Geohydrology and Ground-Water Quality of Southern Canaan Valley, Tucker County, West Virginia

By Mark D. Kozar

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For addtional information write to:

District Chief
U.S. Geological Survey
11 Dunbar Street
Charleston, WV 25301

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

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
square foot (ft^2)	0.09290	square meter
foot squared per day (ft^2/d)	0.09290	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
gallons per day (gal/d)	0.003785	cubic meter per day
gallon per minute (gal/min)	0.00006309	cubic meter per second
million gallons (Mgal)	3,785	cubic meter
million gallons per year (Mgal/yr)	0.00012	cubic meter per second
million gallons per day per square mile ($Mgal/d/mi^2$)	9,803	cubic meter per day per square kilometer

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = 1.8(°C) + 32$$

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

Abbreviated water-quality units used in this report: Chemical concentration, temperature, and specific conductance are given in metric units. Chemical concentration is expressed in milligrams per liter (mg/L) or milliequivalents per liter (meq/L), except for iron, manganese, and pesticides, which are expressed in micrograms per liter (μg/L). The activity of the radon-222 radioactive isotope is expressed in picocuries per liter (pCi/L). Specific conductance is expressed in microsiemens per centimeter (μS/cm) at 25 degrees Celsius.

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Abstract

Canaan Valley is a popular recreation and retirement area in rural Tucker County, W.Va. The valley is underlain by carbonate and noncarbonate sedimentary rocks. Ground-water flow is primarily in joints, faults, bedding-plane partings, and other fractures in the rock.

Well yields are generally adequate for most domestic and commercial needs. The average yield of inventoried wells completed in the Pottsville/Mauch Chunk, Greenbrier, and Pocono aquifer zones were, respectively, 23.3, 22.5, and 19.2 gallons per minute. The ground-water recharge rate estimated for the southern part of the valley, based on discharge data for the gaging station at Cortland, is estimated to be about 0.9 million gallons per day per square mile. Approximately 10 percent of the water used in Canaan Valley is supplied from ground-water sources. An estimated 199.4 million gallons of surface water is withdrawn annually from the Blackwater River and its tributaries, whereas only 22 million gallons of ground water is withdrawn annually from aquifers within the valley. Commercial facilities serving skiers, hikers, campers, and other recreationalists withdraw 94 percent of all water used (208.3 million gallons annually). Only 6 percent is being withdrawn by residents of the valley for domestic use.

Fifty ground-water samples were collected and analyzed as part of the investigation. Most chemical constituents of water samples collected in Canaan Valley (including pesticides) did not exceed drinking-water standards established by the U.S. Environmental Protection Agency (USEPA). The constituents that commonly exceeded the drinking-water standards were fecal coliform and fecal streptococcus bacteria, radon, and manganese. Manganese concentrations exceeded USEPA secondary maximum contaminant levels (SMCL's) at 20 percent of the ground-water sites sampled, and iron concentrations exceeded SMCL's at only 2 percent of the sites. The most prevalent contaminants of concern are bacteria and radon. Fecal coliform bacteria were detected in samples from 22 percent of the sites, and concentrations of fecal streptococcus bacteria were detected at 48 percent of the sites. At 67 percent of 50 sites sampled for radon, concentrations (activity levels) exceeded the proposed USEPA maximum contaminant level (MCL) of 300 picocuries per liter.

INTRODUCTION

Canaan Valley is a small, oval basin in rural Tucker County, W. Va. (fig. 1). The northern half of the valley contains large tracts of undeveloped wetlands, and the southern half is devoted largely to recreation and tourism. State parks and ski resorts attract 1.2 million visitors to Canaan Valley each year (Chris MaClay, Tucker County Information Center, oral commun., 1993). The area is also a popular site for vacation and retirement homes. The population of Tucker County increased 16 percent between 1980 and 1990 (U.S. Bureau of the Census, 1991).

Future increases in population and commercial development could affect the availability and quality of water resources in Canaan Valley. For example, large volumes of water currently are withdrawn from the Blackwater River and its tributaries for snow making, golf course irrigation, and lodge and park

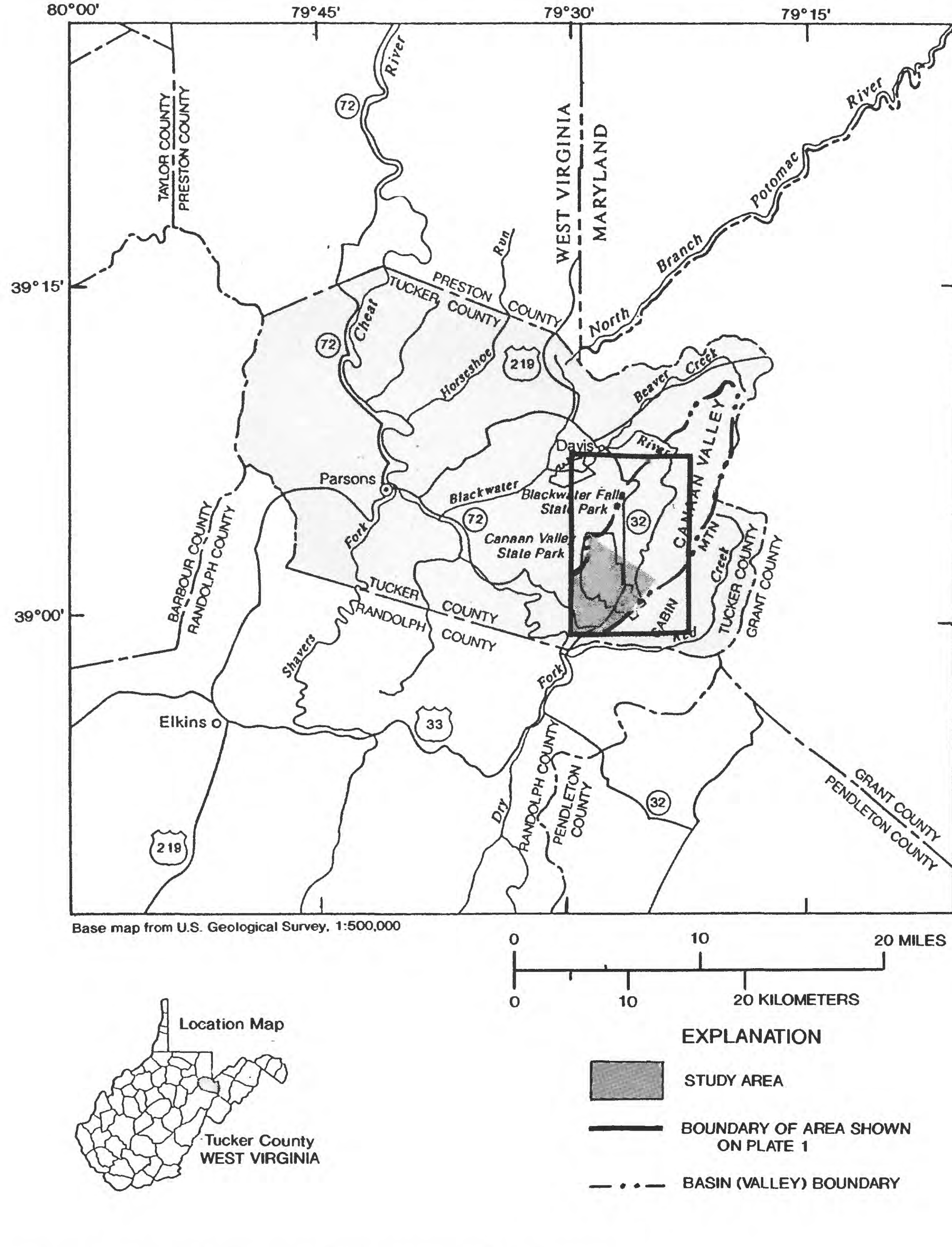

Figure 1. General location of Canaan Valley and study area.

operations. The consequences of increased water demands on the flow and quality of the Blackwater River are unknown. The first step toward predicting future effects of increased withdrawals on the hydrologic system is to understand the current state of the system. The geology of Canaan Valley was surveyed by Reger and others (1923), but a comprehensive survey of the water resources in the area has never been done.

In response to these needs, an investigation of the ground-water resources of Canaan Valley was done by the U.S. Geological Survey (USGS), in cooperation with the West Virginia Division of Environmental Protection, the West Virginia Geological and Economic Survey, and the Canaan Valley Task Force. A concurrent study of the surface-water resources is the subject of a separate USGS report.

Purpose and Scope

This report presents results of an investigation of ground-water resources in Canaan Valley. Specific topics discussed include the geohydrologic framework, aquifer characteristics, ground-water flow, water use, chemical characteristics of ground water, and factors that control ground-water quality.

Description of Study Area

Canaan Valley lies within an eroded anticline (fig. 2) in the Allegheny Mountain Section of the Appalachian Plateaus Physiographic Province. The study area includes approximately 24 mi^2 of the southern part of the valley. Canaan Valley is drained by the Blackwater River and its tributaries, which are part of the Cheat River drainage system. The Blackwater

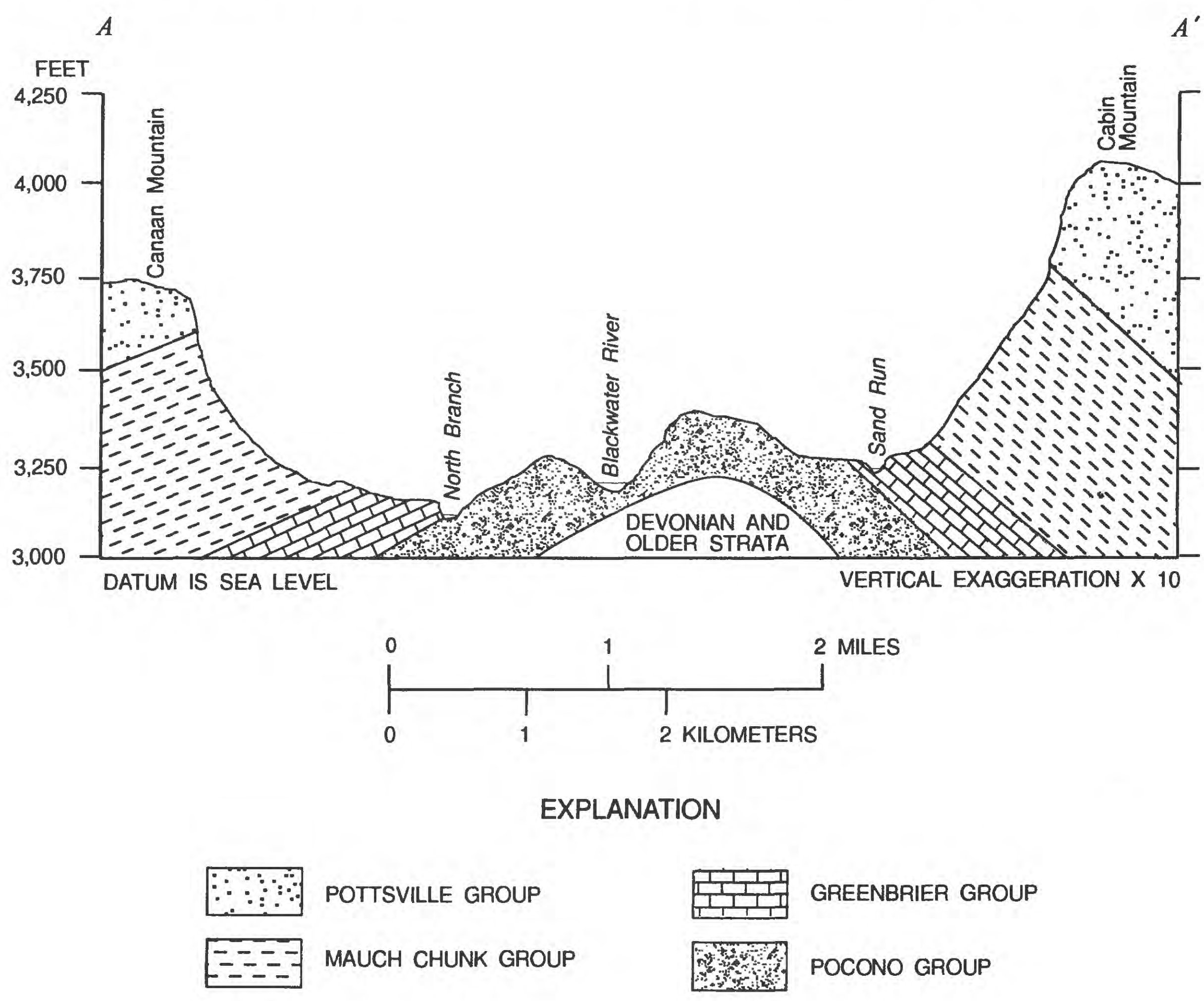

Figure 2. Generalized geologic section of Canaan Valley, West Virginia (location shown in fig. 3).

River begins in the southern part of the valley, flows northward, and exits the valley through a breach in the west valley wall of Canaan Mountain at Davis, W. Va. (fig. 3). Wetlands are present along some reaches of the streams and in scattered areas throughout the valley.

The eastern and western boundaries of the study area correspond to the drainage divides of the Blackwater River. Canaan Mountain forms the west boundary, and Cabin Mountain forms the east boundary (fig. 3). The northern boundary is defined by an arbitrary line (A–A′ in fig. 3) that crosses the valley perpendicular to the valley axis. The northern half of Canaan Valley (the part of the valley north of line A–A′ in fig. 3) is excluded from the study area because of a sparsity of wells and inaccessibility of the few wells that are available.

Acknowledgments

Technical aspects of the report were reviewed by Professors Henry W. Rauch and Joseph J. Donovan of the Geology Department, West Virginia University. The author thanks the residents of Canaan Valley who allowed access to their property for collection of water samples and measurement of water levels.

GEOHYDROLOGY

The availability and quality of ground water in Canaan Valley are controlled primarily by geologic structure and lithology, which differ significantly among the major geologic formations in the valley. Ground water is stored in and moves through a fairly shallow layer of fractured rock near the surface of all the geologic formations. All ground water in Canaan Valley originates from precipitation (rain and snow) falling in the valley, and ground water interacts in complex ways with surface water. Average annual precipitation, which is nearly constant over the entire valley, is a secondary factor affecting the hydrology of the area. Ground water in Canaan Valley flows within an intricate system of fractures composed of joints, faults, and bedding planes. As a result of the near-surface fracture system, ground water in Canaan Valley generally is under water-table (unconfined) conditions.

This section describes the geologic strata, structure, and fracture patterns that control ground-water movement and availability; interprets ground-water levels within each geologic unit in terms of the flow direction; and describes a conceptual model of ground-water flow in the valley. Characteristics of the geologic units that principally affect water quality are discussed in a later section.

Geohydrologic Framework

The oval-shaped (fig. 3), breached anticline (upward fold in the rocks) in which Canaan Valley is located has been described by Reger and others (1923). The average elevations of the valley floor and the surrounding ridges are approximately 3,200 and 3,900 ft above sea level, respectively. The valley area is underlain primarily by carbonate rocks of the Greenbrier Group[1], with outcrops of the more resistant sandstones of the Pocono Group near the center of the valley (fig. 3). Noncarbonate sandstones and shales of the Pottsville and Mauch Chunk Groups form the hillsides and ridges of the valley (fig 3). The bedrock is overlain by a discontinuous layer of unconsolidated deposits (weathered rock, alluvium, and wetland peat and clay), which ranges from 0 to approximately 30 ft in thickness.

The Pocono Group of Early Mississippian age overlies the Hampshire (Catskill) Formation and is the oldest geologic unit from which ground water is withdrawn in Canaan Valley. The Pocono crops out along a 2- by 7-mi area in the center of the valley. The thickness of the Pocono Group in Canaan Valley is 155 to 185 ft for measured sections near the study area. Its upper part is characterized by a 50- to 100-ft-thick pebbly zone, known as the Big Injun sand by drillers. The Pocono Group below the Big Injun sand is typified by slightly conglomeratic sandstones (Reger and others, 1923).

The Greenbrier Group of Early Mississippian age, which overlies the Pocono Group, is the most exposed unit in the lowland portion of the valley. The Greenbrier Group is composed of marine limestones separated by thin red or gray shales (Reger and others, 1923). These limestones are generally thinner and more siliceous in its upper part and thicker, more massive, and higher in carbonate composition in its basal part. Measured sections south of Canaan Valley indicate a total thickness of approximately 255 ft. Within the valley itself, the thickness ranges from a few

[1]The geologic names used within this report are those adopted by the West Virginia Geological and Economic Survey (Cardwell and others, 1968).

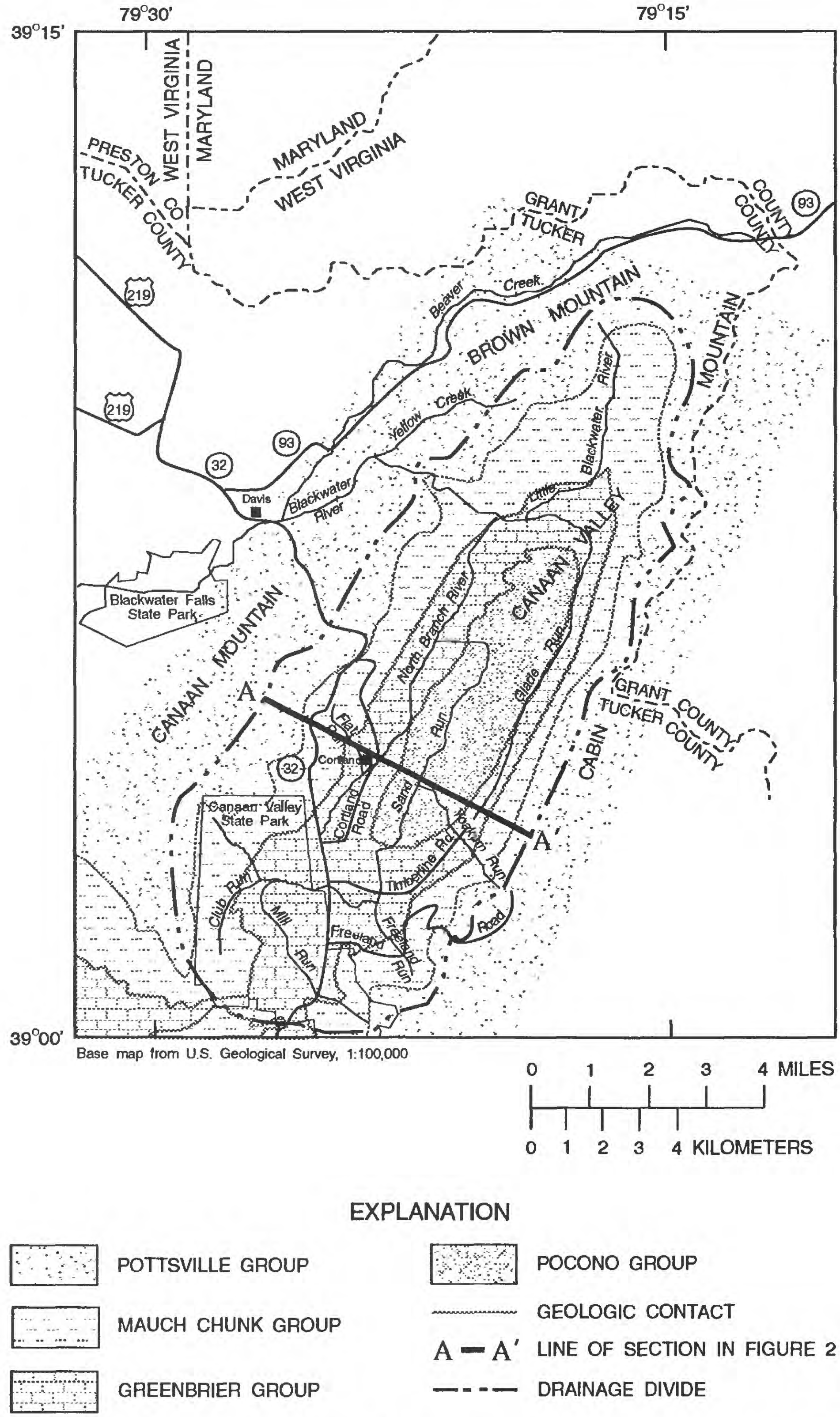

Figure 3. Generalized geology of Canaan Valley (from Reger and others, 1923, as modified by Fedorko, 1994).

inches near the Pocono-Greenbrier contact to an estimated 255 ft near the Mauch Chunk-Greenbrier contact.

The Mauch Chunk Group of Late Mississippian age directly overlies the Greenbrier Group. It is composed of red shales interbedded with thin, fine-grained sandstones (Reger and others, 1923). On the basis of measurements made within the valley, the thickness of the Mauch Chunk Group is estimated to be 700 ft. The Mauch Chunk forms the lower slopes of Canaan and Cabin Mountains. Colluvial deposits are commonly found at the base of Canaan and Cabin Mountains near the Mauch Chunk-Greenbrier contact.

The ridges of Canaan and Cabin Mountains are composed of sandstone, shale, and coal of the Pottsville Group of Early Pennsylvanian age. The Pottsville overlies the Mauch Chunk and is subdivided into an upper Kanawha Formation and lower New River Formation. Maximum measured thickness of the New River Formation is 225 ft. Much of the Kanawha Formation has been eroded and does not crop out in the study area. The New River Formation is characterized by massive gray sandstone units (pebbly in many places) and dark, sandy shales. Shales at the base of the New River Formation near the Mauch Chunk contact are reddish or greenish, similar to shales of the Mauch Chunk Group (Reger and others, 1923). The Pottsville and Mauch Chunk Groups have similar hydrologic properties and water-quality characteristics and therefore are treated as a single geohydrologic unit hereafter in this report.

All the geologic formations have been extensively fractured by tectonic stress and by isostatic rebound from stress relief caused by erosion of the core of the anticline. In general, fractures resulting from stress relief are not uniformly distributed. Fracture density is highest near the surface and decreases with depth (Wyrick and Borchers, 1981). Moreover, fracture density within the study area also appears to be highest in the center of valleys and lowest under hillsides and ridgetops, based on examination of fractures in bedrock outcrops and the locations of high-yielding wells. The presence of fractures within bedrock results in increased secondary permeability (Freeze and Cherry, 1979) and recharge. Ground water flows through a network of interconnected fractures (secondary porosity). The aquifer system within the valley consists of such a system of stress-relief and tensile fractures, joints, faults, and bedding planes (fig. 4).

Carbonate rocks are more easily dissolved by soil-derived acid than are noncarbonate rocks. Dissolution of carbonate rocks can result in increased secondary porosity and permeability (conduits) as fractures (bedding planes, joints, and faults) are enlarged by dissolution (Freeze and Cherry, 1979). Fractures have been enlarged by dissolution within the limestones of the Greenbrier Group, and several caverns have been documented (Davies, 1965). Thus, recharge is expected to be higher for the carbonate Greenbrier Group than for the noncarbonate Pottsville/Mauch Chunk and Pocono Groups.

Ground-Water Levels

Measurements of water levels in wells were used to describe water-level trends in each geologic unit and topographic setting, to prepare a potentiometric-surface map, and to relate hydrologic conditions during this investigation to long-term averages. Water-level data also were used to determine the change in ground-water storage during the investigation and to evaluate the hydraulic response of the aquifer to recharge and discharge. Hydraulic gradients from the potentiometric-surface map were then used to determine the directions of ground-water flow.

Water-level data (appendix E) were collected from 54 wells in June 1991 and were used to prepare the potentiometric-surface (water-table) map. Four continuous water-level recorders were operated in the valley during this investigation (fig. 5). The water level in observation well 1 (site 60 on plate 1) has been recorded continuously since 1980. Water-level recorders placed on three additional wells, observation wells 2, 3, and 4 (sites 62, 63, and 51), continuously measured water levels throughout this investigation. Although the aquifers in Canaan Valley are complex and wells typically intersect several water-bearing zones, the greatest porosity generally is in the upper part of the aquifers. Hydraulic head measured in open boreholes is probably a function of the water-bearing zone closest to the surface. Most of the water levels measured are from open boreholes with minimal casing lengths; therefore, these levels should be representative of water-table conditions.

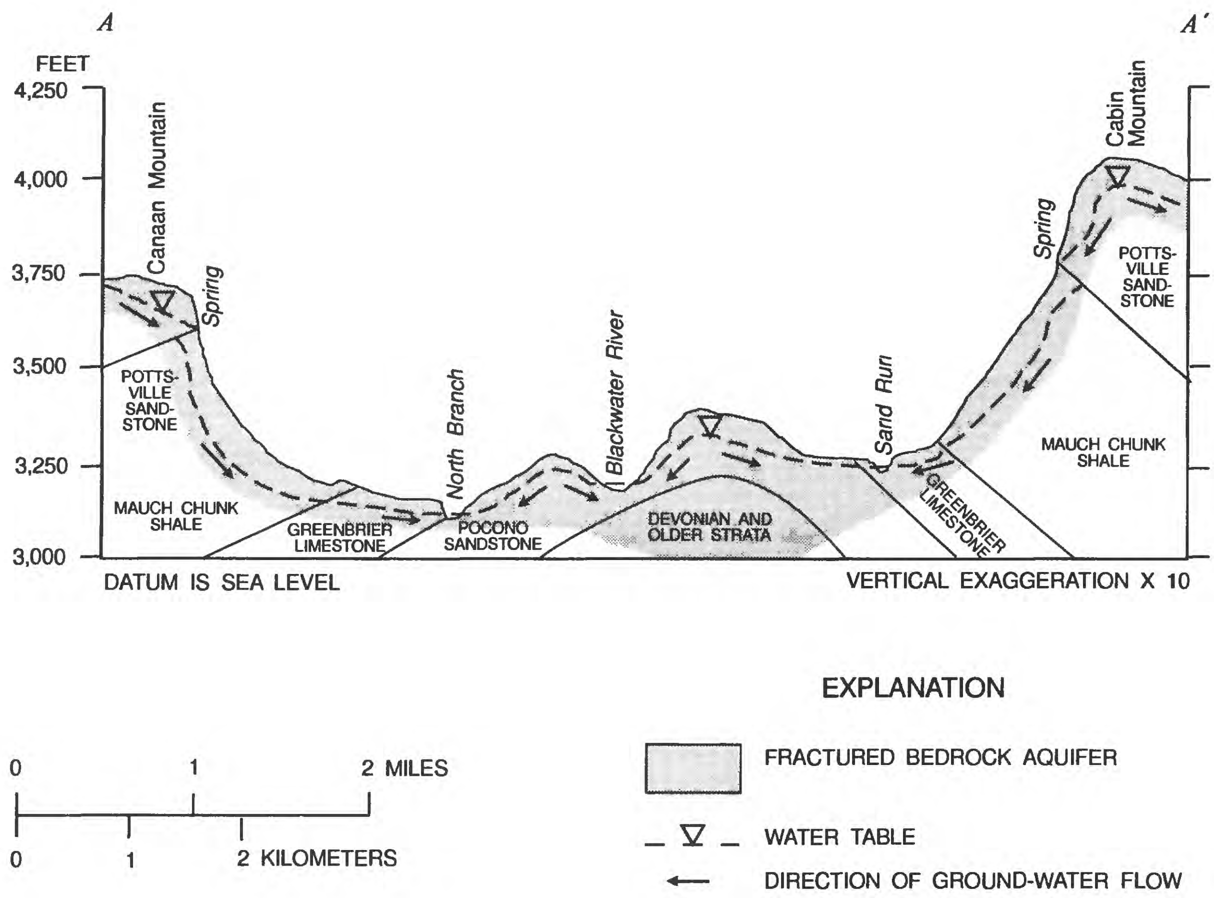

Figure 4. Idealized conceptual ground-water-flow model for Canaan Valley, West Virginia.

Changes in Ground-Water Levels

Water levels in the aquifers fluctuate in response to recharge, discharge, changes in evapotranspiration, and changes in the amount of water held in storage. Examination of water-level hydrographs for three wells completed in the carbonate Greenbrier Group and one well completed within Pottsville/Mauch Chunk bedrock reveal several distinct trends. Water-level response to precipitation is slightly more evident in the carbonate valley wells (wells 1, 2, and 3 in fig. 5) than in the noncarbonate ridgetop well (well 4 in fig. 5). The sharp peaks of the carbonate-well hydrographs indicate a quick response to precipitation, whereas the blunt, rounded peaks of the noncarbonate-well hydrograph indicate a slower recharge rate and a longer time for excess water to exit the area. Water levels in the carbonate Greenbrier Group respond faster to recharge from precipitation than do water levels in the noncarbonate Pottsville/Mauch Chunk and Pocono Groups, primarily because of greater secondary permeability.

Long-term records of water level can be used to describe local ground-water conditions in an area with respect to drought, flood, above-average snowfall, changes in land use, or changes in withdrawal rates from streams and (or) wells. Observation well 1 (fig. 6; site 60 on plate 1), which taps the Greenbrier Group, has been in operation since May 1980. The lowest water level recorded at this well during the 13 years of collected data was 11.79 ft below land surface, on August 21, 1987 (point A in fig. 6). Ground-water levels were similar in periods of drought in

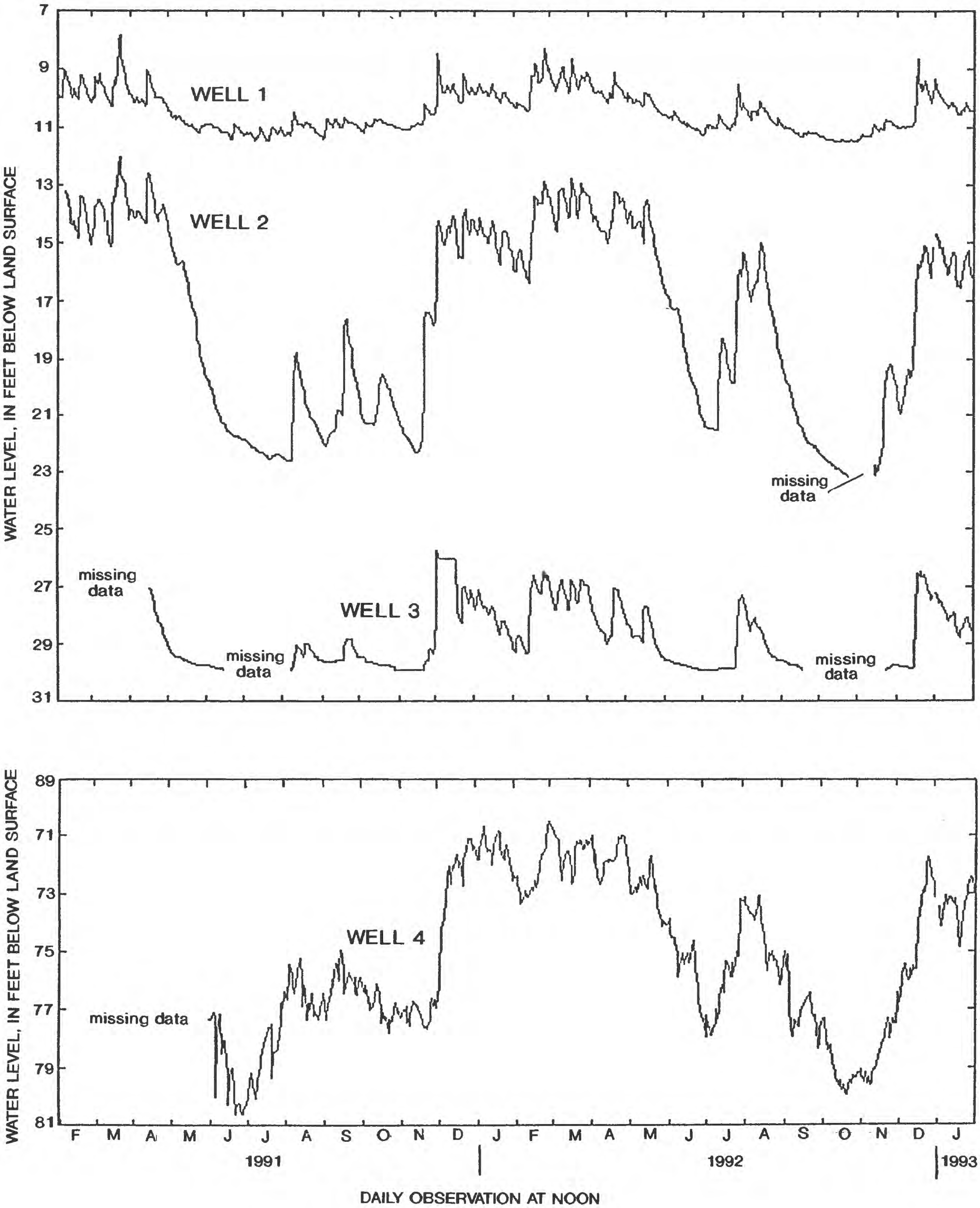

Figure 5. Water levels in observation wells in Canaan Valley, West Virginia.

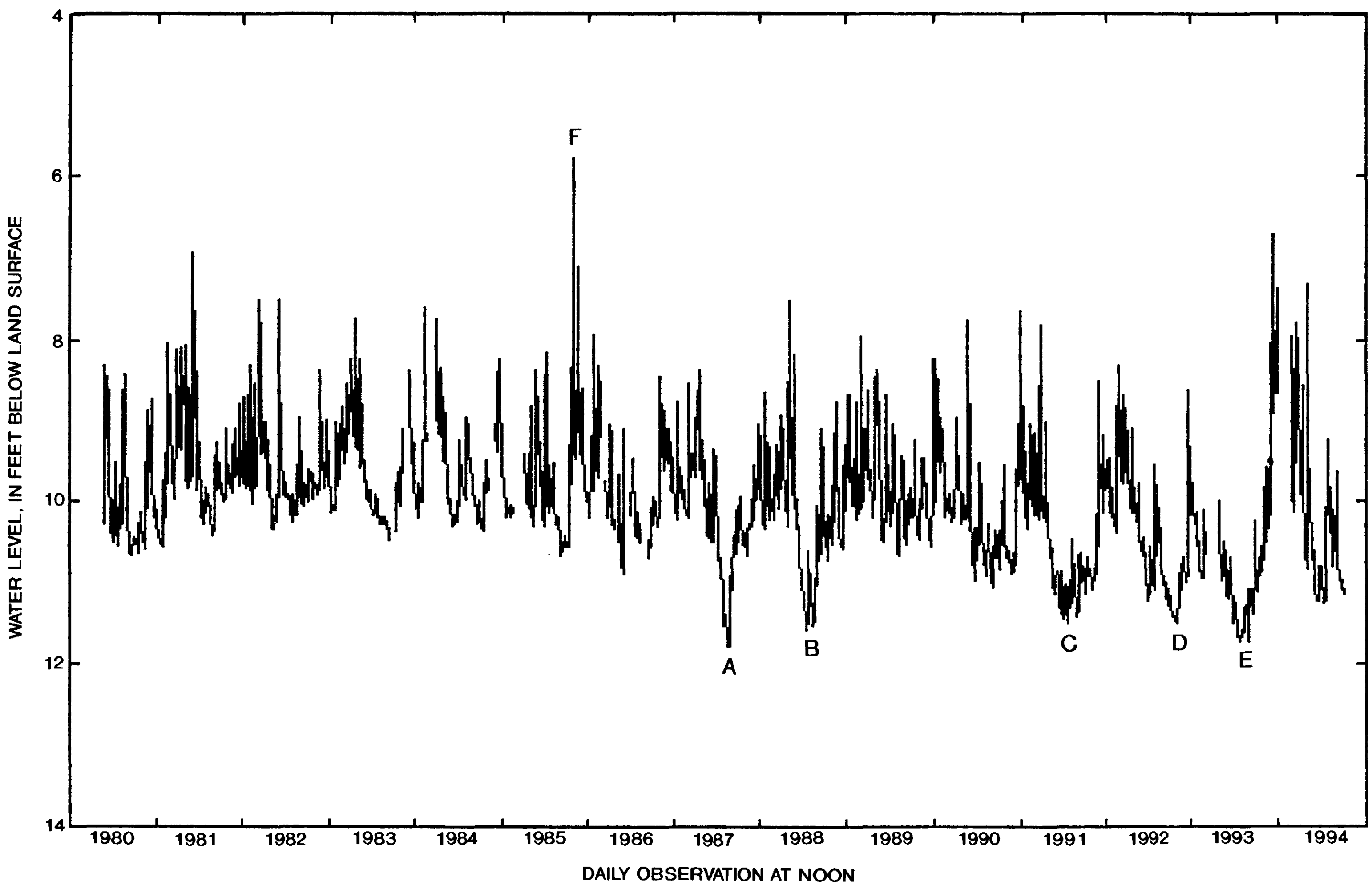

Figure 6. Water levels for observation well 1, Canaan Valley, West Virginia, showing low ground-water levels in (A) 1987, (B) 1988, and (C–E) 1991–93, and a record high level in (F) 1985.

summer 1988 (point B in fig. 6), summer 1991 (point C in fig. 6), and summer and fall 1992 (points C and D in fig. 6). Water levels typically fluctuate between 8.5 and 10.5 ft below land surface at this well. The highest water level recorded, 5.48 ft below land surface on November 5, 1985 (point E in fig. 6), coincides with the record flood in the Cheat and Potomac River Basins in early November 1985.

The 1991–93 range of water-level fluctuations (fig. 5) in observation well 1 (site 60 on plate 1) is only about 2 ft because the well is within the Greenbrier limestone near a zone of ground-water discharge to the Blackwater River. Typically, when water levels in the well increase, discharge to the river also increases; and when ground-water levels decline, discharge to the river decreases. The water level in the well is therefore correlated with the stage of the Blackwater River and does not vary much.

Water levels in observation well 3 (site 63 on plate 1) fluctuate about 4 ft. Observation well 3 also is completed within the Greenbrier Group and is near a small tributary to the Blackwater River. Therefore, water-level fluctuations in this well, as in well 1, are limited by the stage of a nearby stream, and the range of fluctuation in this well is small because the well is near a zone of ground-water discharge.

In contrast to observation wells 1 and 3, water levels in observation well 2 (site 6 on plate 1) fluctuate over a much wider range (approximately 12 ft). All three wells are completed within the Greenbrier Group, but well 2 is on the slope of a small hill composed of Mauch Chunk shale and is farther from a stream than wells 1 and 3. Both factors could contribute to the wider range in water-level fluctuations at well 2. Because rainfall and snowmelt do not infiltrate the shale as quickly as the more permeable limestone, some water may run off the shale and percolate into the ground water at the nearby Greenbrier-Mauch Chunk geologic contact. Observation well 2 is near this contact and is more responsive to periodic recharge from the Mauch Chunk shale than are wells 1 and 3.

At observation well 4 (site 51 on plate 1), the range of fluctuation in ground-water levels is about 10 ft (fig. 5). This well is completed within the Pottsville and Mauch Chunk bedrock in the Canaan Heights area on Canaan Mountain, approximately 500 ft higher than observation wells 1, 2, and 3 within the valley. Hilltop wells in Berkeley County, W.Va., have been shown to have a wider range in water-level fluctuation than valley wells in a similar hydrogeologic setting (Shultz, 1995). Wells on Canaan and Cabin Mountains are hilltop wells, and topography is the primary factor responsible for the wide range in water-level fluctuation at observation well 4.

Water levels in observation wells 2 and 3 dropped to near or below the bottom of the well bore on several occasions during 1991–92 (noted as missing data in fig. 5). Both wells are shallow, only 33 and 42 ft deep, and have accumulated a layer of soft mud in the bottom of the hole. Observation wells 2 and 3 are like most wells in the Greenbrier Group, which are typically drilled less than 150 ft deep to avoid the generally poor water quality in the underlying Pocono Group. During droughts, water levels in these wells can fall to within a few feet of pump intakes. Pumping a well under these conditions can temporarily dewater the well, increase the hydraulic gradient toward the well, increase sediment movement into the well, or damage pumps.

Water usually discharges from the aquifer to the streams in Canaan Valley, but ground-water levels sometimes become so low as to reverse this flow direction and induce recharge from the streams. For example, observation well 1 is at an approximate elevation of 3,227 ft (elevation of well measuring point), and the nearby Blackwater River has a typical water-surface elevation of approximately 3,217 ft—a difference of about 10 ft. Water levels in observation well 1 range from approximately 9 to 11 ft below land surface (Ward and others, 1993). Thus, the stream may gain water during periods of high ground-water levels and lose water during periods of low ground-water levels. Streamflow data (table 1) also indicate that gaining streams (July and August 1992 data) can become losing streams during low ground-water conditions (July and August 1991 data). Additional data, including surveys of stream and well measuring-point elevations, would be needed to verify the pattern in other Canaan Valley streams.

Ground-Water Levels in Summer 1991

Water levels were measured in 54 domestic and commercial wells (appendix E) during well inventories in June and July 1991, a period of low streamflow dominated by base flow (ground-water discharge). Water levels (below land surface) were measured to ± 0.01 ft by use of a steel tape, and the altitude of the land surface for each well was measured to within ± 2.0 ft by use of an aneroid barometer-altimeter.

Table 1. Discharge data for streams in Canaan Valley, West Virginia
[ft^3/s, cubic feet per second. Site locations shown on plate 1]

Upstream station identifier	Discharge at upstream station (ft^3/s)	Downstream station identifier	Discharge at downstream station (ft^3/s)	Difference in discharge between stations (ft^3/s)
		July and August 1991		
C-31	2.66	C-15	2.13	-0.530
C-11	.135	C-14	.126	-.009
C-1	.438	C-2	.333	-.105
C-6	2.05	C-7	1.08	-.970
C-9	2.35	C-31	2.66	+.310
C-19	1.52	C-20	1.14	-.380
		July 1992		
C-11	0.328	C-14	2.02	+1.69
C-1	.860	C-2	2.20	+1.34
C-6	5.98	C-7	15.3	+9.32
C-19	4.27	C-20	5.92	+1.65
		August 1992		
C-31	16.4	C-15	17.2	+0.80
C-11	.440	C-14	1.46	+1.02
C-1	2.26	C-2	2.22	-.040
C-6	11.2	C-7	13.2	+2.00
C-9	16.1	C-31	16.4	+.300
C-19	4.87	C-20	5.12	+.250

Mean, median, maximum, and minimum water levels for wells in three topographic settings and for wells in the three lithologic units are summarized in table 2. Water levels were typically shallower in valley settings (averaging 31.9 ft below land surface) than in hillside settings (averaging 87.3 ft below land surface) or hilltop settings (averaging 62.4 ft below land surface). Water levels in Greenbrier Group wells (averaging 52.8 ft below land surface) are typically less than those in Pocono Group wells (averaging 69.8 ft below land surface) or Pottsville/Mauch Chunk Group wells (averaging 67.2 ft below land surface).

The data were compiled into a potentiometric-surface map (plate 1) that represents composite heads in the Greenbrier, Pocono, and Pottsville/Mauch Chunk Groups. Each well used for preparation of the potentiometric-surface map is shown on plate 1, along with associated water-level depth and elevation data. Water-level contours were drawn manually and were based on water-level depth, elevation of land surface, topography, and elevations of springs and streams. The accuracy of elevations of the water-level contours is approximately $\pm$ 10 ft. Water-level contours (lines of equal head) can be used in conjunction with topographic elevations to estimate depth to ground water.

Table 2. Well-yield, water-level, and well-construction data, by aquifer zone and topographic setting, Canaan Valley, West Virginia
[gal/min, gallons per minute; ft bls, feet below land surface; ft, feet]

Well characteristic	Aquifer zone			Topographic setting		
	Pocono	Greenbrier	Pottsville/Mauch Chunk	Hilltop	Hillside	Valley
Mean well yield (gal/min):	**19.2**	**22.5**	**23.3**	**23.3**	**22.3**	**17.6**
No. of sites analyzed	9	11	11	14	11	6
Standard deviation	22.4	12.9	20.1	22.0	17.3	10.1
Maximum	60.0	50.0	70.0	70.0	50.0	28.0
Minimum	1.0	5.0	3.0	1.0	1.0	2.5
Mean water level (ft bls):	**69.8**	**52.8**	**67.2**	**62.4**	**87.3**	**31.9**
No. of sites analyzed	12	25	17	19	18	17
Standard deviation	59.9	42.3	46.1	37.8	60.5	20.4
Maximum	241.	129	176	155	241	80.0
Minimum	10.0	7.7	-.2	-.2	10.9	7.7
Mean casing length (ft):	**45.6**	**53.4**	**110**	**58.1**	**92.2**	**37.5**
No. of sites analyzed	11	8	9	13	11	4
Standard deviation	12.6	41.9	128	39.7	118	12.8
Maximum	70.3	145	450	144	455	50.0
Minimum	21.0	15.5	20.0	15.5	21.0	16.0
Mean well depth (ft bls):	**263**	**126**	**149**	**184**	**222**	**105**
No. of sites analyzed	17	30	15	21	20	21
Standard deviation	146	94.0	93.0	127	130	83.0
Maximum	496	505	455	496	505	373
Minimum	67.0	33.0	60.0	42.0	85.0	33.0

Conceptual Ground-Water-Flow Model

In Canaan Valley, ground water flows through a network of bedrock fractures (fig. 4). Ground water is recharged by precipitation, which infiltrates the fracture network. On a local scale, ground water flows in the general direction of hydraulic gradient through numerous intricate paths, such as interconnected fractures, faults, joints, and bedding planes. Generally, the density of fractures is greatest near the surface and decreases with depth. The three geologic formations that crop out in Canaan Valley are considered to be components of a single ground-water-flow system, in which ground water flows through bedrock fractures.

General directions of ground-water flow can be inferred by drawing flow lines perpendicular to the potentiometric contours, in the direction of decreasing hydraulic gradient (plate 1). The hydraulic gradient, which is the ratio of the distance that the potentiometric surface declines in a given horizontal distance, is approximately 0.520 ft/ft in the Pottsville/Mauch Chunk groups on the sides of the valley and approximately 0.012 ft/ft in the Greenbrier and Pocono Groups in the center of the valley. These gradients are primarily southeast and northwest towards the Blackwater River and its major tributaries and constitute the primary local ground-water-flow system. A slight northeast gradient of approximately 0.004 ft/ft between the south end of Canaan Valley and an area in the center of the valley east of Canaan Heights is indicative of a more regional component of ground-water flow. The flow lines indicate that the general direction of ground-water flow is from the ridges surrounding the valley towards the North Branch or the Blackwater River. An exception is in the center of the valley, where ground water flows outward from topographic highs in the Pocono sandstone towards either the Blackwater River, the North Branch, or Sand Run (plate 1). A cross-sectional depiction of the ground-water-flow system is given in fig. 4.

Aquifer Transmissivity

Transmissivity is a characteristic of an aquifer that expresses its capacity to transmit water. Transmissivity is the rate at which water of a prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient (Bates and Jackson, 1984). In common units, if 1 cubic foot of water flows through the entire thickness of an aquifer in a section 1 foot square under a hydraulic gradient of 1.0, the transmissivity is 1.0 $(ft^3/d)/ft$ or 1.0 ft^2/d (expressed as 1 foot squared per day). The total flow in an aquifer can be computed if the transmissivity of the aquifer is known.

Transmissivity and related characteristics of aquifers such as hydraulic conductivity, saturated thickness, and storage coefficient can be used in analytical and numerical models of ground-water flow. For instance, if the hydraulic conductivity, saturated thickness, and storage coefficient of an aquifer are known, one can predict the size and shape of a cone of depression around a well at a specific pumping rate for a specified amount of time. Such models can also be used to determine the regional effects on an aquifer resulting from sustained pumping at a specified rate or at variable rates.

In this study, transmissivity was determined by two methods. First, aquifer tests were done by pumping water from a well at a known rate and measuring the rate of return of water into the well bore after pumping stopped. The recovery data were analyzed by use of the Theis single-well method (Ferris and others, 1962). Five aquifer tests were done, two at wells completed in the Pottsville/Mauch Chunk Group and three at wells completed in the Greenbrier Group (table 3). The analyses of these aquifer tests are given in detail by Kozar (1995).

Transmissivities were also calculated by use of stream base-flow methods (Heath, 1983). During low-flow periods, such as in late summer and early fall, streamflow consists largely of ground- water discharge. Streamflow is measured at two points along a stream, and the increase in streamflow represents discharge from the section of aquifer between the two points. This method yields a transmissivity that is averaged over a large area and therefore takes into account the local variations in fracture density. Aquifer tests yield a transmissivity that is strictly applicable only in the area near the pumped well. In this study, transmissivities calculated by base-flow methods are comparable to those from aquifer tests. Eleven transmissivity estimates were made by the base-flow method, three for the Greenbrier Group, one for the Pocono Group, and seven for the combined Greenbrier and Pocono Groups (Kozar, 1995). Transmissivities for these 11 sites are summarized in table 3, and the streamflow data from which the estimates were made are listed in table 1.

Individual transmissivities values vary widely, but the median transmissivity of the Greenbrier Group is higher than median transmissivities of the Pottsville/Mauch Chunk or Pocono Groups (table 3). Higher median transmissivity within the Greenbrier Group is probably attributable to the presence of fractures within the limestone that have been enlarged by dissolution.

Water Availability and Use

Water availability can be estimated in at least three different ways, all of which are important for understanding the potential for the use of ground water in Canaan Valley. First, a water budget, which quantifies the inputs and outputs of water from an area, can be used for qualitative assessment of water availability. Water-budget information is crucial in mathematical ground-water-flow modeling and for developing water-management strategies. Mathematical ground-water-flow modeling can be used to assess current water demands and availability and also can assess effects of increased demands on ground-water reservoirs. Second, water availability and use for an area must be known so that quantitative assessments of present and future water demand can be made. Third, data on the yields of wells, in conjunction with other well-construction data, can be used to assess whether an aquifer can yield an adequate supply of water for specific uses. In some areas, low well yields may be adequate for private homes or small commercial facilities but inadequate for large industrial facilities. For instance, a well yielding 5-10 gal/min can easily provide the 70 gal/d of water typically used in a single-family home. Such a well, however, could not meet the demands of an industrial site that may need 100,000 gal/d or more of water for plant operations.

Table 3. Hydraulic characteristics for aquifer zones in the Canaan Valley, West Virginia, area
[Transmissivities are in feet squared per day. Well sites and stream reaches (defined by streamflow measuring sites) are shown on plate 1]

Well site or stream reach	Transmiss-ivity of aquifer[1]	Method used to compute transmissivity
	Pottsville/Mauch Chunk Group	
Well 46	3.1	Single-well aquifer test
Well 47	10.0	Single-well aquifer test
Median	**7.0**	
	Greenbrier Group	
Well 60	117.0	Single-well aquifer test
Well 62	18.0	Single-well aquifer test
Well 63	13.4	Single-well aquifer test
C-1 to C-2	102.0	Base-flow method
C-5 to C-7	4,500.0	Base-flow method
C-5 to C-7	971.0	Base-flow method
Median	**110.0**	
	Greenbrier and Pocono Groups	
C-9 to C 31	11.4	Base-flow method
C-19 to C-20	11.7	Base-flow method
C-11 to C-14	143.0	Base-flow method
C-11 to C-14	86.0	Base-flow method
C-9 to C-31	685.0	Base-flow method
C-19 to C-20	77.4	Base-flow method
C-19 to C-20	11.7	Base-flow method
Median	**77.4**	
	Pocono Group	
C-31 to C-15	20.4	Base-flow method

[1]A combined estimate of transmissivity was made for those sections of the Blackwater River receiving ground-water discharge from both the Greenbrier and Pocono aquifers.

All these aspects must be taken into account in order to determine water availability and the adequacy of the available water.

Water Budget

On the basis of measurements of average annual precipitation, average annual ground-water discharge to streams, average annual surface-water runoff, and estimates of average annual evapotranspiration, one can prepare a water budget for a closed drainage basin. A water budget consists of three components: water inputs, water outputs, and changes in water held in storage. The water budget for Canaan Valley (table 4) is based on data collected from November 1, 1991, through October 31, 1992, and was computed for the part of the valley from the south end to the stream-flow- gaging station at Cortland (the study area as defined for this report).

Table 4. Water budget for Canaan Valley, West Virginia, November 1991–October 1992

[For this budget, water inputs are equivalent to the water outputs plus the changes in water held in storage. The total combined evapotranspiration and underflow for Canaan Valley during the period of this investigation was estimated to be 23.0 in., and the sum of estimates of individual underflow and evapotranspiration components must not therefore exceed this value. Changes in water held in storage were assumed to be zero for the period of this investigation on the basis of water levels and precipitation, which were nearly equal at the beginning and end of the study]

Water inputs			**51.0 in.**
1. Rainfall and snow		51.0 in.	
2. Streamflow from outside of study area		0.0 in.	
3. Ground water from outside of study area		0.0 in.	
Water outputs			**51.0 in.**
1. Surface water		28.0 in.	
a. Surface-runoff component	9.3 in.		
b. Ground-water discharge component	18.7 in.		
2. Evapotranspiration and underflow		23.0 in.	
a. Evapotranspiration	minimum 19.5 in.		
	maximum 23.0 in.		
b. Underflow	minimum 0.0 in.		
	maximum 3.5 in.		
Assumed changes in water storage			**0.0 in.**

Water inputs to Canaan Valley consist solely of precipitation. Daily precipitation records for the period of interest indicate that a total of 51.0 in. of precipitation was measured during the period (National Oceanic and Atmospheric Administration, 1991a,b; 1992). The changes in ground water and surface water held in storage and unsaturated-zone water held in storage are assumed to be zero for this water budget. This assumption is supported by water-level data (fig. 6) showing that ground-water levels were similar at the beginning and at the end of the period of interest. Precipitation and streamflow also were similar at the beginning and at the end of the observation period, providing further support for this assumption.

Water outputs were determined primarily from streamflow records. Data from four streamflow-gaging stations maintained throughout the period of this study were used in hydrograph separations and in analyses to determine recharge and discharge rates and to prepare the water budget. These stations were all on the Blackwater River, one 0.75 mi east of Cortland (site C-31 on plate 1), one at Canaan Valley State Park (site C-5 on plate 1), one upstream from Davis, and one in Davis (the latter two are not in the study area and are not shown on plate 1). The streamflow-gaging station on the Blackwater River at Cortland was especially useful in that its location was at the downstream margin of the study area for this investigation. It accounts for 80 percent of the streamflow that leaves the study area. The remaining 20 percent is attributable to streamflow exiting the study area by the North Branch, a tributary of the Blackwater River. Because there was no gaging station on the North Branch, the amount of discharge exiting the basin by the North Branch was estimated from discharge measurements made on the North Branch and Blackwater Rivers at Cortland and drainage areas of these streams. Based on daily discharge data for the Blackwater River at Cortland (Ward and others, 1993; Ward and others, 1994), 14,300 ft^3/s (28 in.) of water left the study area by the Blackwater River. Assuming the North Branch has a hydrologic and geologic setting similar to that of the Blackwater River, an estimated 3,600 ft^3/s (28 in.) of water left the study area by the North Branch. Results of hydrograph separations are summarized in table 5 and were used to estimate the components of a basin water budget for Canaan Valley.

Hydrograph separations (table 5) were used to partition streamflow into its surface-runoff and ground-water-discharge components (Hjelmfelt and Cassidy, 1975). A computer program (HYSEP) developed by the U.S. Geological Survey (Sloto, 1991) was

Table 5. Results of hydrograph separations for selected streamflow-measurement stations in Canaan Valley, West Virginia
[in., inches; ft^3/s, cubic feet per second; %, percent of total; mi^2, square miles; $Mgal/d/mi^2$, million gallons per day per square mile]

Streamflow measurement or gaging station	Total annual streamflow		Components of annual streamflow						Drainage area of basin (mi^2)	Annual ground-water recharge rate ($Mgal/d/mi^2$)
			Surface runoff			Ground-water discharge				
	(in.)	(ft^3/s)	(in.)	(ft^3/s)	(%)	(in.)	(ft^3/s)	(%)		
Blackwater River at Cortland[1]	28.0	14,300	9.3	4,750	33	18.7	9,550	67	18.5	0.892
North Branch at Cortland[1]	28.0	4,400	9.3	1,460	33	18.7	2,940	67	5.7	.892
Total for Blackwater River and North Branch at Cortland[2]	28.0	18,700	9.3	6,210	33	18.7	12,490	67	24.2	.892
Blackwater River near Davis[3]	27.8	41,200	12.2	18,100	44	15.6	23,100	56	55.0	.745
Blackwater River at Davis[3]	28.6	67,900	15.5	36,800	54	13.1	31,100	46	86.2	.737

[1]The Blackwater River at Cortland and the North Branch at Cortland stations are in the study area.

[2]Total discharge leaving the study area (including the North Branch) was estimated on the basis of drainage-area ratios and discharge data for the Blackwater River at Cortland station.

[3]The Blackwater River at Davis and the Blackwater River near Davis stations are a few miles north of the study area, but were used in hydrograph analysis for comparison purposes. The station on the Blackwater River at Davis had 68 years of record available for analysis. The Blackwater River near Cortland and the Blackwater River near Davis stations had only one year of streamflow record available for analysis. Data from the station at Davis were used to verify the separations for those stations with minimal data. The period of record used for hydrograph analysis was November 1, 1992, through October 31, 1994.

used for the hydrograph separations. Hydrograph separations (table 5) were done for three of the four streamflow-gaging stations to determine the ground-water and surface-runoff components of streamflow at specific locations along the Blackwater River. The streamflow-gaging station at Canaan Valley State Park was not used because the record was less than a full year.

Calculations based on the results of the hydrograph separations show that ground-water recharge rates (0.74 and 0.75 Mgal/d/mi^2) were lower for the areas near Davis in the northern part of the valley than they were for the southern part of the valley (table 5) near Cortland (0.89 Mgal/d/mi^2). Moreover, ground-water discharge to streams was much higher and surface runoff much lower (67 and 33 percent, respectively) in the southern part of the valley than in the northern part (average of 55 and 45 percent, respectively). This difference is not surprising because the southern part of the valley is dominated by limestone, whereas the northern part of the valley is dominated by clastic sedimentary rocks, especially sandstone and shale. Higher permeabilities due to the presence of solutionally enlarged fractures in the limestone are one possible explanation for higher recharge rates in the limestone-dominated part of the southern portion of Canaan Valley. Hydraulic conductivities are probably lower in the clastic-dominated areas than in the limestone (karst) areas. Surface runoff to streams is higher in the sandstone-dominated areas primarily because of the lower recharge capacity of the noncarbonate rocks.

Another possible explanation for lower recharge rates in the northern part of the valley could be the dominance of vast wetlands and the potentially higher evapotranspiration rates there. The southern part of the valley has only a few small, scattered wetlands. The high percentage of wetlands in the northern part of the valley, in conjunction with the poorly permeable clay and organic material associated with wetlands, could be responsible for reducing the amount of recharge and increasing the percentage of surface runoff. Decreases in streamflow between the Cortland gaging station (28.0 in. annually) and the gaging station upstream from Davis (27.8 in. annually) may be related to underflow beneath the stream segment downstream from the station at Cortland. There was a slight increase in streamflow between the station upstream from Davis (27.8 in. annually) and the station at Davis (28.6 in. annually).

It is reasonable to assume that most of the 51 in. of precipitation that fell in the valley during the study period left the area as streamflow or was lost to evaporation or transpiration by plants. Underflow, defined as the water flowing beneath the bed of a stream or through the soil zone (Bates and Jackson, 1984), would be expected to be a small, probably a negligible amount of water in the general water budget of a closed valley. The only major component of the water budget that has not been accounted for by direct measurement is the amount of water consumed by evapotranspiration (ET). Because ET is the only variable unaccounted for, it can be determined mathematically by subtracting the combined annual ground-water discharge and surface runoff to streams from the annual precipitation for the study area (ET = precipitation - [ground-water discharge + surface runoff] = 51.0 in. - [18.7 in. + 9.3 in.] = 23.0 in). An average of 23.0 in. of water per year is therefore estimated as ET over the 18.5 mi^2 drainage basin.

Independent estimates of ET in or near the study area have been made by other researchers. ET was estimated by the West Virginia University, Department of Agriculture, to be 18.7 in/yr, on the basis of pan-evaporation data from May through September 1983; by extrapolating to account for ET that occurred in the remaining 6 months of the year (Kohler and others, 1959), 24.6 in. is estimated. Potential evapotranspiration (PET) was estimated from precipitation and temperature data collected by the National Oceanic and Atmospheric Administration (NOAA) at a weather station in Canaan Valley for September 1981 through October 1982. Estimates of 22.2 in. of PET were made for each year (Wieder and Lang, 1984). Similar estimates of PET were made for this study by use of Thornthwaite's method (1948) and recent climatological data from the NOAA weather station at Canaan Valley. The estimates were made for the period from October 1991 through September 1992, the same time period for which streamflow data are available and for which hydrograph separations were done. In the Thornthwaite method, air temperature is assumed to be an index of the total energy available for ET and is correlated with the effects of solar radiation. The method does not take the effects of vegetative cover into account and therefore estimates potential ET (PET), not actual ET. The estimated PET's are adjusted for climate on the basis of latitude. PET for the study area was estimated at 19.5 in. by use of the Thornthwaite method (Kozar, 1995). Independent computations of ET, therefore, yield similar estimates. Computations of ET based on the hydrologic budget compared favorably with PET estimated by the Thornthwaite method.

The PET estimated by the Thornthwaite method for the period of hydrograph separations can, in turn, be used to estimate the amount of underflow. Assuming changes in storage to be equivalent to zero, one can compute underflow by subtracting the combined ground-water discharge to streams, surface runoff to streams, and PET from the precipitation (underflow = precipitation - [surface runoff + ground-water discharge + potential ET] = 51.0 in. - [9.3 in. + 18.7 in. + 19.5 in.] = 3.5 in.). Thus, 3.5 in. of water may have exited the study area as underflow during the course of the investigation. The actual amount of underflow was probably between 0 and 3.5 in., and the actual ET is probably between 19.5 and 23.0 in. for the timeframe of this investigation.

The 51.0 in. of precipitation measured for the study period is close to the normal annual precipitation of 52.5 in. (National Oceanic and Atmospheric Administration, 1991a), and the estimates presented here should closely reflect the actual water budget during years of normal hydrologic conditions and precipitation.

Water Use

Most of the water used in Canaan Valley is withdrawn by Canaan Valley State Park and Timberline Four Seasons Resort (table 6). Canaan Valley State Park pumped water from the Blackwater River for golf-course irrigation and operations at the park in 1992 (Stan Burch and Steve Bolar, Canaan Valley State Park, oral commun., 1993). Additional water was pumped from a tributary to the Blackwater River for snow-making operations at the ski area within the park during the same period (John Teter, Canaan Valley State Park, oral commun., 1993). Most of the water withdrawn for operations at Timberline and Canaan Valley resorts is returned to the river as sewage-treatment-plant return flows, but a substantial though unmeasured quantity of the water used for snow making and irrigation is lost to evaporation and transpiration.

Timberline Four Seasons Resort, also a ski resort, was the other large water user in the valley. Ground water was pumped for operations at the facility (Lake Huffman, Timberline Four Seasons Resort, oral communication, 1993) and surface water was withdrawn from a tributary to the Blackwater River to make snow at the resort in 1990.

There are approximately 350 permanent residents and an additional 200 seasonal residents within the valley (Chris MaClay, Tucker County Information Center, 1993). The average rural homeowner in West Virginia uses approximately 80 gallons of water per day (Solley and others, 1993). Assuming the typical seasonal resident resides in the valley for 6 months, the total amount of ground water pumped for domestic use is approximately 13.1 Mgal/yr. An estimated 1.2 million skiers, hikers, and tourists visit the area annually. Estimating the water use for this group of people is difficult, but it is probable that most of the water used is supplied by Canaan Valley State Park, Blackwater Falls State Park, and Timberline Four Seasons Resort. There are no large motels, restaurants, or similar commercial facilities in the valley, other than at Canaan Valley State Park and Timberline Four Seasons Resort, that would add significantly to ground- and surface-water withdrawals. The total average ground-water use for the valley is estimated to be 22.0 Mgal/yr or 60,000 gal/d (13.1 Mgal domestic use and 8.9 Mgal commercial use), and the total surface-water use for the valley is estimated to be 199.4 Mgal/yr or 546,000 gal/d (all surface-water use was for commercial purposes).

Most of the water used in Canaan Valley is surface water (90 percent) and only a small part is ground water (10 percent). In addition, much of the water used is returned to streams and to the ground as sewage-treatment return flows or septic-system discharges and is therefore only partly consumed. Therefore, although overall effect of ground- and surface-water withdrawals on the availability of water within the valley is not fully documented, it may not be substantial.

Well Construction and Well Yield

Sixty-eight wells and 7 springs in Canaan Valley were inventoried from November 1990 to July 1991 (appendix E). Data were collected for well yields, water levels, land-surface elevations, well construction, casing length, spring yield, primary and secondary aquifers, and topographic setting. The data were obtained from several sources, including homeowners, data stamped on well caps, and well-completion reports filed with the West Virginia Department of Health.

Drillers' estimates of well yield were available for 31 of the wells inventoried. Mean well yields, well

Table 6. Estimated annual water use in Canaan Valley, West Virginia
[Mgal/yr, million gallons per year; --, not applicable]

Type of use	Water user	Surface water (Mgal/yr)		Ground water (Mgal/yr)		Major use
Commercial	Canaan Valley State Park	29.0		--		General operations
Commercial	Canaan Valley State Park	100.0		--		Snow making
Commercial	Canaan Valley State Park	20.0		--		Golf course irrigation
Commercial	Timberline Four Seasons Resort	--		8.9		General operations
Commercial	Timberline Four Seasons Resort	50.4		--		Snow making
Domestic	Permanent residents	--		10.2		Laundry, showers, dishwashing, etc.
Domestic	Seasonal residents	--		2.9		Laundry, showers, dishwashing, etc.
	Totals	**199.4**	**+**	**22.0**	**=**	**221.4 Mgal/yr total water used**

depths, water levels, and casing lengths are listed for each aquifer zone in table 2. The data indicate that mean well yields are similar for the three aquifer zones, reinforcing the concept that the fracture-dominated flow system functions as one large aquifer system in which individual aquifer zones are delineated by bedrock type (lithology). The casing length in wells is primarily a function of driller's expectations about water quality. Longest casings are found in the Pottsville/Mauch Chunk Group, because shallow ground water in this zone can have high concentrations of iron, manganese, and sulfate (appendix A); therefore, well drillers typically set deep casings in these formations so as to optimize water quality (Charles Henderson, Henderson Drilling, oral commun., 1991). Because most of the wells in the Pottsville/Mauch Chunk Group are on hilltops and hillsides, the data in table 2 indicate that hilltop and hillside wells tend to have longer casings, as well as greater mean depths to water, than valley wells. The deepest wells within the valley are completed in the Pocono Group. A slightly lower mean well yield for the Pocono Group than for the Greenbrier or Pottsville/Mauch Chunk Group could indicate that the Pocono is not as productive as the other formations and that an extended borehole is needed to provide adequate supplies of water. Furthermore, water levels in the Pocono are an average 23 ft deeper than those in the Greenbrier, an indication that deeper wells are needed to tap water-bearing zones. Mean, median, maximum, and minimum water levels, casing lengths, well depths, and well yields for wells in three topographic settings and for wells in the three lithologic units are summarized in table 2.

In previous investigation of the hydrogeology of West Virginia (Shultz, 1995), a correlation was found between well yield and topographic setting (valley, hillside, hilltop). The data in table 2 indicate no such correlation in Canaan Valley. Mean well depths are less and water levels are shallower in valley wells than in hillside or hilltop wells (table 2). This pattern is probably largely due to topography: valley wells are typically near discharge areas, whereas hillside or hilltop wells are near recharge areas. Casing lengths are also shorter for valley wells than for hilltop or hillside wells (table 2).

GROUND-WATER QUALITY

In July 1991, the USGS collected water samples from 43 wells and 7 springs in Canaan Valley (plate 1). The samples were analyzed at the USGS National Water Quality Laboratory in Arvada, Colo., for dissolved solids (DS), and for most common ions, including iron, manganese, sulfate, chloride, sodium, potassium, calcium, magnesium, silica, and fluoride. Concentrations of ammonia, phosphorus, orthophosphorus, nitrate, nitrite, and organic nitrogen also were determined. Field measurements of pH, alkalinity (carbonate and bicarbonate), specific conductance, dissolved oxygen, fecal streptococcus bacteria, and fecal coliform bacteria were made at each of the 50 sites. Samples from 12 of the 50 sites were analyzed for radon-222, a radioactive gas and suspected carcinogen. Water samples from five sites in the valley that were most likely to be affected by pesticide use, as determined on the basis of known land-use criteria, were collected and analyzed for 42 pesticides. The five samples were analyzed for the organochlorine and organophosphate insecticides and the triazine herbicides.

The 50 ground-water sites sampled were selected to characterize the water chemistry of the bedrock aquifer within the valley. In addition, surface-water-quality and precipitation-quality data were obtained to complement and enhance the interpretation of the ground-water-quality data and to develop an understanding of the ground-water/surface-water relations. Stream-discharge and streamwater-quality data were collected during three synoptic surveys. Data were collected at 12 locations on the Blackwater River and its tributaries from July 30 to August 1, 1991; July 14 to July 16, 1992; and August 18 to August 19, 1992. These data were used to compare the water quality of base streamflow with that of ground water.

Occurrence of Selected Chemical Constituents

In general, ground-water quality meets drinking water standards established by way of USEPA maximum contaminant levels (MCL's) and secondary maximum contaminant levels (SMCL's) (table 7), but concentrations of manganese, iron, radon, and fecal bacteria are elevated in certain areas, especially those dominated by noncarbonate bedrock. MCL's are legally enforceable limits established by the USEPA to protect human health. SMCL's are not based on health criteria but rather on esthetic qualities such as odor, taste, and staining of plumbing fixtures. The major factor affecting ground-water quality is aquifer lithology, primarily due to dissolution of minerals within carbonate and noncarbonate bedrock.

Trilinear (Piper) diagrams (fig. 7) were prepared for precipitation, surface water, and ground water from the four major lithologic units. Plots of major ion concentrations on such diagrams can help in characterizing the type of water present in a given area. Determining the ratios of sodium, potassium, calcium, and magnesium to total cations and the ratios of chloride, sulfate, carbonate, and bicarbonate to total anions is another method used to characterize the type of water (table 8). Water from each of the 50 ground-water sites was characterized in this manner.

Comparison of the Piper diagrams indicates that the composition of water in streams within the study area is chemically similar to that for water from the Greenbrier Group (fig. 7). Waters from the Greenbrier Group and the various tributary streams within the study area are predominantly of the calcium bicarbonate type, although some calcium-magnesium bicarbonate water is present. The Piper diagrams for water from the noncarbonate Pottsville/Mauch Chunk and Pocono Groups indicate a mixed type of water, with calcium as the dominant cation; the dominant anion, however, ranges from bicarbonate to sulfate to chloride. Thin beds of limestone and a high percentage of calcium carbonate cement in the sandstones are probably responsible for the calcium bicarbonate signature of some of the water from the noncarbonate rocks. Analysis of water-quality data and a Piper diagram (fig. 7) for precipitation in Canaan Valley indicates that water from precipitation is primarily a sodium bicarbonate/sodium sulfate type. Seven ground-water samples were found to have a sodium bicarbonate type of water (table 8).

Table 7. Statistical summary of ground-water quality for 50 sites sampled in Canaan Valley, West Virginia, July 1991

[USEPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters of sample; pCi/L, picocuries per liter; N/A, not applicable]

Property or constituent (reporting unit)	Mean value	Median value	Standard deviation	Maximum value	Minimum value	USEPA MCL, SMCL or proposed MCL	Percent of samples exceeding MCL, SMCL, or proposed MCL
Specific conductance (µS/cm)	200	190	125	510	18.0	None	N/A
Dissolved oxygen (mg/L)	6.7	7.6	2.7	11.2	0	None	N/A
pH (standard units)	7.02	7.30	1.31	9.80	3.80	6.5-8.5	32
Alkalinity (mg/L as $CaCO_3$)	91.5	81.5	68.6	260	0	None	N/A
Bicarbonate (mg/L)	110	99.5	84.3	317	0	None	N/A
Ammonia + organic N(mg/L)	.26	.20	.11	.60	<.20	None	N/A
Ammonia (total, in mg/L)	.02	.02	.01	.06	<.01	None	N/A
Phosphorous (total, in mg/L)	.02	.01	.46	.32	<.01	None	N/A
Orthophosphorus (mg/L)	.02	.01	.01	.05	<.01	None	N/A
Nitrate (mg/L)	.63	.45	.74	4.40	<.05	10	0
Nitrite (mg/L)	.01	.01	.00	.01	<.01	1	0
Calcium (mg/L)	27.1	23.0	22.7	89.0	.36	None	N/A
Dissolved solids (mg/L)	115	104	71.6	283	6.0	500	0
Magnesium (mg/L)	3.8	2.3	4.0	18.0	<.01	None	N/A
Manganese (µg/L)	49.0	2.00	149	1,000	<1.00	50	20
Potassium (mg/L)	.59	.60	.26	1.20	.10	None	N/A
Silica (mg/L)	7.7	6.6	3.4	20.0	2.4	None	N/A
Sodium (mg/L)	10.5	2.1	21.3	100	.3	None	N/A
Iron (µg/L)	74.0	10.0	380	2,700	3.00	300	2
Chloride (mg/L)	6.09	3.60	8.39	49.0	.10	250	0
Sulfate (mg/L)	9.46	7.55	6.97	33.0	1.30	250	0
Fluoride (mg/L)	.18	.10	.18	1.10	<.10	2	0
Fecal coliform (col/100 ml)	49	1	210	1,300	<1	0	22
Fecal streptococcus (col/100 ml)	76*	1	203	1,200	<1	0	48
Radon-222 (pCi/L)	744	505	654	1,900	<80	300	67

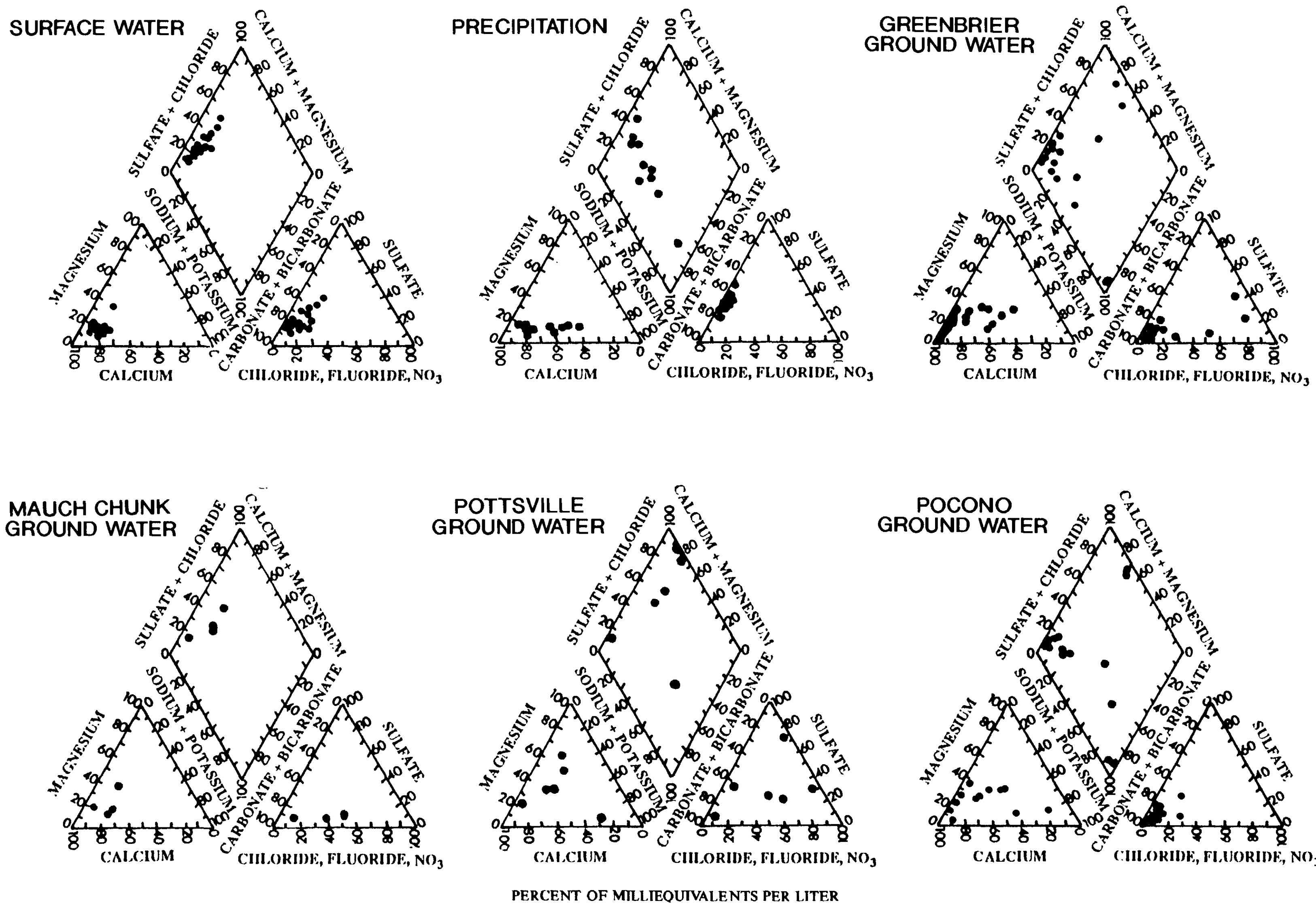

Figure 7. Compositions of surface water, precipitation, and ground water from specific formations in the Canaan Valley area, West Virginia.

Table 8. Ion concentrations, ratios, and water types for ground-water sites sampled in Canaan Valley, West Virginia, July 1991
[meq/L, milliequivalents per liter; site locations shown on plate 1]

Site	Ion concentrations (meq/L)								Ion concentration ratios					Predominant water type
	Cl	SO_4	HCO_3	CO_3	Ca	Mg	Na	K	Cl/ SO_4 +Cl	Na+K/ Ca+Mg +Na+K	Ca+Mg/ Ca+Mg +Na+K	SO_4+Cl/ SO_4+Cl +CO_3	HCO_3+ CO_3/SO_4+ +Cl+CO_3	
1	0.42	0.69	1.56	0.00	1.00	0.24	1.31	0.02	0.38	0.52	0.48	0.42	0.58	Sodium bicarbonate
2	.27	.46	4.28	.00	4.44	.26	.36	.02	.37	.08	.93	.15	.86	Calcium bicarbonate
3	.00	.14	0.52	.00	30.34	.10	.22	.01	.00	.01	.99	.21	.79	Calcium bicarbonate
4	.11	.12	1.52	.00	1.50	.11	.07	.01	.47	.05	.95	.13	.87	Sodium bicarbonate
5	.34	.25	3.77	.00	2.55	1.48	.24	.02	.58	.06	.94	.14	.87	Calcium bicarbonate
6	.17	.17	4.02	.07	0.02	.00	4.35	.02	.50	1.00	.00	.06	.94	Sodium bicarbonate
7	.05	.14	2.11	.00	1.65	.61	.09	.01	.24	.04	.96	.08	.92	Calcium bicarbonate
8	.37	.27	4.59	.00	2.94	1.15	.65	.03	.58	.14	.86	.12	.88	Calcium bicarbonate
9	.01	.10	1.75	.00	1.70	.15	.06	.01	.13	.04	.97	.06	.94	Calcium bicarbonate
10	.21	.19	2.67	.00	2.75	.29	.07	.01	.52	.02	.98	.13	.87	Calcium bicarbonate
11	.01	.16	1.75	.00	1.75	.22	.04	.01	.05	.03	.97	.09	.91	Calcium bicarbonate
12	.26	.25	5.20	.00	3.44	.75	.16	.02	.51	.04	.96	.09	.91	Calcium bicarbonate
13	.03	.10	1.72	.00	1.70	.17	.06	.01	.22	.03	.97	.07	.93	Calcium bicarbonate
14	.28	.25	3.28	.00	3.59	.13	.08	.01	.53	.02	.98	.14	.86	Calcium bicarbonate
15	.01	.11	1.36	.00	1.44	.13	.03	.01	.05	.02	.98	.08	.92	Calcium bicarbonate
16	1.38	.29	3.80	.00	3.54	1.32	.29	.02	.83	.06	.94	.31	.69	Calcium bicarbonate
17	.05	.13	1.72	.00	1.00	.55	.39	.02	.27	.21	.79	.09	.91	Calcium bicarbonate
18	.10	.35	3.03	.00	1.00	.91	1.44	.02	.21	.43	.57	.13	.87	Calcium bicarbonate
19	.01	.42	1.89	.00	1.40	.51	.38	.03	.03	.18	.82	.19	.82	Calcium bicarbonate
20	.13	.25	3.00	.00	2.84	.33	.06	.01	.34	.02	.98	.11	.89	Calcium bicarbonate
21	.01	.08	1.47	.17	1.30	.15	.04	.01	.10	.04	.96	.05	.95	Calcium bicarbonate
22	.01	.07	.52	.00	.42	.14	.07	.01	.07	.13	.87	.13	.87	Calcium bicarbonate
23	.01	.16	.82	.00	.45	.26	.20	.02	.03	.23	.77	.17	.83	Calcium bicarbonate
24	.12	.10	4.20	.00	.18	.06	4.09	.02	.55	.95	.06	.05	.95	Sodium bicarbonate
25	.01	.16	2.00	.00	1.95	.16	.06	.01	.04	.03	.97	.08	.93	Calcium bicarbonate

Table 8. Ion concentrations, ratios, and water types for ground-water sites sampled in Canaan Valley, West Virginia, July 1991—Continued

Site	Ion concentrations (meq/L)								Ion concentration ratios					Predominant water type
	Cl	SO_4	HCO_3	CO_3	Ca	Mg	Na	K	Cl/ SO_4 +Cl	Na+K/ Ca+Mg +Na+K	Ca+Mg/ Ca+Mg +Na+K	SO_4+Cl/ SO_4+Cl +CO_3	HCO_3+ CO_3/SO_4+ +Cl+CO_3	
26	0.03	0.07	0.02	0.00	0.09	0.05	0.03	0.02	0.31	0.25	0.75	0.86	0.14	Calcium sulfate
27	.12	.23	1.71	.00	1.15	.46	.34	.03	.34	.19	.81	.17	.83	Calcium bicarbonate
28	.02	.08	.00	.00	.05	.04	.03	.01	.22	.32	.68	1.00	.00	Calcium sulfate
29	.40	.13	1.12	.00	.25	.18	1.13	.03	.75	.73	.27	.32	.68	Sodium bicarbonate
30	.05	.56	2.66	.00	2.40	.65	.08	.01	.07	.03	.97	.19	.81	Calcium bicarbonate
31	.01	.03	.00	.00	.05	.04	.03	.01	.29	.33	.67	1.00	.00	Calcium sulfate
32	.16	.16	2.18	.00	2.20	.32	.08	.03	.49	.04	.96	.13	.87	Calcium bicarbonate
33	.62	.12	.57	.00	.80	.20	.48	.02	.84	.33	.67	.56	.44	Calcium chloride
34	.14	.17	1.80	.00	2.00	.18	.08	.01	.46	.04	.96	.15	.85	Calcium bicarbonate
35	.01	.05	1.36	.00	1.30	.13	.04	.01	.11	.03	.97	.04	.96	Calcium bicarbonate
36	.07	.16	.26	.00	.35	.21	.12	.03	.31	.20	.80	.47	.53	Calcium bicarbonate
37	.01	.18	.00	.00	.05	.03	.01	.00	.05	.17	.84	1.00	.00	Calcium sulfate
38	.16	.44	3.20	.00	2.99	.49	.09	.01	.26	.03	.97	.16	.84	Calcium bicarbonate
39	.10	.15	3.00	.00	2.30	.71	.08	.02	.39	.03	.97	.08	.92	Calcium bicarbonate
40	.22	.23	1.48	.00	1.35	.40	.26	.01	.49	.14	.87	.23	.77	Calcium bicarbonate
41	.09	.14	3.11	1.27	.07	.01	2.92	.00	.39	.97	.03	.05	.95	Sodium bicarbonate
42	.48	.16	.12	.00	.32	.17	.27	.02	.75	.38	.62	.85	.15	Calcium chloride
43	.12	.09	1.16	.00	1.15	.25	.10	.02	.56	.08	.92	.15	.85	Calcium bicarbonate
44	.54	.16	.67	.00	.95	.20	.29	.02	.77	.21	.79	.51	.49	Calcium chloride
45	.51	.10	.90	.00	1.00	.16	.30	.02	.83	.21	.79	.40	.60	Calcium bicarbonate
46	.07	.07	.10	.00	.09	.12	.04	.02	.50	.22	.78	.57	.43	Calcium sulfate/ Calcium chloride
47	.13	.13	.02	.00	.14	.08	.04	.02	.51	.21	.79	.94	.06	Calcium sulfate/ Calcium chloride
48	.09	.13	1.34	.00	1.15	.30	.03	.02	.41	.04	.96	.14	.86	Calcium bicarbonate
49	.13	.63	1.10	.00	.50	.09	1.18	.01	.17	.67	.33	.41	.59	Sodium bicarbonate
50	.01	.10	.00	.00	.04	.09	.01	.01	.08	.15	.85	1.00	.00	Calcium sulfate

Five of these samples were from deep wells, a sixth was from a spring near a recharge area in the Canaan Heights area, and the seventh was from a shallow well (65 ft deep). The average depth of the five deep wells that produced sodium bicarbonate-type water is 422 ft; average depth is only 174 ft for all 43 wells sampled. The occurrence of sodium bicarbonate water types for these sites (excluding the spring and the shallow well) is most likely a result of cation exchange of calcium for sodium in the deeper parts of the aquifer. Water quality of the shallow spring is most likely reflective of shallow recharge from precipitation, which has a similar chemical signature.

The water-quality constituents that most often exceeded drinking-water standards are radon-222, fecal coliform and fecal streptococcus bacteria, iron, manganese, and pH. Other common constituents, such as sulfate, chloride, fluoride, sodium, potassium, silica, calcium, magnesium, and bicarbonate, typically did not exceed USEPA MCL's or SMCL's. Boxplots of major ions and field measurements (fig. 8) show median, 25th-percentile, and 75th-percentile values for the major constituents determined. The boxplots also illustrate maximum and outlier values above or below the 25th and 75th percentiles.

The pH at 16 (32 percent) of the 50 ground-water sites sampled is either above the 8.5 upper SMCL limit or below the 6.5 lower limit specified by the USEPA (table 7). Two of the sites where the 8.5 pH limit was exceeded are in the Greenbrier Group, and two are in the noncarbonate Pocono Group. Only four of the sites where pH is below the 6.5 pH limit are in the Greenbrier Group, whereas eight are in the noncarbonate Pottsville/Mauch Chunk and Pocono Groups. The low pH's may be a result of oxidation of pyrite, which has caused the production of acid mine drainage (AMD) in many areas of the Appalachian Plateaus Physiographic Province and in watersheds in Tucker County (Wieder and Lang, 1984). The production of AMD correlates with low pH in ground water and surface water. Water whose pH is outside the 6.5-8.5 range can cause corrosion of pipes.

High concentrations of DS also can cause problems with corrosion of pipes and encrusting of pipes and boilers (Landers, 1976). The USEPA SMCL for DS is 500 mg/L (U.S. Environmental Protection Agency, 1988b). None of the 50 sites sampled produced water with DS concentrations in excess of 500 mg/L. The maximum DS concentration was 283 mg/L.

Nitrate, a common constituent of ground water, can cause methemoglobinemia in infants, a condition that reduces the blood's ability to carry oxygen (U.S. Environmental Protection Agency, 1985). The USEPA MCL for nitrate is 10 mg/L. Nitrate and most other nutrients (nitrite, ammonia, phosphorus, and orthophosphorus) were found at low or undetectable concentrations. Likely sources of nutrients in ground water within Canaan Valley are animal feces, septic-system effluent, and sewage-treatment-plant return flows. Also, minor quantities of manure and synthetic fertilizers are used on local farms, gardens, and lawns, and the golf course at Canaan Valley State Park uses fertilizers on greens and fairways.The maximum nitrate concentration was only 4.4 mg/L, and the mean and median concentrations were 0.63 and 0.45 mg/L respectively (table 7). The maximum nitrite concentration was only 0.010 mg/L, whereas the USEPA MCL for nitrite is 1 mg/L (U.S. Environmental Protection Agency, 1988).

Iron and manganese concentrations exceeded drinking-water standards in some samples (table 7). The SMCL for iron is 300 μg/L, and the SMCL for manganese is 50 μg/L (U.S. Environmental Protection Agency, 1988b). These standards are set so as to prevent stains on plumbing fixtures, off-color water, or objectionable taste (Landers, 1976). Iron concentrations exceeded the 300-μg/L SMCL at only 1 of the 50 sites sampled (2 percent), whereas manganese exceeded the 50-μg/L SMCL at 10 of the 50 sites sampled (20 percent). Most sedimentary bedrock waters in the state of West Virginia are potential sources of iron and manganese. Pyrite, an iron sulfide mineral, is a source of iron and sulfate. Pyrite is also a primary factor in the formation of AMD (Wieder and Lang, 1984).

Other than some elevated concentrations of iron and manganese, the chemical quality of ground water within Canaan Valley is satisfactory for drinking and most other uses. Although the chemical composition of water might be satisfactory, the presence of bacteria may make the water unsuitable for human consumption without treatment. Fecal coliform (*Escherichia coli*) and fecal streptococcus bacteria, which are commonly found in the intestinal tracts of warmblooded animals and humans (American Public Health Association and others, 1989), were detected in ground water in the study area. Fecal coliform bacteria are more abundant in the digestive tracts of humans; fecal streptococci bacteria are more abundant in the digestive

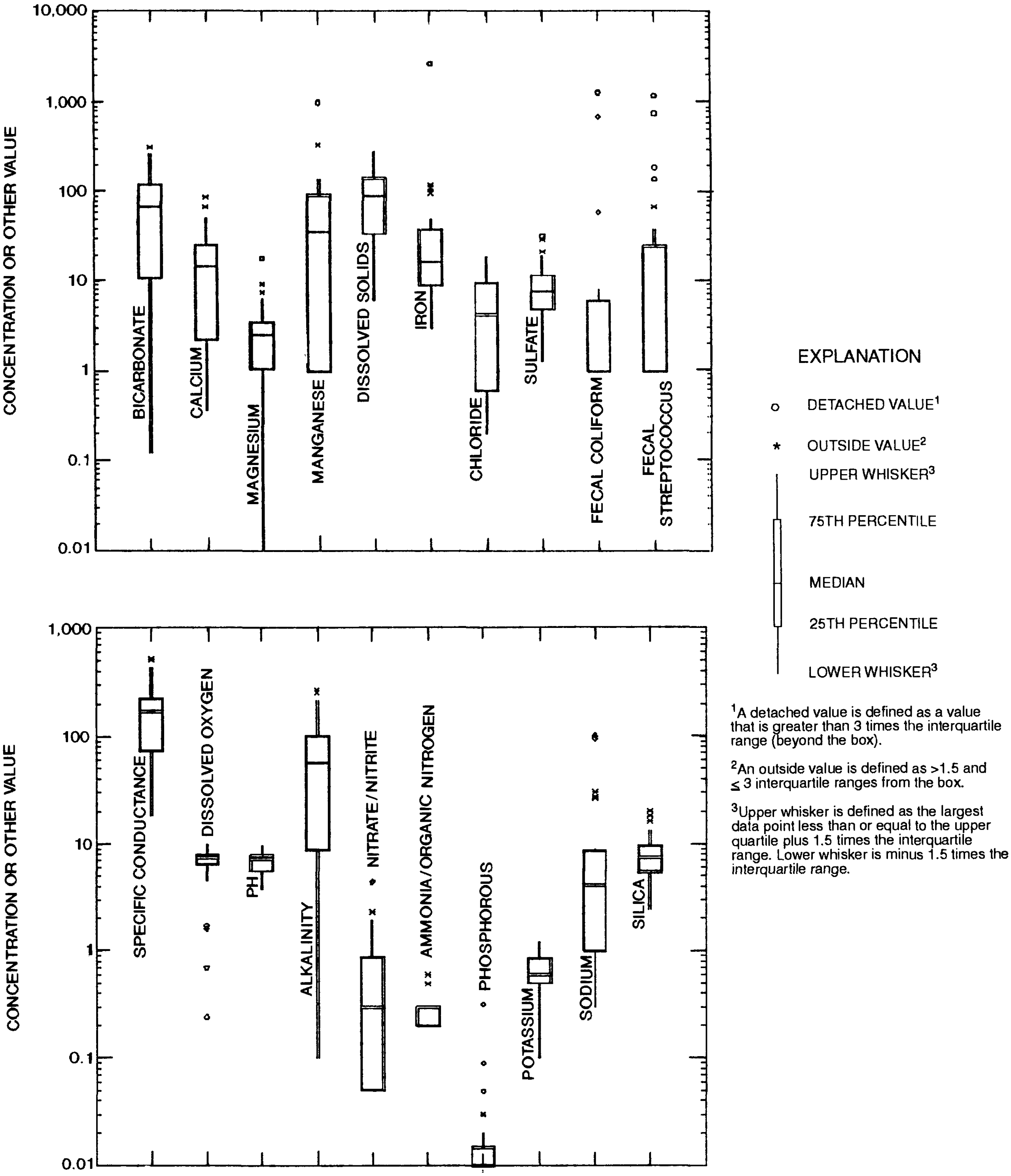

Figure 8. Range in concentrations of major ions and in values of pH, specific conductance, and alkalinity in water samples collected in Canaan Valley, West Virginia. (All data expressed in milligrams per liter except for pH (standard units), iron and manganese (micorgrams per liter), fecal coliform and fecal streptococcus bacteria (colonies per 100 milliliters), and specific conductance (microsiemens per contimeter at 25 degrees Celsius).)

tracts of animals. The bacteria themselves are usually not harmful, but their presence indicates that the water has been contaminated by animal and (or) human fecal waste. They are, therefore, used to indicate the potential presence of pathogenic bacteria and viruses that can lead to serious disease.

Water from 11 of 49 ground-water sites sampled (22 percent) had detectable concentrations of fecal coliform bacteria, and water from 24 of 50 sites sampled (48 percent) had detectable concentrations of fecal streptococcus bacteria (table 7). Improperly sited septic systems, poorly constructed and improperly grouted wells, and large populations of deer, geese, beaver, and other animals are potential contributors to bacterial contamination of wells and springs in the valley. The high proportion of fecal streptococcus bacteria to coliform bacteria could indicate that animal feces is the primary source of bacteria present within the ground water and surface water of Canaan Valley, but additional data would be needed to confirm this hypothesis. Currently, there are no definitive methods for easily distinguishing between animal and human waste as the source of contamination in water. Regardless of source of bacteria, proper grouting of wells and installation of concrete pads around surface casings as per recommendations of the West Virginia Department of Health probably would help to eliminate some of the bacterial contamination of wells within the valley (West Virginia Board of Health, 1984).

The maximum concentration of fecal streptococcus bacteria was 1,200 colonies per 100 mL of sample (col/100 mL); the mean was 76 col/100 mL, and the median was only 1 col/100 mL (table 7). The maximum concentration of fecal coliform bacteria was 1,300 col/100 mL, the mean was 49 col/100 mL, and the median was only 1 col/100 mL. Only 4 of 11 sites contaminated by fecal coliform bacteria (36 percent) are in the Greenbrier Group, whereas 7 of the 11 sites (64 percent) are in the noncarbonate Pottsville/Mauch Chunk and Pocono Groups (table 9). Fecal streptococcus bacteria concentrations were present at an equal number of sites (50 percent) in the carbonate and noncarbonate areas. Therefore lithology seems to be a factor in bacterial contamination of ground water only for fecal coliform bacteria (primarily in the Pocono and Pottsville/Mauch Chunk aquifer zones). A possible explanation for this finding is that porous, easily drained sandy soil, derived from Pottsville and, to a lesser extent, Mauch Chunk and Pocono bedrock, allows rapid infiltration of septic-system discharge into ground water (Kozar, 1995).

Radon-222, which in great enough concentration (activity levels) can destroy lung tissue and cause lung cancer, is a naturally occurring radioactive gas common in bedrock aquifers of West Virginia (Kozar, 1995). The initial source of radon is uranium. Radioactive decay of uranium to radium and then to radon is the process by which radon gas is formed (Otton, 1992). Radon gas derived from radioactive elements within bedrock can accumulate in poorly ventilated areas such as basements (Otton, 1992). Radon gas present in water can degas into homes when water valves are opened. Showers are a common mechanism by which radon gas escapes from ground water into household air.

Radon gas in water is measured in picocuries per liter (pCi/L). One picocurie is equivalent to the decay of about two atoms per minute. In general, 10,000 pCi/L of radon in water will degas to an equivalent volume of 1 pCi/L in indoor air (Otton, 1992). The USEPA MCL for radon in air within buildings is currently 4 pCi/L. The current USEPA proposed MCL for radon in water is 300 pCi/L (U.S. Environmental Protection Agency, 1991). All rocks contain some uranium, the initial source of radon. Sandstone, limestone, and coal are common rocks in West Virginia that can contain significant amounts of uranium. Water samples from nine wells and three springs were analyzed for the presence of radon-222 (table 10). The maximum concentration reported was 1,900 pCi/L, and the minimum was <80 pCi/L. The mean concentration for the 12 sampled sites was 744 pCi/L, and the median concentration was 505 pCi/L. Concentrations at 8 of the 12 sites sampled (67 percent) exceeded the proposed 300-pCi/L [USEPA] MCL. The mean radon concentration for five wells in the Pottsville/Mauch Chunk Group was 582 pCi/L, whereas the mean for four wells in the Pocono Group was 888 pCi/L and the mean for three wells in the Greenbrier Group was 330 pCi/L. Thus, on the basis of a small data set, radon contamination of ground water appears to be more severe in the noncarbonate Pocono and Pottsville/Mauch Chunk Groups than it is in the Greenbrier Group. This pattern is not surprising, in that shale and sandstone aquifers, such as the Pottsville/Mauch Chunk and Pocono Groups, tend to have higher concentrations of dark shales than do calcium-rich carbonate aquifers.

Table 9. Statistical summary of ground-water-quality data segregated by aquifer, Canaan Valley, West Virginia

[Data in this table are in milligrams per liter except for specific conductance, pH, fecal coliform and fecal streptococcus bacteria, iron, and manganese. Specific conductance is reported in microsiemens per centimeter, pH in standard units, bacteria in colonies per 100 milliliters of sample, and iron and manganese in micrograms per liter. Alkalinity is expressed in milligrams per liter as $CaCO_3$]

Constituent	Pocono aquifer				Greenbrier aquifer				Pottsville/Mauch Chunk aquifer			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Specific conductance	243	211	18.5	510	212	193	29.0	470	111	119	24.0	194
Dissolved oxygen	5.5	7.0	0.2	8.7	7.0	7.8	0	11.2	7.8	7.7	6.2	9.9
pH	7.3	7.3	4.6	9.5	7.3	7.5	4.0	9.8	6.0	6.3	3.8	7.8
Alkalinity	116	90.8	0.1	260	103	9.0	1.0	230	27.8	23.5	.1	67.0
Phosphorous	.04	.01	.01	.32	.01	.01	.01	.04	.01	.01	.01	.05
Nitrate/nitrite	.59	.13	.05	4.40	.54	.55	.05	1.20	.87	.57	.05	2.30
Calcium	26.3	21.5	.4	89.0	33.8	32.0	1.4	72.0	10.8	8.6	.9	23.0
Dissolved solids	140	130	11.0	283	125	115	16.0	280	54.7	59.0	6.0	100
Magnesium	4.4	3.05	.01	18.0	4.3	2.2	.16	16.0	1.9	1.7	.39	3.6
Manganese	111	12.0	1.00	1,000	6.00	1.00	1.00	36.0	73.0	84.0	1.00	140
Potassium	.72	.70	.40	1.20	.52	.40	.10	1.10	.60	.60	.10	1.10
Silica (SiO2)	9.7	8.0	4.9	20.0	7.0	6.5	4.8	11.0	6.7	6.4	2.4	12.0
Sodium	20.9	6.7	.7	100	7.1	1.80	.7	67.0	4.9	1.7	.3	27.0
Iron	205	11.0	3.00	2,700	13.0	6.00	3.00	120	51.0	37.0	5.00	120
Chloride	5.56	4.15	.20	15.0	6.44	3.40	.10	49.0	5.91	3.70	.30	19.0
Sulfate	11.2	7.95	1.30	33.0	8.97	7.35	2.20	27.0	8.33	6.10	3.10	30.0
Fecal coliform	60	<1	<1	700	12	<1	<1	200	132	<1	<1	1,300
Fecal streptococcus	33	<1	<1	190	53	<1	<1	240	198	<1.5	<2	1,200

Table 10. Radon data collected at ground-water sites in Canaan Valley, West Virginia
[pCi/L, picocuries per liter]

Site number (plate 1)	Station number	Latitude	Longitude	Geologic unit	Date	Radon-222, total (pCi/L)	Radon-222, total, 2-sigma (pCi/L)
8	390147079263701	39°01'47''N	079°26'37''W	Greenbrier	07-17-91	230	38
19	390313079245301	39°03'13''N	079°24'53''W	Pocono	07-16-91	170	40
21	390324079232501	39°03'24''N	079°23'25''W	Greenbrier	07-15-91	340	25
23	390329079240701	39°03'29''N	079°24'07''W	Pocono	07-16-91	<80	25
28	390338079235201	39°03'38''N	079°23'52''W	Pocono	07-16-91	1,700	47
31	390356079234201	39°03'56''N	079°23'42''W	Pocono	07-16-91	1,600	41
34	390358079253901	39°03'58''N	079°25'39''W	Greenbrier	07-15-91	420	28
45	390546079254501	39°05'46''N	079°25'45''W	Mauch Chunk	07-17-91	1,000	33
47	390559079254801	39°05'59''N	079°25'48''W	Pottsville	07-16-91	710	41
48	390600079254401	39°06'00''N	079°25'44''W	Pottsville	07-16-91	380	40
49	390610079255301	39°06'10''N	079°25'53''W	Pottsville	07-16-91	190	25
50	390612079254501	39°06'12''N	079°25'45''W	Pottsville	07-16-91	630	27

Pesticide use within Canaan Valley is not widespread and is associated primarily with greenskeeping activities at the golf course in Canaan Valley State Park, operations at a few small privately owned orchards and farms, and household lawn care and gardening. As mentioned previously, ground-water samples from five sites were collected and analyzed for organochlorine, organophosphate, and triazine pesticides (appendix B). Of the 42 pesticides analyzed for, only 1 (at site 8, plate 1) was found at a detectable concentration: the herbicide 2,4,-D (2,4-dichlorophenoxyacetic acid) was detected at a concentration of 0.03 µg/L. The USEPA MCL for 2,4,-D is 70 µg/L.

Nine ground-water sites were sampled five times from November 1990 to July 1991 to characterize seasonal variations in water chemistry (appendix D). Results indicate that ground-water chemistry does not vary much by season. Similar attempts to document seasonal variations in water chemistry in previous investigations (Kozar and others, 1991; Shultz, 1995) produced similar results; that is, water from fractured bedrock aquifers within West Virginia varies only slightly in composition of dissolved constituents throughout the year. The only perceptible trend was a slight increase in fecal coliform and fecal streptococcus bacteria in March and July 1991.

Factors Affecting Water Quality

Two primary factors, geochemical and anthropogenic, affect the quality of water in Canaan Valley. Geochemical factors are natural processes that affect water quality primarily through the dissolution of minerals in rocks as ground water flows through them. Several of the most common processes are pyrite oxidation, resulting in sulfate production; radioactive decay of uranium and its daughter products, resulting in radon gas in ground waters; and reduction and oxidation of iron and manganese minerals combined with dissolution of carbonate rock within bedrock aquifers, resulting in high concentrations of iron, manganese, and alkalinity in ground water. Anthropogenic factors, those that result primarily from human activity, include acid rain, resulting in lowered pH of stream water; use and storage of organic chemicals, resulting in ground-water contamination; agricultural practices, resulting in nitrate, ammonia, and fecal bacteria contamination of surface water and ground water; septic-system effluent discharge to ground-water reservoirs, resulting in bacterial contamination; and highway deicing, resulting in chloride contamination of ground water and surface water.

Geochemical Factors

Analysis of water-quality data for the three aquifer zones (table 9) can aid in understanding the geochemical processes in a particular aquifer system. The lowest median values for alkalinity, pH, specific conductance, calcium, DS, magnesium, silica, sodium, and sulfate among the three zones were found for water from the Pottsville/Mauch Chunk Group. The small amount of carbonate minerals and calcite cement in sandstone of the noncarbonate Pottsville/Mauch Chunk is responsible for the low alkalinity and low DS concentration in water from this aquifer zone.

The low median values of DS, calcium, magnesium, alkalinity, and pH in water from the Pottsville/Mauch Chunk Group (table 9) reflect bedrock type. The Pottsville is mostly massive sandstone, and the Mauch Chunk is mostly red shale. Thus, pH and concentrations of alkalinity, DS, calcium, and magnesium would be expected to be low because the Pottsville/Mauch Chunk is not a carbonate system, and iron and manganese concentrations would be expected to be high because most noncarbonate aquifers contain pyrite and other iron- and manganese-bearing oxyhydroxide minerals. Water from the Pottsville/Mauch Chunk Group had high dissolved-oxygen concentrations (table 9), resulting mostly from the highly permeable soils overlying bedrock that allow rapid infiltration of oxygen-rich water.

Water from the Greenbrier Group had the lowest median concentrations of iron, manganese, potassium, and chloride, the highest median concentrations of calcium and dissolved oxygen, and the highest median pH of the three lithologic units (table 9). Calcium, resulting from dissolution of calcium carbonate (limestone), is the primary dissolved constituent in most carbonate-aquifer waters. The median pH of the Greenbrier Group is typical of that for carbonate aquifers. The high dissolved-oxygen concentration of water within the Greenbrier Group also is characteristic of limestone-dominated aquifer systems. Enlargement of fractures by dissolution of calcium carbonate increases the near-surface permeability of the bedrock, enhancing ground-water recharge; this, in turn, allows rapid infiltration of oxygen-rich recharge water to the underlying aquifer.

Water from the Pocono Group had the highest median values of specific conductance, alkalinity, DS, magnesium, potassium, silica, sodium, chloride, and sulfate. Whereas the Pottsville/Mauch Chunk Group is dominated by iron- and manganese-bearing minerals, the Pocono Group, which is composed primarily of sandstone, produced water with the highest concentrations of most of the other minerals found in noncarbonate aquifers. Water from the Pocono Group also had the lowest median dissolved-oxygen and nitrate concentrations and the lowest mean fecal streptococcus concentrations among the three lithologic units (table 9). The low dissolved-oxygen concentration of water from the Pocono Group indicates that it is less susceptible to contamination than the Pottsville/Mauch Chunk and Greenbrier aquifer zones are. The low nitrate and fecal streptococcus bacteria concentrations in this zone also indicate less susceptibility to contamination, probably because less permeable bedrock and (or) soils retard the downward percolation of contaminants. Moreover, well depths in the Pocono Group are the greatest, on average, among the three lithologic units, an indication that dissolved oxygen and contaminants such as bacteria, nitrate, and chloride have a longer path to travel and are therefore less likely to reach the water table.

Anthropogenic Factors

Human activities can also affect the quality of ground water in a region. Nitrate and fecal bacteria are common contaminants found in ground water. Sources of these constituents could be discharge of bacterially contaminated septic-system effluent, sewage-treatment-plant return flows, fertilizers used on lawns and gardens and on the local golf course, and animal wastes. Nitrification of ammonia present in these sources can result in high concentrations of nitrate in ground water.

Data supplied by a local well driller (Charles Henderson, Henderson Drilling, oral commun., 1992) indicate that many drillers install long casings in the Pottsville/Mauch Chunk Group to avoid shallow contamination in this zone. The high concentrations of iron and manganese in this zone support this reasoning. Apparently, however, long casings do not prevent contamination to the degree anticipated because the Pottsville/ Mauch Chunk Group is contaminated with fecal coliform and fecal streptococcus bacteria. Many wells in Canaan Valley are not properly cased and grouted, especially older wells installed before legislation required wells to be grouted and concrete well pads to be installed (West Virginia Board of Health, 1984). Improper casing and grouting of wells may be responsible for bacterial contamination of wells within the Pottsville/Mauch Chunk aquifer zone.

Relation Between Precipitation, Ground Water, and Surface Water

Analysis of rainfall in an area can provide significant insight into the factors that affect ground-water quality. Rain typically has significant concentrations of nitrate, ammonia, and sulfate. Thus, an examination of the shallow ground water in an area should indicate that nitrate, sulfate, and ammonia concentrations are similar to those in precipitation in the area. Rain is a source of sulfate and nitrate in ground water and surface water of Canaan Valley. It affects the quality of ground water in the upland recharge areas of the valley, especially in the shallow zones of the Pottsville/Mauch Chunk Group. Rain has lower concentrations of dissolved constituents than most ground water and surface water in Canaan Valley. The mean concentrations of alkalinity, chloride, nitrate, magnesium, sodium, potassium, sulfate, ammonia, and calcium for rain collected at the Fernow Experimental Forest near Parsons during the Canaan Valley ground-water investigation are listed in table 11. Data for these same constituents in ground water are listed in table 7 and for those in surface water in table 12. In all cases, concentrations of these constituents in the valley were higher in ground water and surface water than in precipitation. Concentrations of nitrate and sulfate, however, were similar in rain and in ground water and surface water. These data indicate that acid rain could be an important source of nitrate and sulfate in ground water and surface water within the valley, although possibly not the only source.

A spring fed by the Pottsville Group in the Canaan Heights area (site 49 on plate 1) was sampled as part of a bimonthly sampling network. The spring is at an elevation of 3,750 ft. Bearden Knob, the highest point in the recharge area of the spring, is at an elevation of 3,853 ft. Thus, the spring derives most of its recharge from the upper 100 ft of Pottsville rock, which crops out to the east of the spring. The sole source of recharge is precipitation, which falls on thin rock overburden and shallow topsoil. A review of the bimonthly water-quality data for this spring (appendix D) and for three additional sites in shallow bedrock aquifers in the Canaan Heights area (sites 37, 43, and 50 on plate 1) indicate that the water for these sites is similar in chemical composition to precipitation at the Fernow Experimental Forest near Parsons (table 11). Average specific conductance for the four sites was 19.2, 27.8, 58.2, and 25.0 µS/cm. The average specific conductance for precipitation from the Fernow Forest was 38.6 µS/cm. Thus, shallow ground-water recharge in the upper part of the Pottsville/Mauch Chunk Group is primarily from rain, and acid precipitation may therefore have a significant effect on the quality of shallow ground water throughout the valley.

A comparison between the quality of ground water and surface water in an area can provide insight into the geochemical processes in an aquifer or a stream system. In general, the quality of ground water in Canaan Valley differs from that of surface water in several respects. First, the bacteria concentrations in surface water (table 12 and appendix C) are much higher than those typically found in ground water (table 7). Water-quality data for the surface-water sites sampled are listed in appendix C. In 100 percent of the surface water samples collected, concentrations of fecal coliform exceeded the USEPA MCL, whereas concentrations in only 22 percent of ground-water samples exceeded the USEPA MCL. The mean and median fecal coliform concentrations for surface-water sites sampled were 371 and 255 col/100 mL, respectively (appendix C). The mean and median fecal coliform concentrations for ground-water sites sampled were only 49 and 1 col/100 mL, respectively (table 7).

Surface water is easily contaminated by bacteria from various sources. Bacteria from animal feces is a primary source because of the many deer, geese, beaver, and other wildlife in the valley.

Individual domestic septic systems are an additional potential source for bacteria that could seep into surface-water supplies by percolating through soil horizons into streams or by ground water that discharges to streams. Return flows from package sewage-treatment plants are a third important source of bacteria entering the surface waters of the area. Septic systems are more of a concern for ground-water contamination than for surface-water contamination. Impermeable soils and bedrock and microbial degradation of fecal wastes in the soil and ground water, however, can reduce the contamination of ground-water reservoirs by fecal wastes.

Eliminating bacterial contamination of ground- and surface-water supplies by deer, geese, and other wildlife is virtually impossible. Proper grouting and casing of wells may help to reduce ground-water contamination but will not significantly reduce surface-water contamination. Chlorination is the most common method of treatment for bacterially contaminated surface- or ground-water supplies.

Table 11. Mean values for selected water-quality characteristics of precipitation at the Fernow Forest, West Virginia

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; in., inches; meq/L, milliequivalents per liter. Data from Mary Beth Adams, U.S. Department of Agriculture, Forest Service, written commun., 1993]

Month sample collected	pH	Specific conductance (μS/cm)	Alkalinity (mg/L as $CaCO_3$	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Ammonia (mg/L)
Nov. 90	4.38	37.8	12.75	0.70	0.43	3.97	0.71	0.21	6.08	0.10	0.17
Dec. 90	4.39	19.0	4.00	.17	.13	1.87	.18	.03	.07	.18	.07
Jan. 91	4.27	24.2	5.80	.12	.34	1.84	.12	.01	.04	.06	.13
Feb. 91	4.10	36.8	6.50	.18	.45	2.93	.15	.03	.05	.10	.21
Mar. 91	4.38	23.8	4.50	.13	.38	2.45	.36	.04	.08	.08	.29
Apr. 91	4.10	41.0	9.00	.24	.52	4.50	.49	.08	.37	.14	.41
May 91	4.41	28.0	8.25	.10	.60	3.50	1.01	.24	1.51	.10	.31
June 91	3.92	61.3	9.33	.15	.35	5.25	.20	.02	.07	.07	.19
July 91	3.94	55.0	8.00	.05	.35	4.00	.21	.02	.03	.06	.05
Aug. 91	3.90	58.7	9.00	.15	.50	7.85	.37	.03	.07	.08	.24
Mean	**4.18**	**38.6**	**7.71**	**.20**	**.41**	**3.82**	**.38**	**.07**	**.84**	**.10**	**.21**

Month sample collected	Total precip. (in.)	Alkalinity (mg/L as HCO_3)	Alkalinity (meq/L as HCO_3)	Chloride (meq/L)	Nitrate (meq/L)	Sulfate (meq/L)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	Potassium (meq/L)	Ammonia (meq/L)
Nov. 90	1.89	15.54	0.255	0.020	0.007	0.083	0.035	0.017	0.264	0.003	0.009
Dec. 90	5.12	4.88	.080	.005	.002	.039	.009	.002	.003	.005	.004
Jan. 91	7.22	7.07	.116	.003	.005	.038	.006	.001	.002	.002	.007
Feb. 91	3.65	7.92	.130	.005	.007	.061	.007	.002	.002	.003	.012
Mar. 91	5.77	5.49	.090	.004	.006	.051	.018	.003	.003	.002	.016
Apr. 91	6.16	10.97	.180	.007	.008	.094	.024	.007	.016	.004	.023
May 91	2.11	10.06	.165	.003	.010	.073	.050	.020	.066	.003	.017
June 91	3.42	11.38	.186	.004	.006	.109	.010	.002	.003	.002	.010
July 91	2.74	9.75	.160	.001	.006	.083	.010	.002	.001	.002	.002
Aug. 91	2.78	10.97	.180	.004	.008	.163	.018	.002	.003	.002	.013
Mean	**4.09**	**9.40**	**.150**	**.006**	**.006**	**.079**	**.019**	**.006**	**.036**	**.003**	**.011**

Table 12. Statistical summary of selected surface-water-quality data, Canaan Valley, West Virginia

[USEPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; mg/L, micrograms per liter; col/100 mL, colonies per 100 milliliters; N/A, not applicable]

Property or constituent (reporting unit)		Mean value	Median value	Standard deviation	Maximum	Minimum	USEPA MCL, SMCL, or proposed MCL	Percentage of samples exceeding standards
Specific conductance	(µS/cm)	133	144	477	230	30.0	None	N/A
Dissolved oxygen	(mg/L)	8.5	8.1	2.2	14.4	5.8	None	N/A
pH	(standard units)	7.63	7.60	.61	9.10	6.80	6.5-8.5	36
Ammonia + organic N	(mg/L)	.59	.55	.23	1.30	<.20	None	N/A
Ammonia	(total, mg/L)	.03	.02	.02	.08	<.01	None	N/A
Phosphorus	(total, mg/L)	.04	.03	.04	.20	<.01	None	N/A
Orthophosphorus	(mg/L)	.02	.01	.03	.13	<.01	None	N/A
Nitrate	(mg/L)	.11	.05	.10	.43	<.05	10.0 mg/L	0
Nitrite	(mg/L)	.01	<0.01	.00	.03	<.01	1.0 mg/L	0
Calcium	(mg/L)	19.8	19.0	9.5	41.0	1.3	None	N/A
Dissolved solids	(mg/L)	88	87	32	162	13	500 mg/L	0
Magnesium	(mg/L)	1.8	1.8	.6	3.2	.7	None	N/A
Manganese	(µg/L)	118	110	90.0	440	<1.00	50 µg/L	82
Potassium	(mg/L)	.76	.70	.28	1.60	.40	None	N/A
Silica	(mg/L)	2.7	2.9	1.0	4.2	.30	None	N/A
Sodium	(mg/L)	3.6	2.9	2.0	7.8	.70	None	N/A
Iron	(µg/L)	570	570	330	1,200	10.0	300 µg/L	77
Chloride	(mg/L)	4.53	4.30	3.22	12.0	.30	250 mg/L	0
Sulfate	(mg/L)	8.56	8.20	3.83	18.0	2.70	250 mg/L	0
Fluoride	(mg/L)	.11	.10	.03	.20	<.10	2 mg/L	0
Fecal coliform	(col/100 mL)	371	255	408	1,600	7	0/100 mL	100

Concentrations of most chemical constituents, including fluoride, sulfate, chloride, sodium, silica, magnesium, DS, calcium, and nitrate are higher in ground water (table 7) than in surface water (table 12). Longer residence time of ground water in contact with bedrock is the primary explanation for the higher concentrations of these constituents in ground water. Minerals within bedrock are the primary source of silica, magnesium, potassium, calcium, sodium, sulfate, and fluoride in ground- and surface-water reservoirs within the valley.

A few constituents were found at higher concentrations in surface water than in ground water. Among them are fecal coliform bacteria, organic ammonia, phosphorus, iron, manganese, and dissolved oxygen. The mean concentrations of phosphorus, orthophosphorus, and ammonia for surface-water sites, although greater than those in ground water, were only 0.044, 0.021, and 0.59 mg/L, respectively. Mean iron and manganese concentrations were 7.5 and 2.5 times higher, respectively, in surface water (table 12) than in ground water (table 7). Iron concentrations exceeded the USEPA SMCL at 77 percent of surface-water sites, whereas iron concentrations at only 2 percent of ground-water sites exceeded the SMCL. Manganese concentrations exceeded the USEPA SMCL at 82 percent of surface-water sites, whereas manganese concentrations at only 20 percent of ground-water sites exceeded the SMCL. The 570-µg/L median concentration of iron for surface-water sites sampled in Canaan Valley is somewhat higher than would be expected for a stream not affected by acid mine drainage. The reason for higher concentrations of iron and manganese in surface water is unclear at present. One possible explanation is that bacteria and other microorganisms are involved in the oxidation and reduction of iron- and manganese-bearing minerals. Certain bacteria, such as *Gallionella, Crenothrix,* and *Leptothrix* can oxidize iron at a rapid rate (Hem, 1985). Other sulfur-oxidizing bacteria can attack sulfide minerals such as pyrite and marcasite, liberating iron into surface- and ground-water reservoirs. If iron and manganese-rich ground water is the primary source of discharge to surface-water tributaries, however, the dissolved manganese and iron present would most likely quickly be oxidized in oxygen-rich streams and precipitated as iron and manganese oxyhydroxides. This process would most likely cause iron and manganese concentrations to decrease in surface water and accumulate in stream sediments as oxyhydroxide precipitates. Because iron and manganese concentrations are higher in surface water than in ground water, some other process must be keeping iron and manganese from being oxidized in the oxygen-rich environment of Canaan Valley streams.

The presence of vast areas of wetlands within Canaan Valley indicates that various organic complexes, such as fulvic and humic acids, are present in significant concentrations. Wetlands are known to contain large amounts of decaying vegetation such as moss and algae, as well as other sources of organic carbon. It is possible that iron and manganese are being assimilated in various organic complexes (Stumm and Morgan, 1981) and are therefore not available for oxidation in oxygen-rich streams. Analysis of surface-water samples is, therefore, most likely to detect iron and manganese in organic, rather than dissolved, ionic species. Bacterial reduction of iron- and manganese-bearing minerals and organic complexation could be responsible for the anomalously high concentrations of iron and manganese in Canaan Valley streams. Additional data would need to be collected and analyzed to verify this hypothesis. The forms (dissolved or organic) and valence states (if dissolved) of iron and manganese and the forms of organic carbon present in various parts of the hydrologic system must be determined for this phenomenon to be fully understood. Whatever the mechanism that may be responsible for adding a large flux of iron and manganese into surface waters of the valley, it is probable that iron- and manganese-bearing oxides, hydroxides, and sulfides within bedrock are the original source of the iron and manganese in ground water and surface water.

The mean dissolved-oxygen concentration of surface water also is higher than that found in ground water within the valley. The mean and median dissolved-oxygen concentrations for surface-water sites were 8.5 and 8.1 mg/L, respectively (table 12). The mean and median dissolved-oxygen concentrations for ground-water sites (table 7) were 6.73 and 7.60 mg/L, respectively. The higher concentrations in surface water reflect samples that are at equilibrium with respect to atmospheric oxygen. Most ground-water systems are partly isolated from the atmosphere; therefore, ground water tends to have lower concentrations of dissolved oxygen than surface water does. Moreover, production of oxygen by algae, cyanobacteria, and aquatic plants can be responsible for high concentrations of oxygen in surface water.

SUMMARY

Canaan Valley, a popular recreation and retirement area in rural Tucker County, W.Va., was studied by the U.S. Geological Survey to help define availability and quality of local ground-water resources. Canaan Valley is underlain by carbonate and noncarbonate sedimentary rocks. Ground-water flow is primarily in joints, faults, bedding-plane partings, and other fractures.

Well yields are generally adequate for most domestic and commercial needs. The average yields of wells inventoried within the Pottsville/Mauch Chunk, Greenbrier, and Pocono Groups were 23.3, 22.5, and 19.2 gal/min, respectively. The average transmissivities for sites inventoried in the Pottsville/Mauch Chunk, Greenbrier, and Pocono Groups were 7.0, 110, and 20.4 ft^2/d, respectively. Flow lines from a potentiometric-surface map prepared for the valley indicate that the general direction of ground-water flow is from the ridges surrounding the valley towards the North Branch or the Blackwater River. An exception is in the center of the valley, where ground water flows outward from a topographic high in the Pocono sandstone. A ground-water recharge rate estimated for the southern part of the valley based on discharge data for the gaging station at Cortland was 0.892 $Mgal/d/mi^2$.

Approximately 22 Mgal/yr of ground water is withdrawn from domestic and commercial wells. Approximately 199.4 Mgal/yr of surface water is withdrawn for golf-course irrigation, snow making, and general operations at local ski resorts and state parks. Total water input (recharge) to the basin based on precipitation amounts to 51 in. annually. Of the 51 in. of input, 18.7 in. leaves Canaan Valley by ground-water discharge to streams, and 9.3 in. is surface runoff to streams. Evapotranspiration accounts for 20 to 23 in. of output, and as much as 3.5 in. may be exiting the study area as underflow.

Analysis of ground-water-quality data for Canaan Valley indicates that iron concentrations at only 2 percent of ground-water sites sampled exceeded the USEPA secondary maximum contaminant level (SMCL) for drinking water, whereas concentrations of manganese exceeded the USEPA SMCL at 20 percent of the sites. At 28 percent of ground-water sites sampled, pH was either above or below the USEPA SMCL. Bacteria in ground water were the most significant contaminants of concern; fecal coliform concentrations exceeded the USEPA maximum contaminant levels (MCL) at 22 percent of ground-water sites sampled, and fecal streptococcus concentrations exceeded the USEPA MCL at 48 percent.

Radon-222, a radioactive carcinogenic gas, is another contaminant of concern in the valley. At 8 of the 12 ground-water sites sampled and analyzed for radon (67 percent), the radon concentration exceeded the proposed USEPA MCL of 300 pCi/L. Radon concentrations are higher in the noncarbonate Pocono and Pottsville/Mauch Chunk Groups than in the Greenbrier Group. The mean radon concentrations for five wells in the Pottsville/Mauch Chunk Groups and four wells in the Pocono Group were 582 and 888 pCi/L, respectively. The mean radon concentration for wells sampled in the Greenbrier Group was only 330 pCi/L.

Of 42 pesticides sampled at five sampling locations, only 1 was found at a detectable concentration: the herbicide 2,4-D (2,4-dichlorophenoxyacetic acid) was detected at a concentration of 0.03 μg/L in one well (the USEPA MCL for 2,4-D is 70 μg/L).

Acid precipitation is a possible source of nitrate, sulfate, and ammonia in ground water in Canaan Valley. Minerals in the bedrock, however, are the primary source of iron, manganese, and other dissolved constituents in ground water of the area. Reduction and oxidation of iron and manganese oxyhydroxides and oxidation of pyrite are processes that could be responsible for high iron and manganese concentrations found in ground water of Canaan Valley.

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APPENDIXES

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia

[col, colonies; deg. C, degrees Celsius; IT, incremental titration; MF, membrane filtration; mg/L, milligrams per liter; mL, milliliters; mm, millimeters; µm, micrometers (microns); µS/cm, microsiemens per centimeter at 25 degrees Celsius. Degree, minute, and second symbols omitted from latitudes and longitudes. Missing data represented by dashes]

Site number	Station number	Latitude	Longitude	Geologic unit	Date sampled	Temperature, water (deg C)	Barometric pressure (mm of Hg)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)
1	390018079281201	39 00 18 N	079 28 12 W	Pocono	07-16-91	11.0	674	295	7.1
2	390034079280701	39 00 34 N	079 28 07 W	Pocono	07-16-91	13.0	679	510	7.9
3	390107079250101	39 01 07 N	079 25 01 W	Greenbrier	07-16-91	8.5	678	70	0.0
4	390119079255601	39 01 19 N	079 25 56 W	Greenbrier	07-16-91	10.0	681	172	9.3
5	390122079263701	39 01 22 N	079 26 37 W	Pocono	07-17-91	11.0	678	420	7.4
6	390127079262801	39 01 27 N	079 26 28 W	Pocono	07-16-91	12.5	681	420	6.9
7	390133079251901	39 01 33 N	079 25 19 W	Pocono	07-16-91	10.5	681	223	7.6
8	390147079263701	39 01 47 N	079 26 37 W	Greenbrier	07-17-91	11.0	677	470	8.6
9	390205079253401	39 02 05 N	079 25 34 W	Greenbrier	07-15-91	9.0	682	200	7.1
10	390218079263801	39 02 18 N	079 26 38 W	Greenbrier	07-15-91	12.0	681	310	3.8
11	390231079235501	39 02 31 N	079 23 55 W	Pocono	07-16-91	9.5	682	192	7.6
12	390236079264701	39 02 36 N	079 26 47 W	Pocono	07-15-91	10.5	680	430	8.6
13	390237079235701	39 02 37 N	079 23 57 W	Greenbrier	07-16-91	10.0	682	185	8.2
14	390243079262801	39 02 43 N	079 26 28 W	Greenbrier	07-17-91	10.0	679	310	7.6
15	390247079234901	39 02 47 N	079 23 49 W	Greenbrier	07-17-91	12.0	680	153	8.4
16	390254079265001	39 02 54 N	079 26 50 W	Greenbrier	07-16-91	10.5	681	130	6.6
17	390307079234201	39 03 07 N	079 23 42 W	Greenbrier	07-15-91	13.0	681	190	7.1
18	390312079265201	39 03 12 N	079 26 52 W	Greenbrier	07-16-91	12.0	684	345	2.6
19	390313079245301	39 03 13 N	079 24 53 W	Pocono	07-16-91	12.5	680	225	.2
20	390316079261201	39 03 16 N	079 26 12 W	Greenbrier	07-17-91	10.0	681	73	6.3
21	390324079232501	39 03 24 N	079 23 25 W	Greenbrier	07-15-91	18.5	682	134	10.4
22	390328079225901	39 03 28 N	079 22 59 W	Greenbrier	07-17-91	9.5	677	67	7.8
23	390329079240701	39 03 29 N	079 24 07 W	Pocono	07-16-91	10.0	682	81	1.6
24	390332079260401	39 03 32 N	079 26 04 W	Pocono	07-17-91	10.5	682	200	4.5
25	390332079265901	39 03 32 N	079 26 59 W	Greenbrier	07-17-91	2.0	680	195	7.7

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Latitude	Longitude	Geologic unit	Date sampled	Temperature, water (deg C)	Barometric pressure (mm of Hg)	Specific conductance (μS/cm)	Oxygen, dissolved (mg/L)
26	390334079253001	39 03 34 N	079 25 30 W	Greenbrier	07-17-91	10.0	680	29	8.5
27	390336079244701	39 03 36 N	079 24 47 W	Pocono	07-17-91	12.5	679	200	1.7
28	390338079235201	39 03 38 N	079 23 52 W	Pocono	07-16-91	11.5	680	21	6.7
29	390346079241501	39 03 46 N	079 24 15 W	Pocono	07-17-91	11.0	678	167	0.7
30	390352079263801	39 03 52 N	079 26 38 W	Greenbrier	07-17-91	10.5	678	312	4.0
31	390356079234201	39 03 56 N	079 23 42 W	Pocono	07-16-91	11.5	680	18	7.9
32	390356079254201	39 03 56 N	079 25 42 W	Greenbrier	07-15-91	14.5	684	262	6.6
33	390356079270001	39 03 56 N	079 27 00 W	Greenbrier	07-16-91	10.0	682	190	8.6
34	390358079253901	39 03 58 N	079 25 39 W	Greenbrier	07-15-91	9.0	684	233	9.4
35	390409079225201	39 04 09 N	079 22 52 W	Greenbrier	07-17-91	12.0	676	140	8.8
36	390410079244301	39 04 10 N	079 24 43 W	Pottsville	07-15-91	14.0	684	83	6.7
37	390446079270501	39 04 46 N	079 27 05 W	Mauch Chunk	07-16-91	14.0	685	52	8.8
38	390448079254801	39 04 48 N	079 25 48 W	Greenbrier	07-17-91	10.0	680	370	11.2
39	390457079252601	39 04 57 N	079 25 26 W	Greenbrier	07-17-91	10.0	681	362	8.2
40	390458079255701	39 04 58 N	079 25 57 W	Greenbrier	07-17-91	9.5	678	218	4.4
41	390507079264301	39 05 07 N	079 26 43 W	Greenbrier	07-16-91	11.5	---	310	1.3
42	390527079254501	39 05 27 N	079 25 45 W	Greenbrier	07-16-91	14.0	680	73	9.3
43	390534079254401	39 05 34 N	079 25 44 W	Mauch Chunk	07-16-91	10.0	679	154	8.8
44	390540079255001	39 05 40 N	079 25 50 W	Mauch Chunk	07-17-91	9.5	673	169	8.1
45	390546079254501	39 05 46 N	079 25 45 W	Mauch Chunk	07-17-91	10.5	676	168	7.0
46	390558079254601	39 05 58 N	079 25 46 W	Pottsville	07-16-91	10.5	672	48	9.9
47	390559079254801	39 05 59 N	079 25 48 W	Pottsville	07-16-91	9.5	672	65	6.2
48	390600079254401	39 06 00 N	079 25 44 W	Pottsville	07-16-91	10.0	670	155	7.5
49	390610079255301	39 06 10 N	079 25 53 W	Pottsville	07-16-91	17.5	672	194	7.7
50	390612079254501	39 06 12 N	079 25 45 W	Pottsville	07-16-91	11.5	669	24	7.7

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	pH, water water, whole, field	Alkalinity, water, dissolved, IT, field (mg/L as $CaCO_3$)	Carbonate, water, dissolved, IT, field (mg/L as CO_3)	Bicarbonate, water, dissolved, IT, field (mg/L as HCO_3)	Nitrogen ammonia + organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)
1	390018079281201	8.3	78	0	95	0.50	<.01	<.01	<.01	<.01	.01
2	390034079280701	7.3	214	0	261	.60	.02	.01	<.01	<.01	.01
3	390107079250101	7.2	26	0	32	.40	.03	<.01	.01	<.01	.02
4	390119079255601	7.5	76	0	93	.30	.02	<.01	.03	<.01	.02
5	390122079263701	7.7	189	0	230	.30	.02	<.01	<.01	<.01	<.01
6	390127079262801	9.5	201	32	245	<.20	.03	.02	<.01	<.01	.02
7	390133079251901	7.9	106	0	129	<.20	.02	<.01	<.01	<.01	.01
8	390147079263701	7.8	230	0	280	.50	.02	<.01	<.01	<.01	<.01
9	390205079253401	7.3	88	0	107	.20	<.01	.02	.01	<.01	.02
10	390218079263801	7.5	134	0	163	<.20	.01	.02	<.01	<.01	.02
11	390231079235501	7.3	88	0	107	<.20	<.01	<.01	<.01	<.01	.01
12	390236079264701	7.2	260	0	317	.20	.06	<.01	<.01	<.01	<.01
13	390237079235701	7.3	86	0	105	<.20	<.01	.03	.04	<.01	.01
14	390243079262801	7.8	164	0	200	.30	.03	<.01	<.01	<.01	<.01
15	390247079234901	7.6	68	0	83	.20	.02	<.01	<.01	<.01	<.01
16	390254079265001	6.7	190	0	232	.20	.01	.03	.02	<.01	.03
17	390307079234201	8.0	86	0	105	<.20	.01	<.01	<.01	<.01	.01
18	390312079265201	7.8	152	0	185	<.20	.02	<.01	<.01	<.01	.01
19	390313079245301	7.6	94	0	115	.20	.04	.01	.02	<.01	.03
20	390316079261201	7.5	150	0	183	<.20	.02	<.01	<.01	<.01	<.01
21	390324079232501	8.8	74	5	90	.30	.03	<.01	<.01	<.01	<.01
22	390328079225901	<6.3	76	0	32	<.20	.02	.04	.03	<.01	.05
23	390329079240701	6.7	41	0	50	<.20	.03	<.01	.09	<.01	<.01
24	390332079260401	8.8	210	0	256	.30	.02	.03	.03	<.01	.05
25	390332079265901	7.2	100	0	122	<.20	.02	.02	.03	<.01	.03

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	pH, water, whole, field	Alkalinity, water, dissolved, IT, field (mg/L as $CaCO_3$)	Carbonate, water, dissolved, IT, field (mg/L as CO_3)	Bicarbonate, water, dissolved, IT, field (mg/L as HCO_3)	Nitrogen ammonia + organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)
26	390334079253001	4.0	<1	0	<1	0.20	0.04	<0.01	<0.01	<0.01	0.02
27	390336079244701	7.3	85	0	104	<.20	.02	.01	<.01	<.01	<.01
28	390338079235201	4.6	<1	0	<1	<.20	.01	<.01	.02	<.01	<.01
29	390346079241501	6.6	56	0	68	<.20	.04	<.01	.32	<.01	<.01
30	390352079263801	7.8	133	0	162	--	--	--	--	--	--
31	390356079234201	4.7	<1	0	<1	0.30	.02	<.01	<.01	<.01	<.01
32	390356079254201	7.0	109	0	133	<.20	.02	<.01	<.01	<.01	.03
33	390356079270001	6.2	29	0	35	<.20	.01	<.01	<.01	<.01	<.01
34	390358079253901	7.0	90	0	110	<.20	.03	<.01	<.01	<.01	.01
35	390409079225201	7.5	68	0	83	<.20	<.01	<.01	<.01	<.01	.01
36	390410079244301	6.1	13	0	16	0.20	.02	<.01	.01	<.01	<.01
37	390446079270501	3.8	<1	0	<1	0.30	.02	<.01	<.01	<.01	<.01
38	390448079254801	7.7	160	0	195	<0.20	<.01	<.01	<.01	<.01	<.01
39	390457079252601	7.5	150	0	183	0.30	.03	<.01	<.01	<.01	<.01
40	390458079255701	7.4	74	0	90	0.60	.02	<.01	<.01	<.01	<.01
41	390507079264301	9.8	156	38	190	<0.20	<.01	0.03	.02	<.01	.02
42	390527079254501	5.2	6	0	7	<0.20	.02	<0.01	<.01	<.01	<.01
43	390534079254401	7.8	58	0	71	0.20	.03	0.02	<.01	<.01	.03
44	390540079255001	6.6	34	0	41	0.50	.02	<0.01	<.01	<.01	<.01
45	390546079254501	7.6	45	0	55	<0.20	.02	<0.01	<.01	<.01	.01
46	390558079254601	5.0	5	0	6	<0.20	.03	<.01	<.01	<.01	<.01
47	390559079254801	4.4	<1	0	<1	<0.20	.03	<.01	<.01	<.01	<.01
48	390600079254401	6.4	67	0	82	0.30	.03	<.01	.05	<.01	<.01
49	390610079255301	7.7	55	0	67	<0.20	.04	.01	<.01	<.01	<.01
50	390612079254501	4.7	<1	0	<1	<0.20	<.01	.02	.01	<.01	<.01

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Calcium, dissolved (mg/L as Ca)	Solids, residue at 180 deg. C, dissolved (mg/L)	Magnesium, dissolved (mg/L as Mg)	Manganese, dissolved (μg/L as Mn)
1	390018079281201	0.16	<0.01	0.02	<0.01	0.16	20.0	149	2.9	<1
2	390034079280701	4.40	<.01	.01	.01	4.40	89.0	283	3.2	<1
3	390107079250101	.84	.01	.03	<.01	.83	6.8	28	1.2	8
4	390119079255601	.71	.02	.02	<.01	.71	30.0	92	1.3	<1
5	390122079263701	.52	.01	.02	<.01	.53	51.0	222	18.0	<1
6	390127079262801	<.05	.02	.03	<.01	<.05	0.4	221	<.01	1
7	390133079251901	.78	.01	.02	.01	.79	33.0	121	7.4	<1
8	390147079263701	.12	<.01	.01	<.01	.12	59.0	235	14.0	1
9	390205079253401	.53	<.01	.02	<.01	.52	34.0	101	1.8	7
10	390218079263801	.28	.02	.02	<.01	.30	55.0	152	3.5	<1
11	390231079235501	.93	<.01	.02	<.01	.91	35.0	106	2.7	<1
12	390236079264701	.09	<.01	.03	.01	.05	69.0	225	9.1	53
13	390237079235701	.58	<.01	.01	<.01	.57	34.0	111	2.1	1
14	390243079262801	.42	.01	<.01	.01	.44	72.0	202	1.6	<1
15	390247079234901	.59	<.01	<.01	<.01	.59	29.0	83	1.6	<1
16	390254079265001	.31	.01	.03	<.01	.23	71.0	280	16.0	<1
17	390307079234201	.83	<.01	.02	<.01	.81	20.0	99	6.7	1
18	390312079265201	.13	<.01	.01	<.01	.13	20.0	174	11.0	2
19	390313079245301	<.05	.03	.04	<.01	<.05	28.0	138	6.2	75
20	390316079261201	.47	.01	.01	<.01	.45	57.0	152	4.0	<1
21	390324079232501	.44	<.01	.03	.01	.44	26.0	83	1.8	29
22	390328079225901	.40	.04	.02	<.01	.39	8.5	42	1.7	1
23	390329079240701	<.05	.01	.03	<.01	<.05	9.0	48	3.2	1,000
24	390332079260401	<.05	.05	.03	<.01	<.05	3.5	221	0.8	4
25	390332079265901	.28	.03	.02	<.01	.30	39.0	114	2.0	<1

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Calcium, dissolved (mg/L as Ca)	Solids, residue at 180 deg. C, dissolved (mg/L)	Magnesium, dissolved (mg/L as Mg)	Manganese, dissolved (μg/L as Mn)
26	390334079253001	0.93	<.01	0.02	<0.01	1.20	1.8	16	0.6	21
27	390336079244701	<.05	<.01	.01	<.01	<0.05	23.0	106	5.6	38
28	390338079235201	.41	<.01	.02	<.01	.39	1.0	11	.4	21
29	390346079241501	<.05	<.01	.03	<.01	<.05	4.9	89	2.2	340
30	390352079263801	--	--	--	--	--	48.0	162	7.9	4
31	390356079234201	.72	<.01	.02	<.01	.72	1.0	19	.5	21
32	390356079254201	1.00	.02	.03	<.01	.98	44.0	147	3.9	<1
33	390356079270001	.55	<.01	.02	<.01	.54	16.0	93	2.4	19
34	390358079253901	.73	.01	.02	<.01	.74	40.0	123	2.2	2
35	390409079225201	.65	<.01	.01	<.01	.64	26.0	76	1.6	<1
36	390410079244301	2.30	.02	.04	.01	2.30	7.1	39	2.6	77
37	390446079270501	<.05	<.01	.02	<.01	<.05	0.9	30	.4	130
38	390448079254801	.12	<.01	.03	<.01	.20	60.0	180	6.0	<1
39	390457079252601	.55	<.01	.03	.01	.56	46.0	151	8.6	36
40	390458079255701	.83	<.01	.02	<.01	.82	27.0	116	4.8	2
41	390507079264301	<.05	.02	.02	<.01	<.05	1.4	182	.2	2
42	390527079254501	1.20	<.01	.02	<.01	1.30	6.4	51	2.0	9
43	390534079254401	.81	.03	.01	.01	.84	23.0	79	3.0	<1
44	390540079255001	1.90	<.01	.03	<.01	1.80	19.0	89	2.4	35
45	390546079254501	.33	.01	.01	<.01	.34	20.0	94	1.9	1
46	390558079254601	.94	<.01	<.01	<.01	.96	1.7	6	1.5	120
47	390559079254801	1.90	<.01	.04	<.01	1.90	2.7	11	1.0	140
48	390600079254401	.09	.03	.03	.01	.12	23.0	84	3.6	96
49	390610079255301	.13	<.01	.04	<.01	.12	10.0	100	1.1	37
50	390612079254501	.29	<.01	.03	<.01	.26	.9	15	1.1	91

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)	Sodium, dissolved (mg/L as Na)	Iron, dissolved (µg/L as Fe)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Coliform, fecal, 0.7-mm-MF (col/ 100 mL)	Streptococci, fecal, KF agar (col/ 100 mL)
1	390018079281201	0.60	6.2	30.0	11	15.0	33.0	0.60	60	39
2	390034079280701	.80	4.9	8.3	4	9.5	22.0	<.10	<700	190
3	390107079250101	.30	6.4	5.0	3	<.1	6.6	<.10	<1	<1
4	390119079255601	.40	4.8	1.7	3	3.8	5.9	<.10	<1	K1
5	390122079263701	.90	7.5	5.4	6	12.0	12.0	<.10	<1	<1
6	390127079262801	.60	8.4	100.0	10	6.0	8.1	.40	--	<1
7	390133079251901	.40	7.3	2.1	<3	1.6	6.9	.10	<1	<1
8	390147079263701	1.0	10.0	15.0	6	13.0	13.0	.10	<1	240
9	390205079253401	.40	5.9	1.3	22	.5	4.7	.10	<1	1
10	390218079263801	.40	9.0	1.5	<3	7.3	9.0	.10	<1	81
11	390231079235501	.40	5.4	1.0	6	.3	7.8	.10	1	9
12	390236079264701	.70	8.6	3.6	11	9.3	12.0	.20	6	<1
13	390237079235701	.40	5.6	1.3	3	1.0	4.8	.30	<1	<1
14	390243079262801	.40	6.6	1.9	<3	9.9	12.0	<.10	<1	<1
15	390247079234901	.30	4.8	.7	5	.2	5.2	.10	<1	<1
16	390254079265001	.70	8.9	6.6	8	49.0	14.0	.10	<1	<1
17	390307079234201	.80	7.0	9.0	<3	1.7	6.2	.30	<1	240
18	390312079265201	.80	9.5	33.0	15	3.4	17.0	.40	<1	<1
19	390313079245301	1.1	16.0	8.7	29	.4	20.0	.10	<1	<1
20	390316079261201	.40	6.5	1.4	4	4.5	12.0	.20	<1	<1
21	390324079232501	.40	5.2	1.0	120	.30	3.8	.10	63	88
22	390328079225901	.30	7.4	1.7	24	.20	3.4	.10	<1	<1
23	390329079240701	.70	18.0	4.6	2,700	.20	7.8	1.1	<1	140
24	390332079260401	.70	8.5	94.0	12	4.1	4.6	.50	7	69
25	390332079265901	.40	6.7	1.4	6	.20	7.5	.10	<1	<1

Appendix A. Ground-water-quality data for sites sampled July 15–17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)	Sodium, dissolved (mg/L as Na)	Iron, dissolved (µg/L as Fe)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Coliform, fecal, 0.7-mm-MF (col/100 mL)	Streptococci, fecal, KF agar (col/100 mL)
26	390334079253001	0.6	5.5	0.7	8	1.1	3.4	<0.10	<1	<1
27	390336079244701	1.1	13.0	7.9	8	4.2	11.0	.20	<1	<1
28	390338079235201	.4	5.9	.7	21	.8	3.8	<.10	<1	<1
29	390346079241501	1.2	20.0	26.0	35	14.0	6.2	.20	<1	<1
30	390352079263801	.5	5.6	1.9	10	1.6	27.0	<.10	<1	170
31	390356079234201	.5	5.4	.7	19	.4	1.3	.20	<1	4
32	390356079254201	1.1 5	.7	1.8	14	5.5	7.9	.10	<1	<1
33	390356079270001	.7	9.7	11.0	10	22.0	5.8	.10	<1	47
34	390358079253901	.5	5.6	1.8	7	5.1	8.2	.10	200	79
35	390409079225201	.3	6.6	.9	<3	.2	2.2	.10	<1	<1
36	390410079244301	1.1	8.9	2.7	42	2.6	7.8	.10	1,300	1,200
37	390446079270501	.1	4.5	.3	50	.3	8.7	.10	8	11
38	390448079254801	.5	6.1	2.1	7	5.5	21.0	.20	<1	<1
39	390457079252601	.7	5.4	1.8	4	3.4	7.2	.10	33	130
40	390458079255701	.4	11.0	6.0	4	7.8	11.0	<.10	<1	210
41	390507079264301	.1	10.0	67.0	13	3.2	6.8	.40	<1	<1
42	390527079254501	.7	5.7	6.3	29	17.0	7.6	<.10	5	62
43	390534079254401	.6	10.0	2.4	5	4.2	4.4	.10	<1	<1
44	390540079255001	.6	7.2	6.6	120	19.0	7.6	.20	<1	1
45	390546079254501	.6	12.0	6.8	11	18.0	4.9	.10	<1	<1
46	390558079254601	.6	5.5	1.0	32	2.3	3.1	.30	<1	<1
47	390559079254801	.6	4.6	1.0	100	4.6	6.0	.20	<1	760
48	390600079254401	.9	7.7	.7	110	3.2	6.2	.10	<1	2
49	390610079255301	.5	2.4	27.0	22	4.6	30.0	<.10	<1	2
50	390612079254501	.4	4.5	.3	14	.3	4.6	<.10	<1	<1

Appendix B. Pesticide data for ground-water sites sampled July 15–17,1991, Canaan Valley, West Virginia

[polychlor, polychlorinated; recov., recoverable; μg/L, micrograms per liter. Degree, minute, and second symbols omitted from latitudes and longitudes]

Site number	Station number	Latitude	Longitude	Date	2,4-D, total (μg/L)	Dicamba (Mediben; Banvel D), total (μg/L)	2,4-DP, total (μg/L)	Picloram (Tordon; Amdon), total (μg/L)	Silvex, total (μg/L)	2,4,5-T, total (μg/L)
8	390147079263701	39 03 24 N	079 23 25 W	07-17-91	0.03	<0.01	<0.01	<0.01	<0.01	<0.01
9 *	390205079253401	39 03 56 N	079 25 42 W	07-15-91	<.01	<.01	<.01	<.01	<.01	<.01
21*	390324079232501	39 05 59 N	079 25 48 W	07-15-91	<.01	<.01	<.01	<.01	<.01	<.01
32	390356079254201	39 01 47 N	079 26 37 W	07-15-91	<.01	<.01	<.01	<.01	<.01	<.01
47	390559079254801	39 02 05 N	079 25 34 W	07-16-91	<.01	<.01	<.01	<.01	<.01	<.01

Site number	Station number	Aldrin, total (μg/L)	Chlordane, total (μg/L)	Chlorpyrifos, total recov. (μg/L)	DDD, total (μg/L)	DDE, total (μg/L)	DDT, total (μg/L)	Diazinon, total (μg/L)	Dieldrin, total (μg/L)	Disyston, total (μg/L)
8	390147079263701	<0.001	<0.1	<0.01	<0.001	<0.001	<0.001	<0.01	<0.001	<0.01
9 *	390205079253401	<.001	<.1	<.01	<.001	<.001	<.001	<.01	<.001	<.01
21 *	390324079232501	<.001	<.1	<.01	<.001	<.001	<.001	<.01	<.001	<.01
32	390356079254201	<.001	<.1	<.01	<.001	<.001	<.001	<.01	<.001	<.01
47	390559079254801	<.001	<.1	<.01	<.001	<.001	<.001	<.01	<.001	<.01

* Sites 9 and 21 are springs and sites 8, 32, and 47 are wells.

Appendix B. Pesticide data for ground-water sites sampled July 15–17,1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Endo-sulfan, total (µg/L)	Endrin, total (µg/L)	Ethion, total (µg/L)	PCB, total (µg/L)	Naph-tha-lenes, poly-chlor., total (µg/L)	Hepta-chlor, total (µg/L)	Hepta-chlor epoxide, total (µg/L)	Lindane, total (µg/L)	Mala-thion, total (µg/L)
8	390147079263701	<0.001	<0.001	<0.01	<0.1	<0.10	<0.001	<0.001	<0.001	<0.01
9 *	390205079253401	<.001	<.001	<.01	<.1	<.10	<.001	<.001	<.001	<.01
21 *	390324079232501	<.001	<.001	<.01	<.1	<.10	<.001	<.001	<.001	<.01
32	390356079254201	<.001	<.001	<.01	<.1	<.10	<.001	<.001	<.001	<.01
47	390559079254801	<.001	<.001	<.01	<.1	<.10	<.001	<.001	<.001	<.01

Site number	Station number	Meth-oxy-chlor, total (µg/L)	Methyl para-thion, total (µg/L)	Mirex, total (µg/L)	Para-thion, total (µg/L)	Per-thane, total (µg/L)	Phorate, total (µg/L)	Tox-aphene, total (µg/L)	Total tri-thion (µg/L)	Ala-chlor, total recov. (µg/L)
8	390147079263701	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01	<1	<0.01	<0.10
9 *	390205079253401	<.01	<.01	<.01	<.01	<.1	<.01	<1	<.01	<.10
21*	390324079232501	<.01	<.01	<.01	<.01	<.1	<.01	<1	<.01	<.10
32	390356079254201	<.01	<.01	<.01	<.01	<.1	<.01	<1	<.01	<.10
47	390559079254801	<.01	<.01	<.01	<.01	<.1	<.01	<1	<.01	<.10

* Sites 9 and 21 are springs and sites 8, 32, and 47 are wells.

Appendix B. Pesticide data for ground-water sites sampled July 15–17,1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Ame-tryne, total (µg/L)	Atra-zine, total (µg/L)	Cyan-azine, total (µg/L)	Prome-tone, total (µg/L)	Prome-tryne, total (µg/L)	Pro-pazine, total (µg/L)	Sima-zine, total (µg/L)	Sime-tryne, total (µg/L)	Triflur-alin, total recov. (µg/L)
8	390147079263701	<0.10	<0.10	<0.20	<0.20	<0.10	<0.10	<0.10	<0.10	<0.10
9 *	390205079253401	<.10	<.10	<.20	<.20	<.10	<.10	<.10	<.10	<.10
21*	390324079232501	<.10	<.10	<.20	<.20	<.10	<.10	<.10	<.10	<.10
32	390356079254201	<.10	<.10	<.20	<.20	<.10	<.10	<.10	<.10	<.10
47	390559079254801	<.10	<.10	<.20	<.20	<.10	<.10	<.10	<.10	<.10

* Sites 9 and 21 are springs and sites 8, 32, and 47 are wells.

Appendix C. Surface-water-quality data for streams sampled July 30–August 1, 1991, Canaan Valley, West Virginia

[col, colonies; deg. C, degrees Celsius; MF, membrane filtration; mg, milligrams; mg/L, milligrams per liter; mm, millimeter; µg/L, micrograms per liter; µm, micrometers (microns); µS/cm, microsiemens per centimeter at 25 degrees Celsius. Degree, minute, and second symbols omitted from latitudes and longitudes. Missing data represented by dashes]

Site number	Station number	Date sampled	Time	Latitude	Longitude	Temperature, water (deg. C)	Barometric pressure (mm of Hg)	Discharge, cubic feet per second	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)
C-1	390136079273301	07-30-91	1115	39 01 36 N	079 27 33 W	20.5	678	0.4	203	7.0
C-8	390156079254701	08-01-91	1000	39 01 56 N	079 25 47 W	18.0	681	.3	131	8.9
C-7	390158079254801	08-01-91	1005	39 01 58 N	079 25 48 W	19.5	681	1.1	177	7.2
C-9	390211079253601	07-31-91	1415	39 02 11 N	079 25 36 W	26.0	680	2.3	165	13.1
C-6	390215079271401	07-30-91	1200	39 02 15 N	079 27 14 W	20.0	684	2.2	147	6.5
C-2	390215079274701	07-31-91	1200	39 02 15 N	079 27 47 W	25.0	684	.3	230	13.1
C-11	390217079232801	07-30-91	1132	39 02 17 N	079 23 28 W	15.0	671	.1	30	8.2
C-4	390221079274101	07-31-91	1130	39 02 21 N	079 27 41 W	21.0	684	.4	89	5.8
C-5	390222079272001	07-30-91	1400	39 02 22 N	079 27 20 W	26.0	678	1.9	116	7.9
C-12	390246079235601	07-30-91	1130	39 02 46 N	079 23 56 W	19.5	677	.2	90	8.1
C-13	390328079243101	08-01-91	1130	39 03 28 N	079 24 31 W	20.0	681	.1	85	8.1
C-18	390328079262501	08-01-91	1408	39 03 28 N	079 26 25 W	26.5	683	.2	195	14.4
C-10	390344079245001	08-01-91	1300	39 03 44 N	079 24 50 W	24.0	683	1.8	165	9.5
C-14	390346079244801	08-01-91	1245	39 03 46 N	079 24 48 W	22.0	683	.1	93	8.2
C-19	390400079253301	07-31-91	0948	39 04 00 N	079 25 33 W	18.5	680	1.5	152	8.1
C-16	390515079233401	07-31-91	1300	39 05 15 N	079 23 34 W	26.0	682	.5	72	7.8
C-15	390516079233801	07-31-91	1313	39 05 16 N	079 23 38 W	24.0	682	2.1	156	7.6
C-20	390548079242601	07-31-91	1135	39 05 48 N	079 24 26 W	22.5	---	1.1	178	7.7
C-17	390552079242201	07-31-91	1120	39 05 52 N	079 24 22 W	22.0	680	3.3	123	7.1
C-21	390742079232401	08-01-91	1200	39 07 42 N	079 23 24 W	23.0	682	---	136	6.7
C-22	390744079232201	08-01-91	1145	39 07 44 N	079 23 22 W	24.0	682	4.4	91	8.0
C-23	390824079251201	08-01-91	1358	39 08 24 N	079 25 12 W	26.5	682	12.0	108	8.0

Appendix C. Surface-water-quality data for streams sampled July 30–August 1, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Oxygen, dissolved (percent saturation)	pH, water, whole, field	Nitrogen, organic, total (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)
C-1	390136079273301	88	7.1	0.74	0.08	0.06	<0.01	<0.01	0.8
C-8	390156079254701	105	7.7	.48	.03	.02	<.01	<.01	.5
C-7	390158079254801	88	7.8	.69	.03	.01	<.01	<.01	.7
C-9	390211079253601	182	8.6	.58	.03	.02	<.01	<.01	.6
C-6	390215079271401	80	7.1	.77	.06	.03	<.01	<.01	.8
C-2	390215079274701	178	8.7	.59	.04	.01	<.01	.01	.6
C-11	390217079232801	93	6.8	---	.02	<.01	<.01	<.01	<.2
C-4	390221079274101	73	6.8	.87	.06	.03	<.01	<.01	.9
C-5	390222079272001	110	6.9	.68	.05	.02	<.01	<.01	.7
C-12	390246079235601	100	7.6	---	.03	<.01	<.01	<.01	<.2
C-13	390328079243101	100	6.9	.65	.06	.05	<.01	<.01	.7
C-18	390328079262501	201	9.1	.42	.10	.08	.03	.03	.5
C-10	390344079245001	126	8.3	.58	.03	.02	<.01	<.01	.6
C-14	390346079244801	105	7.8	.48	.03	.02	<.01	<.01	.5
C-19	390400079253301	97	7.5	1.2	.09	.06	.01	.01	1.3
C-16	390515079233401	108	7.6	.27	.03	.03	<.01	<.01	.3
C-15	390516079233801	101	7.9	.38	.02	.02	<.01	<.01	.4
C-20	390548079242601	---	7.8	.48	.03	.02	<.01	<.01	.5
C-17	390552079242201	91	7.6	.49	.03	.01	<.01	<.01	.5
C-21	390742079232401	88	7.5	.57	.03	.03	<.01	<.01	.6
C-22	390744079232201	107	7.3	---	.03	<.01	<.01	<.01	.5
C-23	390824079251201	112	7.4	.49	.03	.01	<.01	<.01	.5

Appendix C. Surface-water-quality data for streams sampled July 30–August 1, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Nitrogen, NO_2+NO_3, total (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
C-1	390136079273301	<0.05	<0.05	0.06	0.03	<0.01	94	34.0	2.3	6.1
C-8	390156079254701	.16	.15	.02	.01	<.01	61	21.0	2.1	1.5
C-7	390158079254801	<.05	<.05	.05	.02	<.01	81	29.0	2.0	5.2
C-9	390211079253601	.06	.06	.06	.03	<.01	78	28.0	1.9	5.1
C-6	390215079271401	<.05	<.05	.11	.08	.04	52	18.0	1.8	5.4
C-2	390215079274701	.09	.09	.05	.02	<.01	110	41.0	2.6	7.8
C-11	390217079232801	.29	.26	<.01	<.01	<.01	11	2.9	.9	.7
C-4	390221079274101	<.05	<.05	.05	.02	<.01	35	12.0	1.1	2.8
C-5	390222079272001	<.05	<.05	.04	.02	<.01	46	16.0	1.5	3.8
C-12	390246079235601	.28	.28	.01	<.01	<.01	37	12.0	1.6	1.4
C-13	390328079243101	.12	.12	.03	.02	<.01	36	12.0	1.5	2.8
C-18	390328079262501	.47	.46	.20	.18	.13	83	28.0	3.2	7.6
C-10	390344079245001	<.05	<.05	.02	.02	<.01	75	27.0	1.8	4.9
C-14	390346079244801	.13	.11	.02	.04	<.01	36	12.0	1.5	2.9
C-19	390400079253301	.21	.23	.07	.03	<.01	64	22.0	2.3	5.5
C-16	390515079233401	.08	.07	.01	.02	<.01	6	1.3	.7	.7
C-15	390516079233801	<.05	<..05	.02	<.01	<.01	60	21.0	1.9	2.9
C-20	390548079242601	<.05	<.05	.03	.01	<.01	86	30.0	2.7	4.1
C-17	390552079242201	<.05	<.05	.02	<.01	<.01	51	18.0	1.5	2.6
C-21	390742079232401	<.05	<.05	.03	<.01	<.01	58	20.0	2.0	2.9
C-22	390744079232201	<.05	<.05	.03	.03	<.01	42	14.0	1.6	1.1
C-23	390824079251201	<.05	<.05	.02	.01	<.01	47	16.0	1.6	2.3

Appendix C. Surface-water-quality data for streams sampled July 30–August 1, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Sodium adsorption ratio	Sodium, percent	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as CL)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
C-1	390136079273301	.3	12	1.2	9.0	18.0	<0.1	2.2	860	440
C-8	390156079254701	.1	5	.6	.5	5.2	<.1	2.5	160	92
C-7	390158079254801	.3	12	.7	6.8	9.5	<.1	3.3	610	100
C-9	390211079253601	.3	12	.8	5.4	9.0	<.1	3.3	580	57
C-6	390215079271401	.3	18	.8	6.4	12.0	.1	3.3	780	160
C-2	390215079274701	.3	13	.8	12.0	17.0	.2	3.5	380	140
C-11	390217079232801	.1	12	.4	.5	5.3	<.1	4.2	10	<1
C-4	390221079274101	.2	15	.5	4.0	9.4	.1	3.4	970	150
C-5	390222079272001	.2	15	.6	4.9	13.0	.1	3.3	820	160
C-12	390246079235601	.1	8	.6	.6	6.2	<.1	3.9	120	37
C-13	390328079243101	.2	14	.8	2.5	5.2	<.1	4.2	1,200	190
C-18	390328079262501	.4	16	1.3	10.0	9.6	.1	2.3	99	32
C-10	390344079245001	.2	12	.7	6.0	11.0	.1	2.0	290	59
C-14	390346079244801	.2	15	.8	2.5	5.3	.1	3.5	920	66
C-19	390400079253301	.3	15	1.6	7.9	10.0	.1	2.4	560	160
C-16	390515079233401	.1	18	.5	.4	2.7	.1	.3	880	12
C-15	390516079233801	.2	9	.8	4.6	8.8	.2	1.9	300	66
C-20	390548079242601	.2	9	.8	6.0	7.6	<.1	2.3	300	130
C-17	390552079242201	.2	10	.7	3.1	6.9	<.1	1.2	340	83
C-21	390742079232401	.2	10	.7	3.7	6.7	<.1	1.5	530	170
C-22	390744079232201	.1	5	.4	.3	3.7	.1	3.6	970	180
C-23	390824079251201	.1	10	.6	2.6	6.2	<.1	2.3	770	120

Appendix C. Surface-water-quality data for streams sampled July 30–August 1, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Coliform, fecal, 0.7-mm-MF (col/100 mL)	Solids, residue at 180 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Phosphorus, ortho, total (mg/L as P)	Nitrogen, ammonia, total (mg/L as NH_4)	Nitrogen, ammonia, dissolved (mg/L as NH_4)
C-1	390136079273301	1,300	146	113	<0.01	0.08	0.10
C-8	390156079254701	250	90	69	<.01	.03	.04
C-7	390158079254801	1,600	117	97	<.01	.01	.04
C-9	390211079253601	420	98	94	.01	.03	.04
C-6	390215079271401	400	99	78	.04	.04	.08
C-2	390215079274701	480	162	139	<.01	.01	.05
C-11	390217079232801	13	13	21	<.01	---	.03
C-4	390221079274101	350	68	51	<.01	.04	.08
C-5	390222079272001	450	84	66	<.01	.03	.06
C-12	390246079235601	87	60	49	<.01	---	.04
C-13	390328079243101	370	70	51	<.01	.06	.08
C-18	390328079262501	400	105	107	.14	.10	.13
C-10	390344079245001	20	116	92	<.01	.03	.04
C-14	390346079244801	67	75	50	<.01	.03	.04
C-19	390400079253301	1,000	99	85	<.01	.08	.12
C-16	390515079233401	97	40	27	<.01	.04	.04
C-15	390516079233801	80	108	79	<.01	.03	.03
C-20	390548079242601	260	102	97	<.01	.03	.04
C-17	390552079242201	97	70	66	<.01	.01	.04
C-21	390742079232401	200	83	70	<.01	.04	.04
C-22	390744079232201	210	70	52	<.01	---	.04
C-23	390824079251201	7	69	57	<.01	.01	.04

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia.

[col, colonies; deg. C, degrees Celsius; IT, incremental titration; MF, membrane filtration; mg/L, milligrams per liter; mm, millimeters; µg/L, micrograms per liter; µm, micrometers (microns); µS/cm, microsiemens per centimeter at 25 degrees Celsius. Degree, minute, and second symbols omitted from latitudes and longitudes. Missing data represented by dashes]

Site number	Station number	Latitude	Longitude	Geologic unit	Date sampled	Temperature, water (deg. C)	Barometric pressure (mm of Hg)	Depth below land surface (water level, in feet)	Specific conductance (µS/cm)
8	390147079263701	39 01 47 N	079 26 37 W	Greenbrier	11-07-90	10.0	672	---	520
8	390147079263701	39 01 47 N	079 26 37 W	Greenbrier	01-10-91	9.5	681	69.15	419
8	390147079263701	39 01 47 N	079 26 37 W	Greenbrier	03-06-91	10.0	664	---	440
8	390147079263701	39 01 47 N	079 26 37 W	Greenbrier	05-14-91	10.0	674	---	453
8	390147079263701	39 01 47 N	079 26 37 W	Greenbrier	07-17-91	11.0	677	---	470
18	390312079265201	39 03 12 N	079 26 52 W	Greenbrier	11-06-90	11.0	675	---	359
18	390312079265201	39 03 12 N	079 26 52 W	Greenbrier	01-09-91	10.0	677	---	422
18	390312079265201	39 03 12 N	079 26 52 W	Greenbrier	03-04-91	10.0	661	---	395
18	390312079265201	39 03 12 N	079 26 52 W	Greenbrier	05-13-91	13.5	675	---	361
18	390312079265201	39 03 12 N	079 26 52 W	Greenbrier	07-16-91	12.0	684	---	345
19	390313079245301	39 03 13 N	079 24 53 W	Pocono	11-07-90	11.0	671	94.13	192
19	390313079245301	39 03 13 N	079 24 53 W	Pocono	01-10-91	9.0	681	---	226
19	390313079245301	39 03 13 N	079 24 53 W	Pocono	03-05-91	10.0	667	87.90	217
19	390313079245301	39 03 13 N	079 24 53 W	Pocono	05-14-91	12.0	674	92.42	221
19	390313079245301	39 03 13 N	079 24 53 W	Pocono	07-16-91	12.5	680	---	225
28	390338079235201	39 03 38 N	079 23 52 W	Pocono	11-07-90	10.0	673	---	17
28	390338079235201	39 03 38 N	079 23 52 W	Pocono	01-10-91	10.0	682	---	21
28	390338079235201	39 03 38 N	079 23 52 W	Pocono	03-06-91	9.0	663	---	19
28	390338079235201	39 03 38 N	079 23 52 W	Pocono	05-15-91	9.0	676	---	18
28	390338079235201	39 03 38 N	079 23 52 W	Pocono	07-16-91	11.5	680	---	21
34	390358079253901	39 03 58 N	079 25 39 W	Greenbrier	11-08-90	9.5	680	---	159
34	390358079253901	39 03 58 N	079 25 39 W	Greenbrier	01-09-91	8.0	680	---	136
34	390358079253901	39 03 58 N	079 25 39 W	Greenbrier	03-05-91	7.5	671	---	132
34	390358079253901	39 03 58 N	079 25 39 W	Greenbrier	05-15-91	9.0	680	---	152
34	390358079253901	39 03 58 N	079 25 39 W	Greenbrier	07-15-91	9.0	684	---	233

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Latitude	Longitude	Geologic unit	Date sampled	Temperature, water (deg. C)	Barometric pressure (mm of Hg)	Depth below land surface (water level, in feet)	Specific conductance (µS/cm)
37	390446079270501	39 04 46 N	079 27 05 W	Mauch Chunk	11-08-90	7.0	679	--	18
37	390446079270501	39 04 46 N	079 27 05 W	Mauch Chunk	01-10-91	3.0	680	--	25
37	390446079270501	39 04 46 N	079 27 05 W	Mauch Chunk	03-06-91	3.5	661	--	22
37	390446079270501	39 04 46 N	079 27 05 W	Mauch Chunk	05-13-91	11.0	675	--	22
37	390446079270501	39 04 46 N	079 27 05 W	Mauch Chunk	07-16-91	14.0	685	--	52
43	390534079254401	39 05 34 N	079 25 44 W	Mauch Chunk	11-06-90	10.5	669	--	139
43	390534079254401	39 05 34 N	079 25 44 W	Mauch Chunk	01-07-91	9.0	678	--	136
43	390534079254401	39 05 34 N	079 25 44 W	Mauch Chunk	03-05-91	9.5	665	--	140
43	390534079254401	39 05 34 N	079 25 44 W	Mauch Chunk	05-14-91	10.5	671	--	148
43	390534079254401	39 05 34 N	079 25 44 W	Mauch Chunk	07-16-91	10.0	679	--	154
49	390610079255301	39 06 10 N	079 25 53 W	Pottsville	11-07-90	10.5	664	--	25
49	390610079255301	39 06 10 N	079 25 53 W	Pottsville	01-08-91	6.5	667	--	32
49	390610079255301	39 06 10 N	079 25 53 W	Pottsville	03-06-91	5.0	675	--	26
49	390610079255301	39 06 10 N	079 25 53 W	Pottsville	05-14-91	9.0	661	--	24
49	390610079255301	39 06 10 N	079 25 53 W	Pottsville	07-16-91	17.5	672	--	194
50	390612079254501	39 06 12 N	079 25 45 W	Pottsville	11-08-90	9.5	663	--	25
50	390612079254501	39 06 12 N	079 25 45 W	Pottsville	01-08-91	7.5	666	--	27
50	390612079254501	39 06 12 N	079 25 45 W	Pottsville	03-05-91	6.0	652	81.10	25
50	390612079254501	39 06 12 N	079 25 45 W	Pottsville	05-14-91	10.0	660	--	24
50	390612079254501	39 06 12 N	079 25 45 W	Pottsville	07-16-91	11.5	669	--	24

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Oxygen, dissolved (mg/L)	pH, water, whole, field (standard units)	Alkalinity, water, dissolved, IT, field (mg/L as $CaCO_3$)	Carbonate, water, dissolved, IT, field (mg/L as CO_3)	Bicarbonate, water, dissolved, IT, field (mg/L as HCO_3)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Nitrogen, nitrite, dissolved (mg/L as N)
8	390147079263701	7.4	7.6	219	0	267	<0.2	<0.01	<0.01	<0.01	<0.01
8	390147079263701	7.7	6.9	207	0	252	.4	.02	<.01	<.01	<.01
8	390147079263701	7.5	7.8	208	0	254	<.2	<.01	<.01	.02	<.01
8	390147079263701	6.4	7.0	219	0	267	<.2	<.01	<.01	.02	<.01
8	390147079263701	8.6	7.8	230	0	280	.5	.02	<.01	<.01	<.01
18	390312079265201	5.9	7.7	182	0	222	.3	<.01	<.01	<.01	<.01
18	390312079265201	6.5	6.7	179	0	218	.5	.02	<.01	<.01	<.01
18	390312079265201	5.0	7.4	187	0	228	<.2	.01	<.01	<.01	<.01
18	390312079265201	7.5	7.6	171	0	208	<.2	.01	<.01	.02	<.01
18	390312079265201	2.6	7.8	152	0	185	<.2	.02	<.01	<.01	<.01
19	390313079245301	.6	7.8	94	0	114	<.2	.03	.03	.05	<.01
19	390313079245301	4.6	6.7	98	0	119	.4	.06	.02	.06	<.01
19	390313079245301	.3	7.6	94	0	115	<.2	.05	.04	.06	<.01
19	390313079245301	1.2	7.8	83	0	101	<.2	.02	.03	.05	<.01
19	390313079245301	.2	7.6	94	0	115	.2	.04	.01	.02	<.01
28	390338079235201	7.9	5.1	3	0	4	<.2	<.01	<.01	<.01	<.01
28	390338079235201	6.7	4.1	<1	0	<1	.5	.02	<.01	<.01	<.01
28	390338079235201	7.5	5.0	1	0	1	<.2	<.01	<.01	<.01	.04
28	390338079235201	7.3	5.0	2	0	2	<.2	<.01	<.01	.02	<.01
28	390338079235201	6.7	4.6	<1	0	<1	<.2	.01	<.01	.02	<.01
34	390358079253901	9.2	7.1	66	0	80	<.2	<.01	<.01	<.01	<.01
34	390358079253901	9.0	6.2	51	0	62	.4	.02	<.01	<.01	.01
34	390358079253901	9.1	7.3	56	0	68	<.2	.01	<.01	.01	<.01
34	390358079253901	8.9	7.0	58	0	71	<.2	.02	<.01	.04	<.01
34	390358079253901	9.4	7.0	90	0	110	<.2	.03	<.01	<.01	<.01

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Oxygen, dissolved (mg/L)	pH, water, whole, field (standard units)	Alkalinity, water dissolved IT, field (mg/L as $CaCO_3$)	Carbonate, water, dissolved, IT, field (mg/L as CO_3)	Bicarbonate, water, dissolved, IT, field (mg/L as HCO_3)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Nitrogen, nitrite, dissolved (mg/L as N)
37	390446079270501	9.0	5.4	1	0	2	0.2	<0.01	0.01	<0.01	<0.01
37	390446079270501	11.6	4.5	<1	0	<1	.2	.02	<.01	<.01	<.01
37	390446079270501	11.4	5.3	2	0	2	<.2	<.01	<.01	.02	<.01
37	390446079270501	7.4	5.4	1	0	1	.2	.02	<.01	.02	<.01
37	390446079270501	8.8	3.8	<1	0	<1	.3	.02	<.01	<.01	<.01
43	390534079254401	5.9	8.1	55	0	67	<.2	<.01	.02	.03	<.01
43	390534079254401	7.4	7.1	56	0	69	.3	.02	.02	.02	<.01
43	390534079254401	7.8	7.8	58	0	71	<.2	.01	.04	.03	.02
43	390534079254401	8.0	7.6	58	0	71	<.2	<.01	.03	.06	<.01
43	390534079254401	8.8	7.8	58	0	71	.2	.03	.02	<.01	<.01
49	390610079255301	6.5	5.3	3	0	4	<.2	<.01	<.01	<.01	<.01
49	390610079255301	7.8	4.3	<1	0	<1	.3	.03	<.01	<.01	<.01
49	390610079255301	8.6	5.2	2	0	2	<.2	.02	<.01	<.01	.01
49	390610079255301	8.8	5.1	2	0	2	<.2	<.01	<.01	.04	<.01
49	390610079255301	7.7	7.7	55	0	67	<.2	.04	.01	<.01	<.01
50	390612079254501	8.5	5.3	3	0	4	.2	<.01	<.01	<.01	<.01
50	390612079254501	4.8	4.5	<1	0	<1	.2	.02	<.01	.01	.01
50	390612079254501	8.2	5.0	1	0	1	<.2	<.01	<.01	<.01	<.01
50	390612079254501	8.3	4.9	<1	0	<1	.2	<.01	<.01	.01	<.01
50	390612079254501	7.7	4.7	<1	0	<1	<.2	<.01	.02	.01	<.01

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Phosphorus ortho, dissolved (mg/L as P)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen NO_2 + NO_3, total (mg/L as N)	Calcium, dissolved (mg/L as Ca)	Solids, residue at 180 deg. C, dissolved (mg/L)	Magnesium, dissolved (mg/L as Mg)	Manganese, dissolved (μg/L as Mn)
8	390147079263701	<0.01	0.10	.02	<.01	<.01	.10	66.0	249	17.0	--
8	390147079263701	<.01	<.10	<.01	<.01	<.01	<.10	63.0	247	16.0	--
8	390147079263701	<.01	.06	<.01	.01	.01	.06	60.0	239	15.0	10
8	390147079263701	<.01	.06	<.01	.02	<.01	.09	66.0	248	17.0	8
8	390147079263701	<.01	.12	<.01	.01	<.01	.12	59.0	235	14.0	1
18	390312079265201	<.01	1.20	.01	<.01	<.01	1.20	61.0	196	6.2	--
18	390312079265201	<.01	1.00	<.01	.01	<.01	1.10	77.0	249	4.8	--
18	390312079265201	<.01	.91	<.01	<.01	.01	.88	73.0	224	4.6	1
18	390312079265201	<.01	.67	<.01	.02	<.01	.66	62.0	205	5.3	<1
18	390312079265201	.01	.13	<.01	.01	<.01	.13	20.0	174	11.0	2
19	390313079245301	.02	<.10	.02	.03	<.01	<.10	27.0	124	6.2	--
19	390313079245301	.02	<.10	.02	.06	<.01	<.10	28.0	131	6.3	--
19	390313079245301	.02	<.05	.02	<.01	.02	<.05	28.0	129	6.3	77
19	390313079245301	.01	.06	.01	.02	<.01	.06	29.0	140	6.8	89
19	390313079245301	.03	<.05	.03	.04	<.01	<.05	28.0	138	6.2	75
28	390338079235201	<.01	.50	.01	<.01	<.01	.50	.9	6	.3	--
28	390338079235201	<.01	.50	<.01	<.01	<.01	.50	1.1	5	.3	--
28	390338079235201	<.01	.52	<.01	.03	.05	.52	1.0	5	.3	30
28	390338079235201	<.01	.49	<.01	.03	<.01	.49	.9	17	.4	33
28	390338079235201	<.01	.41	<.01	.02	<.01	.39	1.0	11	.4	21
34	390358079253901	<.01	.70	<.01	.01	<.01	.70	30.0	89	1.7	--
34	390358079253901	<.01	.70	<.01	.01	<.01	.60	23.0	79	1.4	--
34	390358079253901	<.01	.60	<.01	.01	.02	.57	24.0	73	1.4	2
34	390358079253901	<.01	.62	.03	.03	<.01	.62	29.0	93	1.4	3
34	390358079253901	.01	.73	.01	.02	<.01	.74	40.0	123	2.2	2

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Phosphorus ortho, dissolved (mg/L as P)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen NO_2 + NO_3, total (mg/L as N)	Calcium, dissolved (mg/L as Ca)	Solids, residue at 180 deg. C, dissolved (mg/L)	Magnesium, dissolved (mg/L as Mg)	Manganese, dissolved (μg/L as Mn)
37	390446079270501	<0.01	0.20	<0.01	0.01	<0.01	0.20	1.5	12	0.59	--
37	390446079270501	<.01	.50	<.01	<.01	<.01	.50	1.7	9	.61	--
37	390446079270501	<.01	.59	<.01	.01	.02	.58	1.7	13	.68	10
37	390446079270501	<.01	.20	<.01	.02	<.01	.14	1.6	11	.38	12
37	390446079270501	<.01	<.05	<.01	.02	<.01	<.05	.9	30	.39	130
43	390534079254401	.02	.90	.02	.01	<.01	.80	22.0	80	3.00	--
43	390534079254401	.02	.90	.02	.01	<.01	.90	21.0	80	2.90	--
43	390534079254401	.03	.89	.02	.03	.01	.85	21.0	82	2.90	<1
43	390534079254401	.01	.92	.02	.01	<.01	.91	22.0	92	3.00	<1
43	390534079254401	.03	.81	.03	.01	.01	.84	23.0	79	3.00	<1
49	390610079255301	<.01	.50	<.01	.02	<.01	.50	2.7	15	.26	--
49	390610079255301	<.01	.50	<.01	.02	<.01	.50	2.5	13	.33	--
49	390610079255301	<.01	.44	<.01	.03	.04	.48	2.5	8	.39	75
49	390610079255301	<.01	.46	.02	.02	<.01	.90	2.4	78	.39	89
49	390610079255301	<.01	.13	<.01	.04	<.01	.12	10.0	100	1.1	37
50	390612079254501	<.01	.30	<.01	.02	<.01	.30	.9	6	1.20	--
50	390612079254501	<.01	.40	<.01	.01	<.01	.40	1.0	16	1.10	--
50	390612079254501	<.01	.42	<.01	.01	.01	.41	1.3	4	.64	110
50	390612079254501	<.01	.30	<.01	.01	<.01	.31	.9	26	.75	110
50	390612079254501	<.01	.29	<.01	.03	<.01	.26	.9	15	1.10	91

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)	Sodium, dissolved (mg/L as Na)	Iron, dissolved (µg/L as Fe)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Coliform, fecal, 0.7-mm-MF (col/ 100 mL)	Streptococci, fecal, KF agar (col/ 100 mL)
8	390147079263701	0.7	--	10.0	--	12.0	16.0	0.2	--	--
8	390147079263701	.8	--	9.9	--	11.0	19.0	<.1	<1	<1
8	390147079263701	.8	9.7	9.0	6	11.0	19.0	<.1	<1	<1
8	390147079263701	.8	10.0	9.8	12	11.0	15.0	.2	<1	<1
8	390147079263701	1.0	10.0	15.0	6	13.0	13.0	.1	<1	240
18	390312079265201	.6	--	8.9	--	4.0	16.0	.1	--	--
18	390312079265201	.7	--	3.4	--	10.0	17.0	<.1	<1	1
18	390312079265201	.6	6.5	3.5	7	8.7	20.0	.5	<1	<1
18	390312079265201	.6	6.8	6.4	5	6.8	16.0	.2	<1	<1
18	390312079265201	.8	9.5	33.0	15	3.4	17.0	.4	<1	<1
19	390313079245301	.9	--	8.5	--	2.3	18.0	.1	--	--
19	390313079245301	1.1	--	8.5	--	.7	20.0	<.1	<1	<1
19	390313079245301	1.0	15.0	8.5	46	.6	19.0	<.1	<1	<1
19	390313079245301	.9	16.0	9.3	19	.3	23.0	.3	<1	<1
19	390313079245301	1.1	16.0	8.7	29	.4	20.0	.1	<1	<1
28	390338079235201	.4	--	.5	--	.8	2.4	<.1	--	--
28	390338079235201	.5	--	.6	--	.4	2.4	<.1	<1	2
28	390338079235201	.5	3.9	.5	15	.5	2.3	<.1	<1	<1
28	390338079235201	.4	3.9	.5	20	.8	3.3	.2	<1	<1
28	390338079235201	.4	5.9	.7	21	.8	3.8	<.1	<1	<1
34	390358079253901	.5	--	1.3	--	3.2	6.4	<.1	--	--
34	390358079253901	.6	--	.9	--	1.9	5.9	<.1	14	11
34	390358079253901	.6	3.7	.9	18	1.0	6.9	<.1	190	230
34	390358079253901	.5	4.7	1.3	12	3.8	8.3	.3	1	1
34	390358079253901	.5	5.6	1.8	7	5.1	8.2	.1	200	79

Appendix D. Ground-water-quality data for bimonthly sampling sites sampled November 6, 1990–July 17, 1991, Canaan Valley, West Virginia—Continued

Site number	Station number	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)	Sodium, dissolved (mg/L as Na)	Iron, dissolved (µg/L as Fe)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Coliform, fecal, 0.7-mm-MF (col/ 100 mL)	Streptococci, fecal, KF agar (col/ 100 mL)
37	390446079270501	0.1	--	0.3	--	0.8	5.8	<0.1	--	--
37	390446079270501	.3	--	.2	--	.4	5.0	<.1	<1	<1
37	390446079270501	.3	2.9	.2	4	.5	5.0	<.1	<1	<2
37	390446079270501	.3	3.4	.2	4	.7	6.4	.2	<1	<1
37	390446079270501	.1	4.5	.3	50	.3	8.7	.1	8	11
43	390534079254401	.5	--	2.4	--	4.3	4.9	<.1	--	--
43	390534079254401	.6	--	2.4	--	2.3	5.3	<.1	<1	<1
43	390534079254401	.6	9.3	2.3	7	2.6	5.4	<.1	<1	<1
43	390534079254401	.5	9.7	2.3	<3	4.5	6.7	.3	<1	<1
43	390534079254401	.6	10.0	2.4	5	4.2	4.4	.1	<1	<1
49	390610079255301	.3	--	.3	--	.8	4.6	<.1	--	--
49	390610079255301	.4	--	.4	--	.8	5.9	<.1	<1	<1
49	390610079255301	.3	3.2	.3	21	.5	6.0	<.1	<1	<1
49	390610079255301	.3	3.4	.4	11	1.1	6.2	.2	<1	<1
49	390610079255301	.5	2.4	27.0	22	4.6	30.0	<.1	<1	2
50	390612079254501	.4	--	.3	--	.7	4.4	.2	--	--
50	390612079254501	.4	--	.3	--	.5	5.3	<.1	<1	<1
50	390612079254501	.4	3.7	.4	51	.7	5.0	<.1	<1	<1
50	390612079254501	.4	4.3	.3	27	.7	6.2	.3	<1	<1
50	390612079254501	.4	4.5	.3	14	.3	4.6	<.1	<1	<1

Appendix E. Construction data for water wells and springs inventoried in Canaan Valley, West Virginia
[gal/min, gallons per minute. Missing data represented by dashes]

Station number	Site number	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (feet below land surface)	Year well constructed	Primary aquifer	Top of casing (feet above land surface)	Bottom of casing (feet below land surface)	Well yield (gal/min)	Secondary aquifer	Topographic setting
390018079281201	1	3,536	490	241	1987	Pocono	0.0	21.0	1.0	Greenbrier	Hillside
390034079280701	2	3,314	400	--	--	Hampshire	0.0	--	--	Greenbrier	Hilltop
390047079263901	65	3,272	50	10.5	--	Greenbrier	--	--	--	Greenbrier	Valley
390103079264101	64	3,320	61	37.1	--	Greenbrier	--	--	--	Greenbrier	Valley
390119079264301	66	3,300	310	80.0	1960	Greenbrier	0.0	--	--	--	Valley
390119079255601	4	3,260	65	49.0	1989	Greenbrier	-2.0	42.0	25.0	Pocono	Valley
390121079263701	67	3,312	496	90.1	1987	Hampshire	-1.2	42.0	--	Pocono	Hilltop
390121079274901	62	3,263	33	20.1	--	Greenbrier	-1.0	--	--	Greenbrier	Valley
390122079263701	5	3,312	100	--	1970	Pocono	2.0	32.0	2.7	Pocono	Hilltop
390122079264301	63	3,282	42	29.8	--	Greenbrier	-1.4	--	--	Greenbrier	Hilltop
390127079262801	6	3,325	400	--	1983	Hampshire	-1.5	--	60.0	Pocono	Hilltop
390133079251901	7	3,239	75	--	--	Pocono	3.0	--	--	--	Valley
390135079275601	60	3,275	281	10.9	1971	Pocono	-1.6	--	--	Pocono	Hillside
390137079264101	68	3,260	138	65.0	1950	Greenbrier	0.0	--	5.0	--	Valley
390147079263701	8	3,265	135	--	1982	Greenbrier	--	--	--	--	Valley
390201079263601	61	3,215	80	14.2	1984	Pocono	-1.0	50.0	--	Greenbrier	Valley
390218079263801	10	3,218	48	7.7	1983	Greenbrier	-1.5	--	--	Greenbrier	Valley
390231079235501	11	3,323	366	50.7	--	Pocono	-0.6	45.4	50.0	Greenbrier	Hillside
390236079264701	12	3,230	67	10.0	1973	Pocono	-1.5	--	--	Greenbrier	Valley
390237079235701	13	3,278	156	40.9	--	Greenbrier	-1.1	--	50.0	Greenbrier	Hillside

Appendix E. Construction data for water wells and springs inventoried in Canaan Valley, West Virginia—Continued

Station number	Site number	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (feet below land surface)	Year well constructed	Primary aquifer	Top of casing (feet above land surface)	Bottom of casing (feet below land surface)	Well yield (gal/min)	Secondary aquifer	Topographic setting
390243079262801	14	3,240	65	--	1981	Greenbrier	-1.0	16.0	--	--	Valley
390247079234901	15	3,285	110	--	1978	Greenbrier	-1.5	53.5	6.5	Greenbrier	Hillside
390251079263001	59	3,251	75	33.2	1981	Greenbrier	-2.0	--	--	Pocono	Valley
390254079265001	16	3,238	70	26.3	1978	Greenbrier	-2.0	--	--	Greenbrier	Valley
390255079264401	58	3,229	130	20.6	1984	Greenbrier	-0.5	--	28.0	Greenbrier	Valley
390257079225601	57	4,045	455	67.7	--	Mauch Chunk	--	450.0	20.0	Pocono	Hillside
390307079234201	17	3,270	109	39.4	--	Greenbrier	-1.1	--	--	Greenbrier	Valley
390310079261301	69	3,230	44	12.0	1935	Greenbrier	0.0	--	20.0	--	Valley
390312079265201	18	3,218	102	--	1969	Greenbrier	--	--	--	--	Valley
390313079245301	19	3,305	269	94.1	1985	Pocono	--	--	--	--	Hillside
390316079261201	20	3,230	95	22.6	1983	Greenbrier	0.0	--	25.0	Greenbrier	Valley
390328079225901	22	3,352	166	45.1	--	Greenbrier	-1.3	--	--	Mauch Chunk	Hillside
390329079240701	23	3,302	105	53.5	1991	Pocono	-1.7	70.3	10.0	Pocono	Hilltop
390332079260401	24	3,210	373	57.7	1987	Pocono	-1.0	42.0	2.5	Greenbrier	Valley
390332079265901	25	3,241	149	--	1970	Greenbrier	1.0	21.0	10.0	Greenbrier	Hillside
390334079253001	26	3,230	72	37.3	1980	Greenbrier	-2.0	--	--	Greenbrier	Valley
390336079244701	27	3,319	175	96.8	1990	Pocono	-0.5	41.5	40.0	Pocono	Hillside
390338079235201	28	3,278	--	--	--	Pocono	--	--	--	--	Hilltop
390346079241701	70	3,363	330	80.6	1991	Pocono	-1.5	62.0	6.0	Pocono	Hilltop
390346079241501	29	3,363	340	--	--	Pocono	-1.3	50.7	1.0	Pocono	Hillto

Appendix E. Construction data for water wells and springs inventoried in Canaan Valley, West Virginia—Continued

Station number	Site number	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (feet below land surface)	Year well constructed	Primary aquifer	Top of casing (feet above land surface)	Bottom of casing (feet below land surface)	Well yield (gal/min)	Secondary aquifer	Topographic setting
390352079263801	30	3,314	161	129.0	--	Greenbrier	-0.5	--	--	Greenbrier	Hilltop
390356079270001	33	3,318	160	103.0	--	Greenbrier	-0.5	--	--	Mauch Chunk	Hillside
390356079254201	32	3,187	64	35.0	1983	Greenbrier	-1.5	15.5	30.0	Greenbrier	Hilltop
390356079234201	31	3,305	120	38.6	1980	Pocono	0.0	45.0	--	Greenbrier	Hilltop
390409079225201	35	3,322	200	86.8	--	Greenbrier	-0.5	145.0	35.0	Mauch Chunk	Hillside
390410079244301	36	3,260	119	61.6	--	Pottsville	-1.0	--	--	Pottsville	Hillside
390419079265401	56	3,287	85	25.7	1987	Mauch Chunk	-2.5	40.0	5.0	Mauch Chunk	Hillside
390448079254801	38	3,220	102	56.0	--	Greenbrier	0.0	92.0	--	Mauch Chunk	Hillside
390456079255301	75	3,300	--	89.3	--	Greenbrier	--	--	--	--	Hilltop
390458079255701	40	3,298	245	--	--	Greenbrier	-1.0	--	--	Mauch Chunk	Hilltop
390507079264301	41	3,416	505	>200.0	1989	Greenbrier	1.0	42.0	13.0	Mauch Chunk	Hillside
390527079254501	42	3,320	124	45.0	--	Greenbrier	0.7	--	--	Mauch Chunk	Hillside
390534079254401	43	3,380	105	--	1953	Mauch Chunk	--	--	--	--	Hillside
390535079255001	55	3,455	--	122.0	--	Mauch Chunk	--	--	--	--	Hillside
390540079255001	44	3,544	262	176.0	1986	Mauch Chunk	1.4	62.6	15.0	Mauch Chunk	Hillside
390543079260801	54	3,780	--	155.0	--	Pottsville	--	--	--	--	Hilltop
390546079254501	45	3,450	155	48.7	--	Mauch Chunk	1.7	--	--	Mauch Chunk	Hillside
390549079255401	74	3,725	140	45.0	1953	Mauch Chunk	0.0	--	3.0	--	Hilltop
390552079255301	73	3,750	60	12.0	1958	Mauch Chunk	0.0	--	10.0	--	Hilltop
390556079254801	72	3,710	--	61.6	--	Pottsville	--	--	--	--	Hilltop

Appendix E. Construction data for water wells and springs inventoried in Canaan Valley, West Virginia—Continued

Station number	Site number	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (feet below land surface)	Year well constructed	Primary aquifer	Top of casing (feet above land surface)	Bottom of casing (feet below land surface)	Well yield (gal/min)	Secondary aquifer	Topographic setting
390557079254801	71	3,710	--	74.8	--	Pottsville	--	--	--	--	Hilltop
390558079254601	46	3,720	91	51.0	1965	Pottsville	0.9	20.1	70.0	Pottsville	Hilltop
390559079254801	47	3,715	101	37.8	1986	Pottsville	1.4	28.6	40.0	Pottsville	Hilltop
390600079260201	53	3,662	120	-0.2	--	Pottsville	0.0	100.0	16.0	Pottsville	Hilltop
390600079254401	48	3,720	122	--	1971	Pottsville	1.0	20.0	15.0	Pottsville	Hilltop
390605079254201	51	3,710	145	76.8	1989	Pottsville	1.0	144.0	12.0	Pottsville	Hilltop
390608079255401	52	3,750	126	31.4	1988	Pottsville	1.0	125.0	50.0	Pottsville	Hilltop
390612079254501	50	3,780	155	95.0	--	Pottsville	--	--	--	--	Hilltop

Station number	Site number	Altitude of land surface (feet)	Type of spring	Primary aquifer	Spring yield (gal/min)	Secondary aquifer	Topographic setting	Name of spring
390107079250101	3	3,356	----	Greenbrier	20.0	Greenbrier	Hillside	Marcus Spring
390205079253401	9	3,215	Fracture/Depression	Greenbrier	201	Greenbrier	Valley flat	Timberline Spring
390324079232501	21	3,240	Fracture/Depression	Greenbrier	350	Greenbrier	Lake/swamp	Sand Spring
390358079253901	34	3,160	Tubular cave	Greenbrier	---	---	Valley flat	Beall Spring
390446079270501	37	3,260	Perched Contact	Mauch Chunk	---	---	Hillside	Black Cherry Spring
390457079252601	39	3,160	Fracture	Greenbrier	100	Greenbrier	Valley flat	Chestnut Spring
390610079255301	49	3,750	Perched seepage	Pottsville	---	---	Hillside	Easter Spring

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