15.5	350	6.9	8.0	226	0	0.030	0.04	--	<0.010
393424077572801	03-07-90	11.0	750	7.0	9.5	341	0	<0.010	--	--	<0.010
393434078043401	03-06-90	10.0	179	7.0	6.8	113	0	0.040	0.05	--	<0.010
393440078011601	03-05-90	12.5	250	6.8	5.1	82	0	<0.010	--	--	<0.010
393443078062101	08-22-89	14.0	200	6.7	0.3	113	0	<0.010	--	--	<0.010

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	PHOSPHORUS ORTHO, DISSOLVED (MG/L AS P)	HARDNESS TOTAL (MG/L AS CACO3)	HARDNESS NONCARB DISSOLV FLD. AS CACO3 (MG/L)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	SULFATE DISSOLVED (MG/L AS SO4)
392704077530701	03-06-90	11.0	<0.010	470	84	170	12	3.1	4.5	56
392713078012901	03-09-90	0.430	<0.010	380	19	99	32	39	1.8	44
392713078091801	08-23-89	<0.100	<0.010	20	0	2.4	3.3	4.5	0.60	3.0
392714077595001	03-07-90	3.00	<0.010	340	15	100	23	5.7	1.9	14
392725077524701	08-21-89	2.40	<0.010	260	51	83	13	3.5	1.3	10
392726078025001	03-06-90	1.50	<0.010	220	36	55	21	8.5	1.8	24
392728077562501	03-06-90	<0.100	<0.010	150	21	42	11	8.3	0.90	28
392748078065101	03-06-90	<0.100	<0.010	220	44	80	5.3	7.5	0.50	21
392806077505501	08-22-89	4.90	<0.010	310	17	110	9.1	3.9	1.7	21
392812077593101	03-08-90	4.60	<0.010	330	26	96	21	21	2.0	25
392814078020001	03-06-90	1.70	<0.010	320	51	80	30	20	1.3	57
392823077553601	03-07-90	<0.100	<0.010	--	--	57	17	11	0.90	79
392827078022201	08-23-89	<0.100	<0.010	130	5	42	7.0	4.5	0.90	9.0
392837077520401	03-07-90	6.20	<0.010	310	44	110	9.6	3.1	1.1	12
392848077530601	08-22-89	4.60	<0.010	330	28	92	25	12	2.0	16
	03-08-90	5.00	0.010	400	69	110	30	15	1.9	24
392902077595901	08-22-89	0.960	<0.010	360	57	87	34	5.2	2.5	50
392911078060101	08-22-89	<0.100	<0.010	170	29	55	9.0	7.2	0.50	43
392911078071801	08-22-89	<0.100	<0.010	48	0	6.0	8.0	8.5	0.80	3.0
392924077504401	08-22-89	4.00	0.010	320	19	110	12	4.8	14	29
392942077584301	08-23-89	2.90	<0.010	340	4	100	23	6.9	1.7	15
	03-08-90	2.60	<0.010	340	24	98	24	4.4	1.6	16
393004077505601	03-06-90	0.870	<0.010	580	240	210	13	170	1.3	22
393021077551201	08-21-89	0.580	0.010	190	56	55	13	8.5	0.90	55
393034077520301	08-22-89	<0.100	<0.010	310	33	110	9.2	2.9	0.60	20
393040078042601	03-06-90	2.40	0.030	180	31	56	10	5.9	1.0	11
393055078000601	08-23-89	5.90	<0.010	290	3	78	24	7.6	19	42
393113078062501	03-06-90	<0.100	<0.010	110	0	30	8.3	15	0.30	2.1
393116077502401	08-24-89	2.70	<0.010	460	51	150	20	19	1.5	35
	03-06-90	3.70	<0.010	490	55	160	23	31	1.5	31
393123077562201	08-23-89	6.10	<0.010	280	22	93	11	2.7	1.3	10
393125077583401	08-23-89	7.00	<0.010	350	50	92	28	7.8	3.3	28
	03-06-90	6.40	<0.010	350	61	93	29	7.1	2.5	25
393201077544701	03-08-90	<0.100	<0.010	190	56	53	13	7.0	0.80	58
393213077594801	03-06-90	0.300	<0.010	390	150	100	34	18	0.50	180
393242078023201	08-21-89	2.10	0.060	170	8	63	3.7	4.4	2.5	10
393250078053301	08-22-89	<0.100	<0.010	40	0	7.8	5.1	6.6	0.50	4.0
393315077555601	08-23-89	8.70	<0.010	330	81	120	6.4	38	2.3	21
393358077544801	03-08-90	1.30	<0.010	370	36	120	16	4.1	2.4	17
393405078024901	08-22-89	6.90	0.050	140	44	47	5.4	6.7	2.0	13
393419077553601	08-22-89	6.10	<0.010	200	13	65	8.7	2.9	7.3	6.0
393424077572801	03-07-90	8.20	<0.010	350	67	96	26	4.4	2.6	29
393434078043401	03-06-90	<0.100	0.020	--	--	16	7.8	14	0.60	6.9
393440078011601	03-05-90	<0.100	0.020	81	13	17	9.3	8.9	0.80	25
393443078062101	08-22-89	<0.100	<0.010	81	0	16	10	7.6	0.80	4.0

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	IRON, DISSOLVED (µG/L AS FE)	MANGANESE, DISSOLVED (µG/L AS MN)	COLIFORM, FECAL, 0.7 UM-MF (COLS./100 ML)	STREPTOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	RADON 222 TOTAL (PCI/L)
392704077530701	03-06-90	4.0	0.10	12	3	180	<1	<1	512	--
392713078012901	03-09-90	57	0.60	9.9	12	2	<1	<1	502	--
392713078091801	08-23-89	1.4	0.10	19	720	990	<1	<1	44	--
392714077595001	03-07-90	7.9	0.40	12	19	<1	<1	<1	384	--
392725077524701	08-21-89	9.0	0.10	11	10	<1	<1	<1	--	430
392726078025001	03-06-90	10	0.30	8.7	7	2	38	K8	252	--
392728077562501	03-06-90	5.9	0.20	26	300	490	<1	<1	168	--
392748078065101	03-06-90	26	<0.10	17	3500	80	<2	<2	284	--
392806077505501	08-22-89	9.3	0.10	11	8	1	K1	<1	279	--
392812077593101	03-08-90	35	<0.10	12	<3	<1	<1	<1	412	--
392814078020001	03-06-90	13	0.20	11	11	2	<2	<2	389	--
392823077553601	03-07-90	39	0.40	30	1100	420	<1	<1	346	--
392827078022201	08-23-89	3.8	0.10	22	1900	250	<1	K1	156	--
392837077520401	03-07-90	12	0.20	12	7	<1	<1	K1	356	--
392848077530601	08-22-89	23	0.10	8.3	6	<1	<1	K8	380	--
	03-08-90	30	<0.10	9.3	<3	<1	<1	<1	457	--
392902077595901	08-22-89	9.7	0.90	9.2	<3	<1	<1	K1	349	--
392911078060101	08-22-89	0.90	0.20	20	720	41	<1	<1	222	--
392911078071801	08-22-89	0.70	0.20	19	740	370	<1	K5	77	--
392924077504401	08-22-89	8.0	0.10	11	10	2	<1	<1	388	--
392942077584301	08-23-89	17	0.20	14	<3	<1	<1	K2	293	--
	03-08-90	9.0	0.20	14	<3	<1	<1	<1	368	--
393004077505601	03-06-90	420	0.20	11	13	<1	<1	<1	435	--
393021077551201	08-21-89	9.5	0.10	22	220	320	<1	400	270	--
393034077520301	08-22-89	5.7	0.20	7.6	14	3	<1	<1	227	--
393040078042601	03-06-90	5.9	<0.10	11	13	<1	<2	<2	205	--
393055078000601	08-23-89	12	0.20	11	9	<1	<1	<1	497	--
393113078062501	03-06-90	1.0	0.10	22	590	330	<2	<2	159	--
393116077502401	08-24-89	33	0.20	10	5	<1	<1	<1	560	--
	03-06-90	59	0.10	11	68	2	<1	<1	623	--
393123077562201	08-23-89	7.4	0.10	10	5	<1	<1	<1	278	--
393125077583401	08-23-89	13	0.30	10	<3	<1	K1	<1	365	--
	03-06-90	15	0.20	10	7	1	<1	<1	398	--
393201077544701	03-08-90	14	0.80	19	390	320	<1	<1	254	--
393213077594801	03-06-90	7.5	0.30	12	53	77	<2	<2	547	--
393242078023201	08-21-89	7.7	0.10	6.1	18	<1	K5	900	205	500
393250078053301	08-22-89	0.80	0.20	22	450	320	<1	<1	71	--
393315077555601	08-23-89	94	0.10	9.6	8	<1	27	160	514	--
393358077544801	03-08-90	10	0.10	12	10	1	<1	K1	405	--
393405078024901	08-22-89	10	<0.10	6.8	23	23	K14	K480	179	640
393419077553601	08-22-89	6.1	0.20	11	<3	<1	<1	<1	253	--
393424077572801	03-07-90	7.8	0.30	12	9	<1	<1	<1	404	--
393434078043401	03-06-90	2.7	<0.10	26	1400	430	<2	<2	119	--
393440078011601	03-05-90	1.3	0.30	32	84	59	<1	<1	135	--
393443078062101	08-22-89	0.80	0.20	15	680	120	<1	<1	102	670

STATION NUMBER	DATE	TEMPER-ATURE WATER (DEG °C)	SPE-CIFIC CON-DUCT-ANCE (µS/CM)	PH WATER WHOLE FIELD (STAND-ARD UNITS)	OXYGEN, DIS-SOLVED (MG/L)	BICAR-BONATE WATER DIS IT FIELD MG/L AS HCO3	CAR-BONATE WATER DIS IT FIELD MG/L AS CO3	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS NH4)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)
393448077543301	03-08-90	12.0	645	7.1	8.5	390	0	<0.010	--	--	<0.010
393450077510801	08-22-89	14.0	165	6.0	1.0	67	0	0.030	0.04	--	<0.010
393505077571201	08-23-89	17.0	420	6.8	8.5	323	0	0.020	0.03	--	<0.010
393507077593201	08-21-89	15.0	180	7.0	1.3	73	0	<0.010	--	--	<0.010
393531077525201	03-07-90	10.0	270	6.5	1.3	98	0	<0.010	--	--	<0.010
393542077545401	08-22-89	15.0	300	7.0	8.5	207	0	<0.010	--	--	<0.010
393546078032401	03-05-90	12.0	246	7.4	3.2	113	0	<0.010	--	--	<0.010
393621077502401	03-07-90	12.0	170	5.6	5.7	37	0	0.030	0.04	2.28	0.020
393626078015101	08-21-89	13.0	275	7.1	1.9	106	0	0.030	0.04	--	<0.010
393649077525201	08-22-89	15.5	430	6.9	4.0	396	0	<0.010	--	--	<0.010
391950078032900	08-24-89	13.0	640	7.0	7.1	350	0	0.030	0.04	--	<0.010
391956078062600	08-23-89	13.0	575	7.0	5.8	296	0	0.020	0.03	--	<0.010
392124078050501	03-29-89	12.5	660	6.8	7.6	368*	0*	0.010	0.01	--	<0.010
	06-20-89	11.5	623	7.1	8.1	354	0	<0.010	--	--	<0.010
	10-03-89	12.0	578	7.2	8.0	3	0	<0.010	--	--	<0.010
	12-19-89	12.0	670	7.3	8.0	383	0	0.040	0.05	--	<0.010
	03-06-90	11.5	640	7.2	7.2	358	0	<0.010	--	--	<0.010
392241078011901	08-24-89	13.0	680	7.1	4.8	358	0	0.030	0.04	--	<0.010
392333077550500	08-24-89	12.0	585	7.0	7.7	316	0	0.030	0.04	--	<0.010
392359078063901	08-23-89	13.5	335	7.5	4.9	202	0	0.010	0.01	--	<0.010
392431078035101	08-23-89	11.5	605	7.1	7.3	339	0	0.020	0.03	--	<0.010
392534077591401	03-07-90	12.5	610	7.0	7.6	378	0	<0.010	--	--	<0.010
392536077591301	08-24-89	13.0	670	6.8	6.1	341	0	0.020	0.03	--	<0.010
392550078021300	03-28-89	11.5	645	7.1	8.8	306*	0*	0.020	0.03	--	<0.010
	10-03-89	14.5	695	7.1	5.8	290	0	<0.010	--	--	<0.010
	12-19-89	11.5	705	7.4	7.2	367	0	0.040	0.05	--	<0.010
	03-05-90	9.0	750	7.0	8.5	317	0	0.020	0.03	--	<0.010
	06-21-89	12.0	645	7.0	6.6	308	0	<0.010	--	--	<0.010
392619077541200	03-30-89	12.0	660	6.7	8.0	351*	0*	0.020	0.03	--	<0.010
	10-02-89	13.0	730	7.1	6.3	280	0	0.020	0.03	--	<0.010
	12-18-89	11.0	670	7.2	7.5	385	0	0.060	0.08	--	<0.010
	03-05-90	12.0	750	6.8	7.0	329	0	<0.010	--	--	<0.010
	06-21-89	11.5	670	6.4	5.9	358	0	<0.010	--	--	<0.010
392717077530901	08-23-89	11.5	610	7.1	5.3	329	0	0.020	0.03	--	<0.010
392723078103900	03-29-89	8.5	51	4.4	7.8	0*	0*	<0.010	--	--	<0.010
	10-03-89	11.5	43	5.0	4.8	--	--	0.010	0.01	--	<0.010
	12-19-89	9.5	37	5.1	5.8	--		0.030	0.04	--	<0.010
	03-07-90	8.0	38	5.0	6.3	0	0	<0.010	--	--	<0.010
	06-21-89	10.5	39	4.5	6.8	0	0	<0.010	--	--	<0.010
392748078003202	08-22-89	12.5	625	7.1	8.0	337	0	<0.010	--	--	<0.010
392907078013501	03-07-90	11.0	345	6.9	6.3	176	0	<0.010	--	--	<0.010
392950078004601	03-08-90	12.0	750	6.9	7.5	366	0	<0.010	--	--	<0.010
393038078081601	03-06-90	6.5	65	4.6	8.1	0	0	<0.010	--	--	<0.010
393116077535201	08-21-89	22.0	360	7.2	10.7	244	0	0.100	0.13	1.48	0.020
	03-06-90	9.5	500	7.1	10.4	207	0	--	--	--	--

Bicarbonate and carbonate determinations were made on whole water samples rather than dissolved (filtered) water samples.

STATION NUMBER	DATE	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS NONCARB DISSOLV FLD. AS CACO3 (MG/L)	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)	SULFATE DIS-SOLVED (MG/L AS SO4)
393448077543301	03-08-90	7.20	<0.010	340	17	110	15	3.9	2.0	19
393450077510801	08-22-89	<0.100	<0.010	61	6	11	8.1	9.3	0.80	20
393505077571201	08-23-89	4.90	0.010	320	55	87	25	4.6	2.2	38
393507077593201	08-21-89	<0.100	<0.010	60	0	16	4.9	7.5	0.70	15
393531077525201	03-07-90	0.290	<0.010	110	26	26	10	7.2	0.10	30
393542077545401	08-22-89	3.70	<0.010	190	21	67	5.6	4.6	3.0	5.0
393546078032401	03-05-90	<0.100	0.010	--	--	29	9.0	8.1	0.50	19
393621077502401	03-07-90	2.30	<0.010	61	30	12	7.5	6.5	0.90	33
393626078015101	08-21-89	<0.100	0.010	100	15	27	8.5	8.9	0.50	28
393649077525201	08-22-89	3.90	<0.010	330	6	73	36	5.6	1.6	14
391950078032900	08-24-89	3.10	<0.010	320	30	99	17	6.1	2.1	22
391956078062600	08-23-89	5.90	<0.010	280	40	72	25	2.8	1.9	25
392124078050501	03-29-89	6.10	<0.010	360	--	93	30	4.0	2.3	26
	06-20-89	5.70	<0.010	350	60	91	30	3.2	2.4	25
	10-03-89	5.70	<0.010	350	340	91	29	3.5	2.4	26
	12-19-89	5.90	<0.010	350	35	92	29	3.9	2.2	26
	03-06-90	5.90	<0.010	360	64	92	31	3.7	2.1	25
392241078011901	08-24-89	3.50	0.010	330	39	110	14	11	1.7	17
392333077550500	08-24-89	5.40	0.020	310	50	110	8.4	4.4	1.6	18
392359078063901	08-23-89	0.110	0.010	170	3	59	5.3	1.8	0.70	4.0
392431078035101	08-23-89	5.30	<0.010	320	41	80	29	2.8	2.0	21
392534077591401	03-07-90	4.80	0.040	--	--	110	19	12	2.2	27
392536077591301	08-24-89	3.90	0.030	320	44	110	12	11	2.4	23
392550078021300	03-28-89	5.50	<0.010	310	--	81	25	11	2.1	40
	10-03-89	9.30	<0.010	360	120	97	28	10	3.5	40
	12-19-89	7.20	<0.010	350	52	95	28	12	2.6	40
	03-05-90	7.80	<0.010	330	73	89	27	11	2.0	33
	06-21-89	8.30	<0.010	320	72	87	26	9.3	2.9	37
392619077541200	03-30-89	5.40	0.010	350	--	120	13	4.9	2.0	29
	10-02-89	5.80	0.010	340	110	120	10	4.8	2.4	28
	12-18-89	5.60	0.010	350	29	120	11	5.2	2.0	29
	03-05-90	6.20	<0.010	--	--	120	12	5.3	1.4	22
	06-21-89	7.30	<0.010	350	55	120	12	4.9	2.3	26
392717077530901	08-23-89	5.40	<0.010	320	50	110	11	4.5	1.7	25
392723078103900	03-29-89	0.550	<0.010	12	--	3.0	0.99	3.2	0.80	5.5
	10-03-89	0.700	<0.010	9	--	1.8	1.1	1.8	1.0	5.0
	12-19-89	0.570	<0.010	7	--	1.5	0.84	2.1	0.80	4.0
	03-07-90	0.570	<0.010	7	--	1.5	0.87	1.8	0.90	3.9
	06-21-89	0.660	<0.010	8	--	1.4	1.0	1.8	0.90	4.0
392748078003202	08-22-89	4.20	<0.010	320	48	92	23	5.2	2.7	27
392907078013501	03-07-90	1.20	<0.010	--	--	40	18	3.5	1.0	17
392950078004601	03-08-90	6.20	<0.010	360	61	100	27	3.7	1.0	31
393038078081601	03-06-90	2.40	<0.010	18	--	4.2	1.9	0.80	0.80	13
393116077535201	08-21-89	1.50	0.010	240	44	86	7.1	12	1.6	39
	03-06-90	--	--	210	43	73	7.5	9.0	1.1	38

STATION NUMBER	DATE	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	IRON, DISSOLVED (µG/L AS FE)	MANGANESE, DISSOLVED (µG/L AS MN)	COLIFORM, FECAL, 0.7 UM-MF (COLS./100 ML)	STREPTOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	RADON 222 TOTAL (PCI/L)
393448077543301	03-08-90	14	0.10	13	<3	<1	<1	<1	402	--
393450077510801	08-22-89	2.1	0.20	32	1800	720	<1	24	104	--
393505077571201	08-23-89	9.2	0.30	11	9	<1	<1	K12	350	--
393507077593201	08-21-89	1.3	0.10	16	7	14	<1	K2	106	--
393531077525201	03-07-90	6.6	0.30	27	230	350	<1	K10	158	--
393542077545401	08-22-89	10	0.10	12	3	<1	<1	<1	218	--
393546078032401	03-05-90	3.8	0.50	22	9	6	<1	<1	149	--
393621077502401	03-07-90	3.8	0.30	17	12	6	<1	<1	111	--
393626078015101	08-21-89	2.3	0.20	24	25	25	<1	K2	163	--
393649077525201	08-22-89	6.8	0.70	8.5	10	2	<1	<1	276	--
391950078032900	08-24-89	11	0.20	10	5	<1	K2	K2	345	--
391956078062600	08-23-89	6.8	0.30	9.3	<3	<1	<1	K6	302	150
392124078050501	03-29-89	7.2	0.30	12	<3	<1	K2	K2	365	--
	06-20-89	6.5	0.40	12	7	<1	K18	K12	366	410
	10-03-89	6.5	0.30	12	7	<1	0	0	344	--
	12-19-89	6.3	0.30	12	12	4	K3	K2	387	--
	03-06-90	7.4	0.30	12	4	1	<2	<2	392	--
392241078011901	08-24-89	21	0.20	12	<3	2	K13	K33	380	--
392333077550500	08-24-89	10	0.20	9.8	4	1	39	150	339	--
392359078063901	08-23-89	0.90	0.10	11	3	<1	<1	K10	183	--
392431078035101	08-23-89	4.3	0.40	11	<3	<1	K2	K58	339	--
392534077591401	03-07-90	16	0.30	10	<3	<1	K23	K10	415	--
392536077591301	08-24-89	20	0.20	11	5	<1	39	K19	273	--
392550078021300	03-28-89	15	0.20	9.5	6	2	K2	K7	336	--
	10-03-89	12	0.20	12	8	<1	210	360	382	--
	12-19-89	16	0.20	11	<3	<1	47	K1	408	--
	03-05-90	10	0.30	10	6	<1	<3	<3	408	--
	06-21-89	11	0.30	11	5	5	<2	K11	358	1300
392619077541200	03-30-89	11	0.10	10	5	2	K1200	K1200	364	--
	10-02-89	11	0.10	11	11	<1	47	870	391	--
	12-18-89	11	0.10	11	3	1	K7	K2	388	--
	03-05-90	7.0	0.40	11	4	<1	K3	K7	410	--
	06-21-89	12	0.10	11	<3	<1	K17	K16	369	880
392717077530901	08-23-89	11	0.10	9.9	5	1	K7	K12	200	--
392723078103900	03-29-89	6.7	<0.10	4.8	12	64	<1	<1	22	--
	10-03-89	3.4	<0.10	5.9	45	48	2	71	32	--
	12-19-89	3.7	<0.10	5.7	42	54	<1	<1	26	--
	03-07-90	4.0	0.40	5.4	29	50	<2	<2	18	--
	06-21-89	3.9	0.10	5.5	17	52	190	K820	11	1600
392748078003202	08-22-89	9.7	0.30	11	<3	<1	<1	K1	360	--
392907078013501	03-07-90	3.4	0.30	9.7	9	2	<1	<1	194	--
392950078004601	03-08-90	11	0.20	12	<3	<1	<3	<3	414	--
393038078081601	03-06-90	1.8	<0.10	5.6	38	63	<2	<2	43	--
393116077535201	08-21-89	14	0.20	7.4	9	78	1700	600	300	--
	03-06-90	13	0.10	6.7	11	25	K31	K45	261	--

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	TEMPER-ATURE WATER (DEG °C)	SPE-CIFIC CON-DUCT-ANCE (μS/CM)	PH WATER WHOLE FIELD (STAND-ARD UNITS)	OXYGEN, DIS-SOLVED (MG/L)	BICAR-BONATE WATER DIS IT FIELD MG/L AS HCO3	CAR-BONATE WATER DIS IT FIELD MG/L AS CO3	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS NH4)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)
393128077554700	03-30-89	12.5	--	6.8	8.2	397*	0*	0.020	0.03	--	<0.010
	06-22-89	12.0	745	6.7	8.0	383*	0*	.010	--	--	<0.010
	12-19-89	11.0	780	7.2	5.8	380	0	0.040	0.05	--	<0.010
	03-05-90	12.0	930	6.7	6.8	366	0	<0.010	--	--	<0.010
	10-02-89	12.5	800	7.2	5.8	300	0	0.010	0.01	--	<0.010
393138078031600	08-21-89	13.0	460	7.2	7.2	239	0	0.010	0.01	--	<0.010
393143078083101	08-22-89	18.0	28	5.3	2.5	4	0	0.010	0.01	--	<0.010
393252077572000	03-08-90	12.0	720	7.0	8.2	488	0	<0.010	--	--	<0.010
393302077582900	08-23-89	16.0	360	6.9	15.5	268	0	0.020	0.03	3.74	0.060
393334078031800	03-29-89	12.0	420	6.8	7.8	246*	0*	<0.010	--	--	<0.010
	10-03-89	12.0	405	7.3	7.4	190	0	<0.010	--	--	<0.010
	12-20-89	12.0	395	7.4	7.2	241	0	0.030	0.04	--	<0.010
	03-05-90	12.5	420	7.3	6.8	244	0	<0.010	--	--	<0.010
	06-21-89	11.5	436	6.9	6.1	258	0	<0.010	--	--	<0.010
393335077582200	03-30-89	12.0	510	7.3	7.9	267*	0*	0.010	0.01	--	<0.010
	06-22-89	12.5	460	7.4	5.8	246*	0*	.010	--	--	<0.010
	12-18-89	11.5	510	7.4	6.0	271	0	0.030	0.04	--	<0.010
	03-05-90	11.5	570	6.9	6.5	280	0	<0.010	--	--	<0.010
	10-02-89	12.5	540	7.3	5.1	207	0	0.010	0.01	--	<0.010
393337077532900	08-21-89	13.0	450	6.8	7.7	347	0	0.020	0.03	--	<0.010

* Bicarbonate and carbonate determinations were made on whole water samples rather than dissolved (filtered) water samples.

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS NONCARB DISSOLV FLD. AS CACO3 (MG/L)	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)	SULFATE DIS-SOLVED (MG/L AS SO4)
393128077554700	03-30-89	3.10	<0.010	370	--	120	16	26	1.9	37
	06-22-89	2.70	<0.010	360	--	120	15	22	2.0	35
	12-19-89	3.50	<0.010	370	54	120	16	22	1.9	37
	03-05-90	3.40	<0.010	370	65	120	16	23	1.4	31
	10-02-89	3.20	<0.010	360	120	120	15	21	2.1	34
393138078031600	08-21-89	1.40	0.040	210	13	74	5.8	5.6	0.70	19
393143078083101	08-22-89	0.150	<0.010	6	3	1.0	0.87	0.80	1.1	5.0
393252077572000	03-08-90	5.70	<0.010	340	0	93	26	4.5	1.9	32
393302077582900	08-23-89	3.80	<0.010	270	45	65	25	2.9	2.2	21
393334078031800	03-29-89	0.810	<0.010	220	--	77	5.8	2.9	1.0	15
	10-03-89	0.670	<0.010	200	43	70	5.8	2.8	1.1	9.0
	12-20-89	0.560	<0.010	210	9	73	6.0	2.9	0.70	9.0
	03-05-90	0.650	<0.010	210	14	76	6.0	3.1	0.20	<1.0
	06-21-89	0.620	0.010	230	14	80	6.2	3.0	1.0	12
393335077582200	03-30-89	2.60	0.020	260	--	68	21	7.9	2.3	31
	06-22-89	2.20	<0.010	230	--	61	19	7.7	3.5	25
	12-18-89	3.60	<0.010	260	40	67	23	5.7	2.1	25
	03-05-90	3.20	<0.010	260	26	66	22	7.2	1.6	23
	10-02-89	4.10	<0.010	270	96	67	24	4.7	2.5	22
393337077532900	08-21-89	4.00	<0.010	310	23	100	14	5.4	1.6	18

Appendix B-1: Water-quality data values--Continued

STATION NUMBER	DATE	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	IRON, DISSOLVED (µG/L AS FE)	MANGANESE, DISSOLVED (µG/L AS MN)	COLIFORM, FECAL, 0.7 UM-MF (COLS./ 100 ML)	STREPTOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	RADON 222 TOTAL (PCI/L)
393128077554700	03-30-89	44	0.10	11	<3	<1	<1	K4	454	--
	06-22-89	36	0.20	11	<3	<1	K3	K11	448	--
	12-19-89	42	0.10	11	4	<1	<1	<32000	442	--
	03-05-90	39	0.20	11	5	<1	<3	<3	472	--
	10-02-89	35	0.10	11	6	<1	8	19	410	510
393138078031600	08-21-89	9.1	0.10	8.7	3	<1	K8	K570	259	440
393143078083101	08-22-89	1.3	<0.10	7.3	41	63	K4	K330	28	720
393252077572000	03-08-90	10	0.20	11	<3	<1	K17	K15	375	--
393302077582900	08-23-89	5.6	0.30	11	5	1	K3	62	274	--
393334078031800	03-29-89	4.2	0.10	7.4	10	3	K35	60	224	--
	10-03-89	3.3	0.10	8.2	8	2	3000	9000	186	--
	12-20-89	3.8	0.10	8.2	<3	1	K2	K1	221	--
	03-05-90	4.1	0.30	7.9	7	<1	<2	K3	241	--
	06-21-89	4.1	0.10	8.0	<3	<1	52	120	235	510
393335077582200	03-30-89	13	0.20	9.7	8	2	K16	120	274	--
	06-22-89	10	0.30	10	39	1	K4300	K12000	265	--
	12-18-89	10	0.30	11	13	4	43	K18	297	--
	03-05-90	8.1	0.30	10	9	2	K16	K10	299	--
	10-02-89	8.5	0.30	11	12	3	28	200	263	540
393337077532900	08-21-89	11	0.10	9.3	4	<1	K18	220	345	410

Appendix B-2: Chemical analyses for pesticides (includes PCB's and PCN's)

STATION NUMBER	DATE	DI-SYSTON TOTAL (µG/L)	PHORATE TOTAL (µG/L)	PRO-PAZINE TOTAL (µG/L)	TRI-FLURA-LIN TOTAL RECOVER (µG/L)	PER-THANE TOTAL (µG/L)	SIME-TRYNE TOTAL (µG/L)	DI-ELDRIN TOTAL (µG/L)	ENDO-SULFAN, TOTAL (µG/L)	ENDRIN WATER UNFLTRD REC (µG/L)
391809078044301	08-24-89	<0.01	<0.01	<0.10	<0.10	<0.1	<0.10	<0.001	<0.001	<0.001
392144078042401	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-06-90	--	--	--	--	--	--	--	--	--
392412078005401	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-07-90	--	--	--	--	--	--	--	--	--
392527078021801	08-22-89	<0.01	<0.01	--	--	<0.1	--	0.001	<0.001	<0.001
392605078030601	08-22-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	0.002
392617077551301	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-08-90	--	--	--	--	--	--	--	--	--
392630078000601	08-22-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
392713078091801	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
392725077524701	08-21-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
392848077530601	08-22-89	--	--	<0.10	<0.10	--	<0.10	--	--	--
	03-08-90	--	--	--	--	--	--	--	--	--
392902077595901	08-22-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
392942077584301	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-08-90	--	--	--	--	--	--	--	--	--
393055078000601	08-23-89	--	--	<0.10	<0.10	--	<0.10	--	--	--
393116077502401	08-24-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-06-90	--	--	--	--	--	--	--	--	--
393125077583401	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-06-90	--	--	--	--	--	--	--	--	--
393242078023201	08-21-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
393250078053301	08-22-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
393315077555601	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
393419077553601	08-22-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
393450077510801	08-22-89	--	--	<0.10	<0.10	--	<0.10	--	--	--
393649077525201	08-22-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
391950078032900	08-24-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
391956078062600	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
392124078050501	03-29-89	--	--	--	--	<0.1	--	0.011	<0.001	<0.001
	06-20-89	--	--	--	--	<0.1	--	0.003	<0.001	<0.001
	10-03-89	<0.01	<0.01	--	--	<0.1	--	0.015	<0.001	0.012
	12-19-89	<0.01	<0.01	--	--	<0.1	--	0.010	<0.001	<0.001
	03-06-90	<0.01	<0.01	--	--	<0.1	--	0.012	<0.001	0.015
392333077550500	08-24-89	<0.01	<0.01	<0.10	<0.10	<0.1	<0.10	<0.001	<0.001	<0.001
392431078035101	08-23-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
392550078021300	03-28-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
	10-03-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	12-19-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-05-90	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	06-21-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
392619077541200	03-30-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
	10-02-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	12-18-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001

Appendix B-2: Chemical analyses for pesticides--Continued

STATION NUMBER	DATE	ETHION, TOTAL (µG/L)	HEPTA-CHLOR, TOTAL (µG/L)	HEPTA-CHLOR EPOXIDE TOTAL (µG/L)	LINDANE TOTAL (µG/L)	TOX-APHENE, TOTAL (µG/L)	METH-OXY-CHLOR, TOTAL (µG/L)	PCB, TOTAL (µG/L)	MALA-THION, TOTAL (µG/L)	SIMA-ZINE TOTAL (µG/L)
391809078044301	08-24-89	<0.01	0.001	0.11	<0.001	<1	<0.01	<0.1	<0.01	0.10
392144078042401	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-06-90	--	--	--	--	--	--	--	--	--
392412078005401	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-07-90	--	--	--	--	--	--	--	--	--
392527078021801	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392605078030601	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392617077551301	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-08-90	--	--	--	--	--	--	--	--	--
392630078000601	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392713078091801	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392725077524701	08-21-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	0.01	--
392848077530601	08-22-89	--	--	--	--	--	--	--	--	0.10
	03-08-90	--	--	--	--	--	--	--	--	--
392902077595901	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392942077584301	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-08-90	--	--	--	--	--	--	--	--	--
393055078000601	08-23-89	--	--	--	--	--	--	--	--	<0.10
393116077502401	08-24-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-06-90	--	--	--	--	--	--	--	--	--
393125077583401	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-06-90	--	--	--	--	--	--	--	--	--
393242078023201	08-21-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
393250078053301	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
393315077555601	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
393419077553601	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
393450077510801	08-22-89	--	--	--	--	--	--	--	--	<0.10
393649077525201	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
391950078032900	08-24-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
391956078062600	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392124078050501	03-29-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	06-20-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	10-03-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	12-19-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-06-90	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392333077550500	08-24-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	0.10
392431078035101	08-23-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392550078021300	03-28-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	10-03-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	12-19-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-05-90	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	06-21-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392619077541200	03-30-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	10-02-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	12-18-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--

STATION NUMBER	DATE	PROMETONE TOTAL (μG/L)	PROMETRYNE TOTAL (μG/L)	NAPHTHALENES, POLYCHLOR. TOTAL (μG/L)	ALDRIN, TOTAL (μG/L)	CHLORDANE, TOTAL (μG/L)	DDD, TOTAL (μG/L)	DDE, TOTAL (μG/L)	DDT, TOTAL (μG/L)	PARATHION, TOTAL (μG/L)
391809078044301	08-24-89	<0.10	<0.10	<0.10	<0.001	0.1	<0.001	<0.001	<0.001	<0.01
392144078042401	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-06-90	--	--	--	--	--	--	--	--	--
392412078005401	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-07-90	--	--	--	--	--	--	--	--	--
392527078021801	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392605078030601	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392617077551301	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-08-90	--	--	--	--	--	--	--	--	--
392630078000601	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392713078091801	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392725077524701	08-21-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392848077530601	08-22-89	<0.10	<0.10	--	--	--	--	--	--	--
	03-08-90	--	--	--	--	--	--	--	--	--
392902077595901	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392942077584301	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-08-90	--	--	--	--	--	--	--	--	--
393055078000601	08-23-89	<0.10	<0.10	--	--	--	--	--	--	--
393116077502401	08-24-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-06-90	--	--	--	--	--	--	--	--	--
393125077583401	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-06-90	--	--	--	--	--	--	--	--	--
393242078023201	08-21-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393250078053301	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393315077555601	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393419077553601	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393450077510801	08-22-89	<0.10	<0.10	--	--	--	--	--	--	--
393649077525201	08-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
391950078032900	08-24-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
391956078062600	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392124078050501	03-29-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	06-20-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	10-03-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	12-19-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-06-90	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392333077550500	08-24-89	<0.10	<0.10	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392431078035101	08-23-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392550078021300	03-28-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	10-03-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	12-19-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-05-90	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	06-21-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392619077541200	03-30-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	10-02-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	12-18-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01

Appendix B-2: Chemical analyses for pesticides--Continued

STATION NUMBER	DATE	DI-AZINON, TOTAL (μG/L)	METHYL PARA-THION, TOTAL (μG/L)	ATRA-ZINE WATER UNFLTRD REC (μG/L)	MIREX, TOTAL (μG/L)	TOTAL TRI-THION (μG/L)	METHYL TRI-THION, TOTAL (μG/L)	ALA-CHLOR TOTAL RECOVER (μG/L)	CYAN-AZINE TOTAL (μG/L)	AME-TRYNE TOTAL
391809078044301	08-24-89	<0.01	<0.01	0.2	<0.01	<0.01	<0.01	<0.10	<0.10	<0.10
392144078042401	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-06-90	--	--	--	--	--	--	--	--	--
392412078005401	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-07-90	--	--	--	--	--	--	--	--	--
392527078021801	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392605078030601	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392617077551301	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-08-90	--	--	--	--	--	--	--	--	--
392630078000601	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392713078091801	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392725077524701	08-21-89	0.06	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392848077530601	08-22-89	--	--	0.3	--	--	--	<0.10	<0.10	<0.10
	03-08-90	--	--	--	--	--	--	--	--	--
392902077595901	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392942077584301	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-08-90	--	--	--	--	--	--	--	--	--
393055078000601	08-23-89	--	--	0.1	--	--	--	<0.10	<0.10	<0.10
393116077502401	08-24-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-06-90	--	--	--	--	--	--	--	--	--
393125077583401	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-06-90	--	--	--	--	--	--	--	--	--
393242078023201	08-21-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
393250078053301	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
393315077555601	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
393419077553601	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
393450077510801	08-22-89	--	--	<0.1	--	--	--	<0.10	<0.10	<0.10
393649077525201	08-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
391950078032900	08-24-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
391956078062600	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392124078050501	03-29-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	06-20-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	10-03-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	12-19-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-06-90	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392333077550500	08-24-89	<0.01	<0.01	0.9	<0.01	<0.01	<0.01	<0.10	0.10	<0.10
392431078035101	08-23-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392550078021300	03-28-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	10-03-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	12-19-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-05-90	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	06-21-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392619077541200	03-30-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	10-02-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	12-18-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--

Appendix B-2: Chemical analyses for pesticides--Continued

STATION NUMBER	DATE	DI-SYSTON TOTAL (μG/L)	PHORATE TOTAL (μG/L)	PRO-PAZINE TOTAL (μG/L)	TRI-FLURA-LIN TOTAL RECOVER (μG/L)	PER-THANE TOTAL (μG/L)	SIME-TRYNE TOTAL (μG/L)	DI-ELDRIN TOTAL (μG/L)	ENDO-SULFAN, TOTAL (μG/L)	ENDRIN WATER UNFLTRD REC (μG/L)
392619077541200	03-05-90	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	06-21-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
392748078003202	08-22-89	<0.01	<0.01	<0.10	<0.10	<0.1	<0.10	0.001	<0.001	0.005
393128077554700	03-30-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
	06-22-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
	12-19-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-05-90	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	10-02-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
393138078031600	08-21-89	--	--	<0.10	<0.10	--	<0.10	--	--	--
393302077582900	08-23-89	--	--	<0.10	<0.10	--	<0.10	--	--	--
393334078031800	03-29-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
	10-03-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	12-20-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-05-90	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	06-21-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
393335077582200	03-30-89	--	--	--	--	<0.1	--	<0.001	<0.001	<0.001
	06-22-89	--	--	--	--	<0.1	--	<0.001	0.010	<0.001
	12-18-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	03-05-90	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001
	10-02-89	<0.01	<0.01	--	--	<0.1	--	<0.001	<0.001	<0.001

STATION NUMBER	DATE	ETHION, TOTAL (μG/L)	HEPTA-CHLOR, TOTAL (μG/L)	HEPTA-CHLOR EPOXIDE TOTAL (μG/L)	LINDANE TOTAL (μG/L)	TOX-APHENE, TOTAL (μG/L)	METH-OXY-CHLOR, TOTAL (μG/L)	PCB, TOTAL (μG/L)	MALA-THION, TOTAL (μG/L)	SIMA-ZINE TOTAL (μG/L)
392619077541200	03-05-90	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	06-21-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
392748078003202	08-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	<0.10
393128077554700	03-30-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	06-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	12-19-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-05-90	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	10-02-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
393138078031600	08-21-89	--	--	--	--	--	--	--	--	<0.10
393302077582900	08-23-89	--	--	--	--	--	--	--	--	<0.10
393334078031800	03-29-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	10-03-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	12-20-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-05-90	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	06-21-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
393335077582200	03-30-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	06-22-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	12-18-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	03-05-90	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--
	10-02-89	<0.01	<0.001	<0.001	<0.001	<1	<0.01	<0.1	<0.01	--

Appendix B-2: Chemical analyses for pesticides--Continued

STATION NUMBER	DATE	PROME-TONE TOTAL (μG/L)	PROME-TRYNE TOTAL (μG/L)	NAPH-THA-LENES, POLY-CHLOR. TOTAL (μG/L)	ALDRIN, TOTAL (μG/L)	CHLOR-DANE, TOTAL (μG/L)	DDD, TOTAL (μG/L)	DDE, TOTAL (μG/L)	DDT, TOTAL (μG/L)	PARA-THION, TOTAL (μG/L)
392619077541200	03-05-90	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	06-21-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
392748078003202	08-22-89	<0.10	<0.10	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393128077554700	03-30-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	06-22-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	12-19-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-05-90	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	10-02-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393138078031600	08-21-89	<0.10	<0.10	--	--	--	--	--	--	--
393302077582900	08-23-89	<0.10	<0.10	--	--	--	--	--	--	--
393334078031800	03-29-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	10-03-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	12-20-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	03-05-90	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
	06-21-89	--	--	<0.10	<0.001	<0.1	<0.001	<0.001	<0.001	<0.01
393335077582200	03-30-89	--	--	<0.10	<0.001	<0.1	<0.001	0.004	0.003	<0.01
	06-22-89	--	--	<0.10	<0.001	<0.1	<0.001	0.002	<0.001	<0.01
	12-18-89	--	--	<0.10	<0.001	<0.1	<0.001	0.004	0.002	<0.01
	03-05-90	--	--	<0.10	<0.001	<0.1	<0.001	0.001	0.001	<0.01
	10-02-89	--	--	<0.10	<0.001	<0.1	<0.001	0.001	<0.001	<0.01

Appendix B-2: Chemical analyses for pesticides--Continued

STATION NUMBER	DATE	DI-AZINON, TOTAL (μG/L)	METHYL PARA-THION, TOTAL (μG/L)	ATRA-ZINE WATER UNFLTRD REC (μG/L)	MIREX, TOTAL (μG/L)	TOTAL TRI-THION (μG/L)	METHYL TRI-THION, TOTAL (μG/L)	ALA-CHLOR TOTAL RECOVER (μG/L)	CYAN-AZINE TOTAL (μG/L)	AME-TRYNE TOTAL
392619077541200	03-05-90	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	06-21-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
392748078003202	08-22-89	<0.01	<0.01	0.2	<0.01	<0.01	<0.01	<0.10	<0.10	<0.10
393128077554700	03-30-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	06-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	12-19-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-05-90	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	10-02-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
393138078031600	08-21-89	--	--	<0.1	--	--	--	<0.10	<0.10	<0.10
393302077582900	08-23-89	--	--	<0.1	--	--	--	<0.10	<0.10	<0.10
393334078031800	03-29-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	10-03-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	12-20-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-05-90	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	06-21-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
393335077582200	03-30-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	06-22-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	12-18-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	03-05-90	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--
	10-02-89	<0.01	<0.01	--	<0.01	<0.01	<0.01	--	--	--

Appendix C: Ground-water-level measurements from selected wells in Berkeley County, West Virginia, March 1989 to May 1990

Site no.	Variable date	04-25-89	05-09-89	05-25-89	06-13-89	07-12-89	08-08-89	09-13-89
	Date of ground-water-level measurements, in feet below land surface datum							
16	[2]25.46	28.49	26.05	25.60	30.94	30.10	31.32	32.89
[6]18	-	-	34.55	21.35	28.27	34.64	38.94	49.81
21	[1]25.70	26.17	23.91	21.10	22.55	24.50	26.10	26.85
30	[1]10.93	12.48	9.59	8.93	13.01	12.26	16.69	15.36
36	[2]32.98	36.82	32.94	28.73	36.00	39.58	37.46	40.11
[6]37	-	37.54	24.11	24.60	35.25	40.16	43.09	46.79
44	[2]28.61	31.55	30.48	27.22	30.78	30.17	31.02	32.92
50	[5]84.40	84.26	83.22	80.28	80.13	79.52	79.57	81.02
51	[4]42.89	43.82	41.30	34.36	37.40	41.96	45.81	50.26
53	[5]13.90	11.93	8.84	5.96	11.27	9.41	12.30	16.21
54	[5]28.01	27.80	20.58	18.19	28.33	25.09	29.41	33.19
55	[5]176.61	167.12	167.84	165.50	167.11	175.82	165.41	168.64
56	[5] 32.01	31.63	28.34	25.60	31.07	30.45	32.33	33.50
57	[2]29.25	29.98	18.22	23.34	30.64	30.72	31.11	31.73
59	[5]21.70	25.25	7.30	7.29	24.95	18.28	32.75	53.18
[6]70	[4]49.47	50.63	43.17	38.01	41.09	41.66	46.10	53.33
73	[2] 3.00	3.13	2.76	2.48	2.86	2.74	3.04	3.21
76	[4]35.80	36.13	33.51	31.28	34.43	35.85	36.68	37.62
80	[2] 7.38	9.07	5.69	6.36	8.74	8.89	10.58	12.58
82	[5]35.35	36.73	30.52	19.91	26.10	31.08	37.37	44.63
85	[2]21.81	23.37	21.93	21.69	22.91	22.11	24.35	29.21
86	[5]72.55	72.61	71.77	71.59	72.40	72.24	73.16	74.21
90	[4]12.41	13.18	9.68	10.77	11.40	23.80	11.83	12.84
98	[3]77.54	69.87	61.97	43.45	48.40	47.53	55.37	65.86
101	[3]95.47	96.63	92.54	90.15	93.18	94.66	95.90	99.17
103	[3]55.81	54.20	47.99	35.47	39.32	43.24	49.75	51.90
[6]106	[3]56.95	53.81	52.03	49.44	52.27	53.24	51.68	56.02
113	[5]32.43	32.61	30.91	30.86	32.43	31.98	34.35	35.98
115	[3]21.39	21.91	20.33	19.34	20.93	22.37	23.78	25.96
117	[3]84.27	84.22	84.02	80.70	79.45	78.33	76.99	77.50
120	[3]54.18	58.26	57.08	51.37	53.10	58.20	53.71	55.48

1- 03-21-89
2- 03-22-89
3- 03-23-89
4- 04-19-89
5- 04-20-89
6- These sites were equipped with continuous recorders and have hourly data available in the U.S. Geological Survey data base. The data presented here are measurements made when the recorders were serviced.

Appendix C: Ground-water-level measurements from selected wells in Berkeley County, West Virginia, March 1989 to May 1990--Continued

Site no.	Date of ground-water-level measurements, in feet below land surface datum						
	10-18-89	11-15-89	12-14-89	01-11-90	02-22-90	03-22-90	05-03-90
16	33.69	33.40	29.90	28.27	27.85	30.11	28.68
18	52.60	51.19	54.40	54.55	44.09	47.10	43.25
21	27.88	28.17	27.14	27.38	25.58	26.20	25.53
30	15.15	15.40	17.69	12.38	12.01	12.14	11.45
36	40.05	39.29	38.87	38.61	36.83	38.70	39.95
37	46.92	45.11	45.10	37.64	35.65	40.69	39.15
44	32.14	31.55	31.17	30.27	29.48	31.53	31.68
50	81.95	82.59	83.33	84.05	84.20	85.71	84.75
51	52.32	52.53	52.68	52.40	48.28	49.93	48.80
53	15.08	13.48	13.42	11.54	10.05	12.56	11.66
54	31.55	30.94	35.18	30.90	26.38	30.57	30.20
55	171.73	182.86	170.45	173.99	168.20	176.38	167.02
56	34.60	33.78	32.69	31.69	31.14	33.64	31.15
57	31.39	30.73	27.86	30.18	30.50	30.64	30.68
59	52.30	45.54	31.55	19.61	16.82	26.24	24.52
70	55.22	54.87	55.58	55.78	52.89	54.55	52.33
73	3.25	3.68	3.23	3.26	3.07	3.20	3.23
76	38.12	38.19	38.29	38.30	36.97	37.48	36.90
80	12.70	13.10	10.77	9.14	8.19	9.35	9.35
82	50.87	52.73	54.94	53.28	43.27	47.48	45.08
85	27.06	26.00	24.06	24.61	22.00	23.92	23.89
86	74.35	73.73	73.71	73.11	72.52	72.94	72.55
90	12.67	11.86	15.72	10.54	-	11.54	13.27
98	82.20	86.80	88.26	89.39	71.44	78.97	81.04
101	102.82	100.71	100.33	100.49	95.50	97.92	98.34
103	56.97	58.86	56.99	57.99	46.81	49.66	50.95
106	57.80	57.37	54.91	53.55	48.43	49.80	46.72
113	37.10	35.93	35.41	34.57	32.53	34.18	34.09
115	27.33	24.55	23.87	23.24	21.61	22.34	22.36
117	77.40	78.03	78.59	80.90	79.12	79.13	79.21
120	55.05	51.34	51.24	50.05	50.55	51.43	57.02