Summary of Ground-Water Quality in West Virginia

By M.V. Mathes, M.D. Kozar, and D.P. Brown

Prepared by the U.S. Geological Survey for the

West Virginia Division of Environmental Protection,
Office of Water Resources,
Ground-Water Program

Charleston, West Virginia
1998

Summary of Ground-Water Quality in West Virginia

By M.V. Mathes, M.D. Kozar, and D.P. Brown

West Virginia Division of Environmental Protection, Office of Water Resources

Prepared by the U.S. Geological Survey for the

West Virginia Division of Environmental Protection,
Office of Water Resources,
Ground-Water Program

Charleston, West Virginia
1998

Statistical comparisons of data from the NWIS data base and the ambient network data set showed no significant differences except for fecal coliform, iron, and manganese. Median concentrations of these three constituents were several times greater for samples from wells and springs in the ambient network. Statistical differences in values for these constituents could be attributed to differences in the state of constituents sampled (dissolved concentrations of iron and manganese for the NWIS data set as opposed to total concentrations for the ambient network data set) and the smaller number of sites in the ambient network. Statistical resolution could be improved by sampling a greater number of wells and springs that have a greater diversity of geologic and topographic conditions for the ambient network. The present ambient network does not include sites in Silurian or Middle Pennsylvanian geologic units nor sites in hilltop settings. The statistical validity of the ambient network could be improved by sampling additional sites, especially those for aquifers underrepresented in the data set.

INTRODUCTION

Chapter 22 of the West Virginia Code, Article 12, commonly referred to as the "Groundwater Protection Act", went into effect in 1991. One of the major provisions of the act mandated ground-water sampling and evaluation with sufficient frequency to ascertain the characteristics and quality of ground water and to evaluate the effectiveness of the ground-water protection programs established pursuant to the act. Baseline data were needed to document current water quality and to provide a data base against which future data can be compared. Emphasis was placed on sampling and analyzing wells that would reflect ambient ground-water quality. Sites were then selected by the U.S. Geological Survey (USGS) in various hydrogeologic settings to document the ground-water-quality conditions in major aquifers of West Virginia (Kozar and Brown, 1995). Site selection was concentrated in areas of high priority or special interest to the West Virginia Division of Environmental Protection, Office of Water Resources (WVDEP-OWR). These areas included the Eastern Panhandle (an area of recent rapid population growth), the industrialized Ohio River Valley, areas with abandoned coal mines, and karst areas susceptible to ground-water contamination. After site selection was completed in these priority areas, additional sites were chosen from other areas of the state to provide representative areal coverage.

A total of 28 sites were sampled from March 1993 to April 1997. Sites were sampled a maximum of 11 times during this period by either WVDEP-OWR or the USGS. Both WVDEP-OWR and USGS laboratories were used in analyzing the samples.

CONTENTS

Page

Abstract 1
Introduction 2
Purpose and scope 3
Physical setting 3
Ground-water systems 6
Source of ground-water recharge 6
Occurrence and flow of ground water 8
Principal aquifers 9
Ground-water quality 11
Approach to statistical analysis of water-quality data 12
Statistical analysis of water-quality data from National Water Information System data base 13
Spatial analysis by geologic unit 15
Spatial analysis by topographic setting 17
Spatial analysis by well depth 17
Statistical analysis of water-quality data from ambient network 17
Spatial analysis by geologic unit 18
Spatial analysis by topographic setting 19
Temporal analysis by season 19
Additional water-quality constituents 19
Comparison of Data from National Water Information System and Ambient Network 20
Future sampling needs and considerations 20
Summary 21
References cited 23

ILLUSTRATIONS

Page

Figure 1. Map showing general location of West Virginia 4
2. Map showing principal aquifers and physiographic provinces in West Virginia....5
3. Block diagram showing generalized occurrence and movement of ground water in a typical ridge and valley system in the Appalachian Plateaus Province of West Virginia 7
4. Map showing location of ground-water-quality-monitoring sites in West Virginia....14
5. Summary of selected water-quality properties and constituents for aquifers in West Virginia 51

TABLES

Page

Tables 1-3. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to:
1. Bedrock age 25
2. Topographic setting 35
3. Well depth....37

Tables 4-6. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to:
4. Bedrock age 39
5. Topographic setting 44
6. Season 46

7. Summary statistics for total metals data from the West Virginia ambient ground-water-quality network....48
8. Organic constituents for which water samples from the West Virginia ambient ground-water-quality network were analyzed....49

CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
million gallons (Mgal)	3,785	cubic meter
gallon per minute (gal/min)	0.06308	liter per second

mg/L - Milligrams per liter
μg/L - Micrograms per liter
col/100 ml - colonies per 100 milliliters

SUMMARY OF GROUND-WATER QUALITY IN WEST VIRGINIA

By M. V. Mathes, M. D. Kozar, and D. P. Brown

ABSTRACT

Water-quality data for the 28 sites in the West Virginia ambient ground-water-quality network and for wells in the U.S. Geological Survey National Water Information System (NWIS) data base for West Virginia were analyzed statistically to identify any water-quality trends and relations and to compare data from the two data sets. Data for 10 selected properties and constituents (pH, fecal coliform, iron, manganese, sulfate, hardness, nitrate plus nitrite, chloride, fluoride, and dissolved solids) were grouped by geologic unit, topographic setting, well depth, and season; simple statistical descriptors such as mean, median, maximum, minimum, standard deviation, and 10th and 90th percentiles were computed for each property and constituent and are summarized in tables.

Analysis of the data for wells from the NWIS data base showed that highest median concentrations of dissolved iron and dissolved manganese are in samples from the Lower Pennsylvanian units, which are found mainly in the low-sulfur coal fields of southern West Virginia; the highest median concentration of dissolved sulfate is in samples from the Quaternary alluvium along the Ohio and Kanawha Rivers; and the highest median hardness and concentrations of dissolved nitrate plus nitrite are in samples from the Cambrian and Ordovician karst limestone units found mainly in the Eastern Panhandle. The highest median concentrations of dissolved iron and dissolved manganese are in samples from valley wells and wells of shallow depth, and hardness is greatest in samples from hilltop wells. Analysis of data for all wells and springs in the ambient network corroborated statistics for the NWIS data set in that median concentration of total iron is highest in samples from the Lower Pennsylvanian units, median concentration of dissolved sulfate is highest in samples from the Quaternary alluvium, and hardness and median concentrations of total nitrate plus nitrite are highest in samples from the Cambrian and Ordovician units. Data from the ambient network did not show any significant seasonal variations in ground-water quality. Of the additional constituents sampled for in the ambient network, median concentrations of metals were less than U.S. Environmental Protection Agency drinking-water standards, and organic chemical constituents were rarely detected.

Statistical comparisons of data from the NWIS data base and the ambient network data set showed no significant differences except for fecal coliform, iron, and manganese. Median concentrations of these three constituents were several times greater for samples from wells and springs in the ambient network. Statistical differences in values for these constituents could be attributed to differences in the state of constituents sampled (dissolved concentrations of iron and manganese for the NWIS data set as opposed to total concentrations for the ambient network data set) and the smaller number of sites in the ambient network. Statistical resolution could be improved by sampling a greater number of wells and springs that have a greater diversity of geologic and topographic conditions for the ambient network. The present ambient network does not include sites in Silurian or Middle Pennsylvanian geologic units nor sites in hilltop settings. The statistical validity of the ambient network could be improved by sampling additional sites, especially those for aquifers underrepresented in the data set.

INTRODUCTION

Chapter 20 of the West Virginia Code, Article 5-M, commonly referred to as the "Groundwater Protection Act", went into effect in 1991. One of the major provisions of the act mandated ground-water sampling and evaluation with sufficient frequency to ascertain the characteristics and quality of ground water and to evaluate the effectiveness of the ground-water protection programs established pursuant to the act. Baseline data were needed to document current water quality and to provide a data base against which future data can be compared. Emphasis was placed on sampling and analyzing wells that would reflect ambient ground-water quality. Sites were then selected by the U.S. Geological Survey (USGS) in various hydrogeologic settings to document the ground-water-quality conditions in major aquifers of West Virginia (Kozar and Brown, 1995). Site selection was concentrated in areas of high priority or special interest to the West Virginia Division of Environmental Protection, Office of Water Resources (WVDEP-OWR). These areas included the Eastern Panhandle (an area of recent rapid population growth), the industrialized Ohio River Valley, areas with abandoned coal mines, and karst areas susceptible to ground-water contamination. After site selection was completed in these priority areas, additional sites were chosen from other areas of the state to provide representative areal coverage.

A total of 28 sites were sampled from March 1993 to April 1997. Sites were sampled a maximum of 11 times during this period by either WVDEP-OWR or the USGS. Both WVDEP-OWR and USGS laboratories were used in analyzing the samples.

Purpose and Scope

This report summarizes water-quality data collected during the period 1993-97 from the ambient ground-water-quality network described in Kozar and Brown (1995). The report also summarizes ground-water-quality data stored in the USGS National Water Information System (NWIS) water-quality data base for West Virginia. Comparisons are made between the NWIS and ambient network data. This report is intended to serve as an aid to State and Federal agencies in planning future ground-water-quality sampling in West Virginia and is a followup to the report by Kozar and Brown (1995), which provides information for each site in the ambient ground-water-quality network.

Physical Setting

West Virginia is in the eastern United States and is bounded by Pennsylvania and Maryland to the north, Virginia to the east, and Kentucky and Ohio to the west (fig. 1). West Virginia is divided into three physiographic provinces—the Appalachian Plateaus, the Valley and Ridge, and the Blue Ridge—each with distinctive rock types and ground-water characteristics (fig. 2). The western and central parts of the State are in the Appalachian Plateaus Physiographic Province and are underlain by nearly horizontal consolidated sedimentary rocks. Streams have eroded the rocks in these areas to form steep hills and deeply incised valleys. The Allegheny Mountains Section of the Appalachian Plateaus Province is underlain by gently to moderately folded sedimentary rocks. Surface-drainage patterns are dendritic, and surface- and ground-water drainage divides generally coincide and are well defined (Kozar and Brown, 1995).

The eastern part of the State, except for the extreme eastern tip, is in the Valley and Ridge Province. The consolidated sedimentary rocks that underlie this area are extensively faulted and sharply folded; the folded strata form a series of broad, northeast-trending valleys and ridges. Surface drainage typically forms a trellis pattern. Surface- and ground-water drainage divides coincide and are clearly defined in noncarbonate areas, but they generally are not clearly defined and do not coincide with surface drainage divides in carbonate areas. The Blue Ridge Province includes only a very small area along the easternmost part of the State and therefore is not mentioned in this report (Kozar and Brown, 1995).

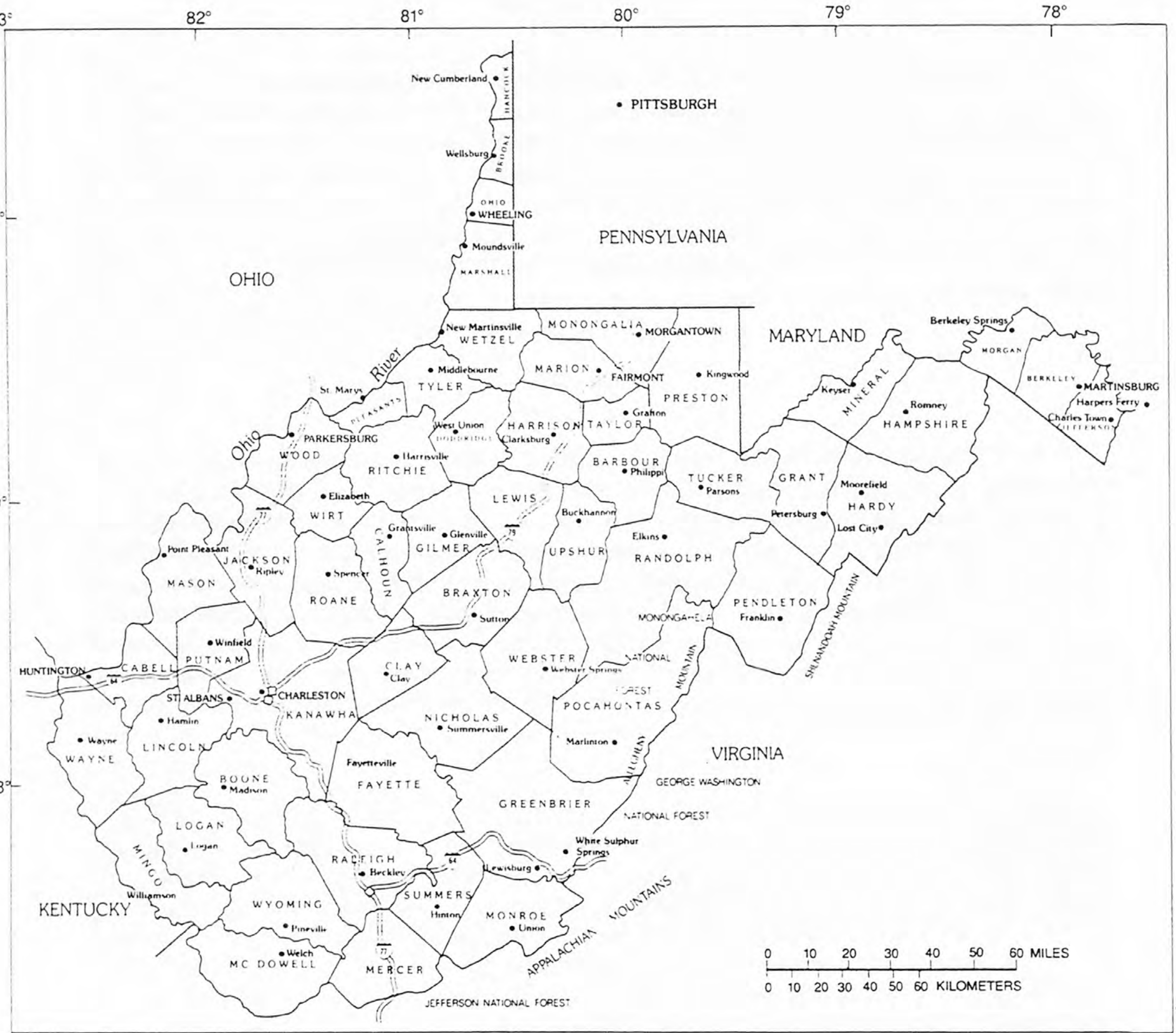


Figure 1. General location of West Virginia.

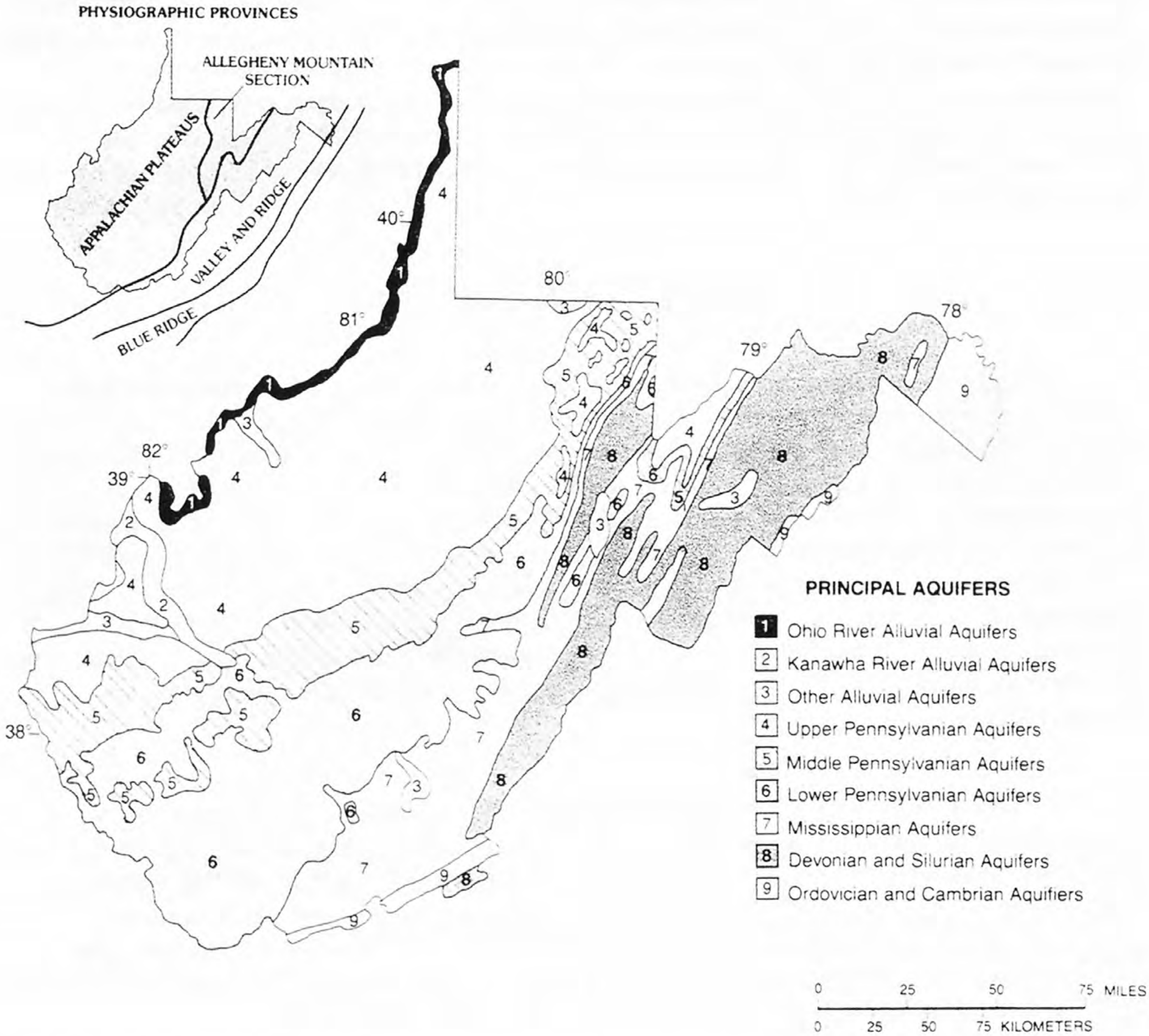


Figure 2. Principal aquifers and physiographic provinces in West Virginia. (Modified from Ferrell (1988, p.524) and Puente (1985, p.441).

GROUND-WATER SYSTEMS

The aquifers and confining beds that underlie an area comprise the ground-water system of that area. Hydraulically, this system serves two functions: it stores ground water in reservoirs and transmits water from recharge areas to discharge areas. In the valley and ridge systems typical of the Appalachian Plateaus Province of West Virginia, water enters ground-water systems in recharge areas and flows downward and laterally through fracture systems, as dictated by hydraulic gradients and hydraulic conductivities, to discharge areas (Heath, 1983) (fig. 3). The flow of ground water generally is slow and may range from a few inches to several hundred feet per year (Kozar and Brown, 1995).

Source of Ground-Water Recharge

Precipitation is the primary source of recharge to the ground-water systems in the State. The orographic effect on the geographic distribution of precipitation is significant. Average annual precipitation ranges from 40 in. along the western boundary of the state to about 60 in. in the higher elevations in the mountainous east-central part of the State. On the eastern side of the mountains, a well-defined rain shadow reduces average annual precipitation to about 36 in. in the Eastern Panhandle. Seasonal variation of precipitation is minimal. About 60 percent of the annual precipitation occurs from March through August. July is typically the wettest month, whereas September, October, and November are typically the driest months. About 50 percent of the precipitation returns to the atmosphere by evapotranspiration. Thunderstorms are common from May through July and can produce intense local rainfall, causing flooding along unregulated streams (Appel, 1986).

Runoff in West Virginia changes seasonally and geographically. Average annual runoff ranges from 12 in. in the Eastern Panhandle to about 40 in. in the higher mountainous areas and to about 16 in. in the western and southern parts of the State. The least amount of runoff generally is from June through November—a period of high evapotranspiration—and the most runoff generally is from December through May—a period of low evapotranspiration. In the higher mountainous areas in the east-central part of the State, where average annual snowfall is as much as 200 in., runoff is significantly affected by spring snowmelt (Appel, 1986).

As a result of evaporation and runoff, only a small part of the precipitation infiltrates the ground to recharge ground water. In the noncarbonate, consolidated-rock areas of the State, annual recharge generally ranges from 2 to 6 in. In the carbonate-rock (primarily limestone) areas in the Valley and Ridge Province, annual recharge ranges from 6 to 12 in. (Appel, 1986).

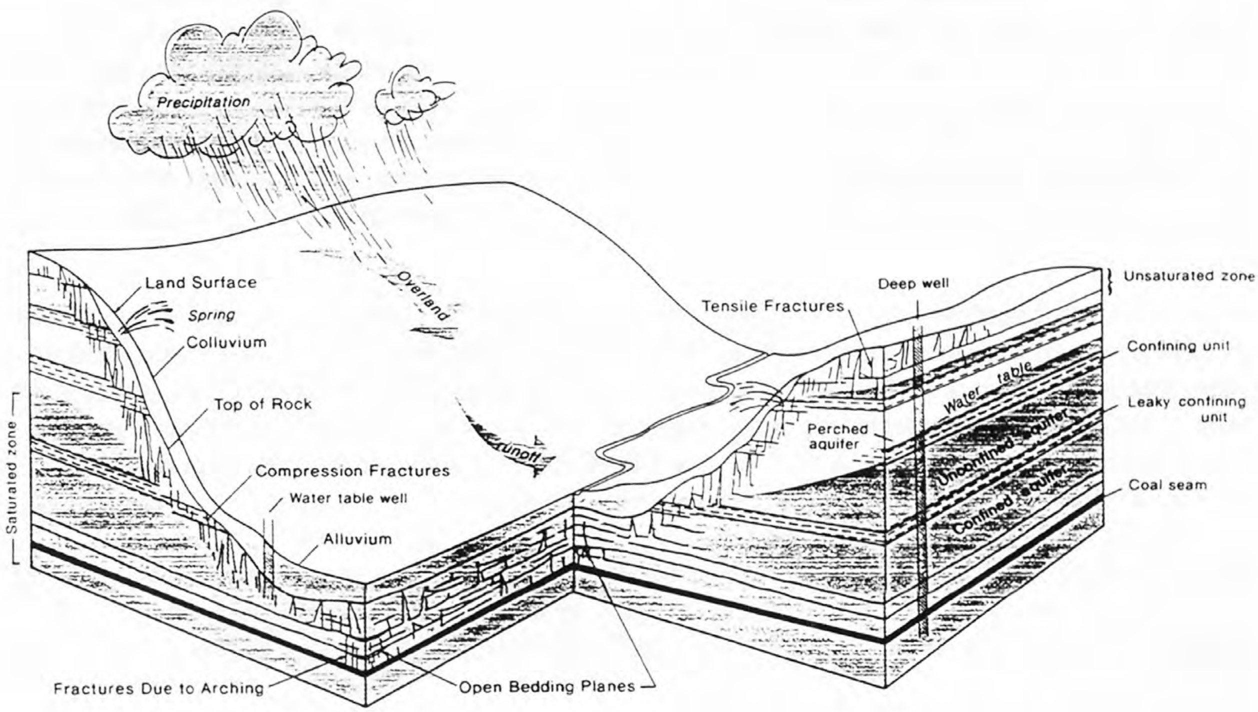


Figure 3. Generalized occurrence and movement of ground water in a typical ridge and valley system in the Appalachian Plateaus Province of West Virginia. (From Heath, 1983, p. 14).

Occurrence and Flow of Ground Water

Some of the precipitation that infiltrates the Earth's surface is retained at shallow depth as soil moisture, and some moves downward and into the underlying aquifers (fig. 3). Where an aquifer is overlain by permeable material, unconfined or water-table conditions exist. Locally, the water table may be perched above impermeable rock layers (confining units) that impede the downward movement of water to the zone of saturation of an aquifer. Wells that tap unconfined aquifers are referred to as "water-table wells." Water levels in these wells indicate the position of the water table in the surrounding unconfined aquifer. Ground water is confined where aquifers lie between or beneath beds of low permeability. Wells drilled into confined aquifers are referred to as "artesian wells." In these wells, the water level rises to some height above the top of the aquifer and represents the potentiometric surface of the confined aquifer (Ehlke and others, 1982).

Intergranular spaces and fractures are both important for storage and flow of ground water in sedimentary rocks. Intergranular spaces are voids or openings between particles of rock that were formed at the time of deposition or are the result of dissolution of cementing material or the rock particle. Primary permeability is a measure of the ease with which water will flow through interconnected intergranular spaces. Unconsolidated material such as alluvium generally will deform without fracturing. Water that infiltrates unconsolidated material can deposit cementing materials in intergranular spaces, thus reducing the intergranular space and the degree of interconnection and causing the rocks to consolidate. Consolidation and cementation also make the rock more brittle and subject to fracturing. Fracturing, which forms openings in rocks through which water may flow, is an example of secondary permeability (Kozar and Brown, 1995).

Alluvium, consisting of stream-deposited or glacially deposited sand, clay, and gravel typically overlain by fluvial silts and clays, is found in river terraces within the Ohio and Kanawha River Valleys. The thickness of the alluvium commonly ranges from 25 to 100 ft and may exceed 140 ft in the Ohio River Valley (Puente, 1985). Alluvial deposits generally are productive sources of ground water.

Within the Appalachian Plateaus Physiographic Province, the bedrock consists predominantly of sandstone and shale interbedded with limestone and coal. Sandstone contains intergranular, bedding-plane, and fracture openings and generally yields from 1 to 100 gal/min of water to wells and may yield as much as 400 gal/min. In areas where the pore spaces or fractures are filled with secondary minerals and little fracturing has occurred, a sandstone may yield little water to wells. Shale and limestone, because of their extremely small intergranular spaces, generally yield little water to wells. In areas of dense fracturing at shallow depth, shales may yield from 1 to 30 gal/min. In limestones, fractures and joints may become widened by dissolution of the calcium carbonate; this widening increases the ability of the rock to store and transmit large volumes of water. The number of joints, fractures, and cavities generally is greatest near land surface. Typical well yields in limestone terranes can range from 1 to 400 gal/min and may exceed 600 gal/min (Puente, 1985).

The degree of primary and secondary permeability varies in bedrock aquifers. Primary permeability of surficial rocks in the Appalachian Plateaus and Valley and Ridge Provinces is low; secondary permeability is much higher. Water in the nearly horizontal bedrock of the Appalachian Plateaus Province flows through and is stored in joints, fractures, bedding planes; and, in carbonate rocks, in solution channels (Wyrick and Borchers, 1981).

Studies by the USGS indicate that fracture systems affect the occurrence and flow of ground water in a typical valley aquifer system of the Appalachian Plateaus. Ground water is found mainly in horizontal bedding-plane fractures under the valley floors and in nearly vertical and horizontal tensile fractures along the valley walls (fig. 3). The fractures pinch out under the valley walls, which form impermeable barriers. The aquifer system is confined under the valley walls and unconfined under the valley floor (Wyrick and Borchers, 1981).

The sandstone, shale, and limestone rocks in the Valley and Ridge Province are a folded series of northeastward-trending anticlines and synclines. The ridges are underlain by more resistant rock, generally sandstone, and the valleys are underlain by less resistant rock, generally shale and limestone. Permeability tends to be greatest along bedding planes, fractures, and faults in the Valley and Ridge Province (Hobba and others, 1973).

Flow in the regional ground-water systems in the Appalachian Plateaus and Valley and Ridge Provinces is predominantly lateral and upward toward major valleys; the flow is slow in comparison to that in the more permeable surficial bedrock flow system. Vertical leakage through confining units beneath major valleys generally is upward. The deeper bedrock aquifers usually contain much older water, which is usually brackish and has not been flushed by shallow ground-water circulation (Kozar and Brown, 1995).

Principal Aquifers

Two principal types of aquifers underlie West Virginia—unconsolidated alluvial deposits and sedimentary bedrock aquifers. The major hydrogeologic units or aquifers of the State have been categorized informally by geologic age because of the vertical differences in lithology in the principal aquifers. The characteristics of the principal aquifers are described below, from youngest to oldest (Puente, 1985).

The alluvial aquifers consist of Pleistocene to recent deposits of sand and gravel interbedded with silt and clay (Carlston and Graeff, 1955). Ground water in the alluvium generally is unconfined to semiconfined (Lew Baker, W.Va. Department of Health, written commun., 1994). The alluvial aquifers along the Ohio River in the western part of the State are the best sources of ground water for public supply and industrial use in the State because of the high yields that can be obtained; for example, the Parkersburg Municipal Water Plant withdraws an average of 5 Mgal of water per day from collector wells constructed within the alluvium (James Furr, Parkersburg Water Plant, written commun., 1993). Well yields depend upon the permeability, areal extent, and saturated thickness of the alluvium and the proximity of wells to rivers in areas where infiltration of large quantities of streamflow can be induced (Kozar and Brown, 1995).

Major sources of ground water in the Appalachian Plateaus Province in the western and central parts of the State are the Upper and Lower Pennsylvanian aquifers (fig. 2). The Upper Pennsylvanian aquifers consist of the Monongahela and Conemaugh Groups, and the Permian aquifers consist of the Dunkard Group. These geologic units are primarily nearly horizontal layers of shale with thin interbeds of fine-grained sandstone, siltstone, limestone, and coal (Cardwell and others, 1968). The Lower Pennsylvanian aquifers, which consist of the Allegheny Formation and the Pottsville Group, are primarily massive coarse-grained sandstone with interbeds of shale, siltstone, coal, and limestone (Puente, 1985).

In the southeastern part of the State, the mostly noncarbonate strata of the Mauch Chunk Group, Maccrady Formation, and the Pocono Group within the Mississippian aquifers are similar in lithology and permeability to the Pennsylvanian aquifers in the Appalachian Plateaus. The rocks comprising the Mississippian aquifers, however, are gently to moderately folded. In this area, some of the sandstones are saturated and are confined by overlying and underlying shales. Under these conditions, the aquifers yield moderate to large amounts of water (Puente, 1985).

The predominantly carbonate Greenbrier Group of the Mississippian aquifers can potentially provide large quantities of ground water. Fracture openings in these strata generally have been enlarged by dissolution of the carbonate rock. Springs and wells that tap solution openings can yield more than 200 gal/min; however, in limestone areas a well that penetrates few fractures or solution openings and is virtually dry may be only a few feet away from a well that taps a large solution opening and produces enough water to supply a small city (Puente, 1985).

Farther to the east, in the Valley and Ridge Province, the aquifers are faulted and compressed into steep folds, and this deformation greatly affects the storage and flow of ground water. In these areas, ground-water conditions are more variable than in the rest of the State. Aquifers in the principal carbonate units, such as the Helderberg Group of Devonian age, the Beekmantown Group of Ordovician age, the Elbrook and Conococheague Formations of Cambrian age, and some of the massive sandstone units, such as the Oriskany Sandstone of Devonian age, can potentially yield large amounts of ground water. Springs with large yields (as much as 15,000 gal/min) are common in the carbonate rocks of the Eastern Panhandle (Puente, 1985).

The water-bearing properties of minor carbonate units, such as the Tonoloway Formation of Silurian age, the Waynesboro Formation, and the Tomstown Dolomite of Cambrian age, generally are comparable to those of the major carbonate units of Mississippian, Devonian, and Ordovician age. Water storage in the minor carbonate units generally is small because of their limited areal extent (Bieber, 1961). The noncarbonate units in the Devonian, the Silurian, the Ordovician, and the Cambrian aquifer systems generally yield small amounts of water (less than 30 gal/min) to wells (Puente, 1985).

GROUND-WATER QUALITY

The chemical quality of ground water is determined by the types and concentrations of minerals it contains. The types and concentrations of minerals present in ground water depend, in turn, on the chemistry of the water that recharges the aquifer, the chemical and physical properties of the soil and rock through which the water moves, and the amount of time the water is in the ground-water system. Generally, water becomes more mineralized as it moves through the flow system. Water at depth moves slowly and typically is highly mineralized (Heath, 1983).

Typically, only the first 10 to 30 ft of a well that taps consolidated bedrock aquifers in West Virginia are cased. The rest of the well typically is an open borehole that ranges from 10 to several hundred feet in depth and usually is 6 in. in diameter. Water typically is derived from several water-bearing zones because of the lithologic variability of the aquifers. The amounts and chemical properties of the water from each zone can be different; thus, the quality of water pumped from a well depends on which zones are tapped and the proportion of water derived from each zone (Kozar and Brown, 1995).

In much of the State, topography influences the shallow ground-water flowpath. Although recharge occurs at all topographic settings, the flow of ground water typically is towards valleys; as a result, the youngest ground water is produced from hilltop wells and the oldest ground water is produced from valley wells. Variations in this pattern occur, particularly in the steeply folded rocks in the eastern part of the State and in limestone areas where the relation of recharge and discharge areas is complex (Ferrell, 1988).

Because of chemical changes that occur as ground water percolates downward into valleys or flows laterally to hillside seeps and springs, the chemical composition of ground water tends to differ with respect to topography. These differences are governed by the type and solubility of the rocks the water contacts, the length of time it is in contact with a particular type of rock, and the chemical properties of the water itself (Ferrell, 1988).

Concentrations of iron and manganese in rocks of Pennsylvanian age generally are greater in ground water from valley settings than in ground water from hilltop settings. Where limestone is common, such as the Upper Pennsylvanian aquifers, hardness is highest in hilltop settings and least in valley settings. The relation between hardness and sodium content primarily is the result of sodium-calcium ion exchange, a softening process by which calcium ions are exchanged for sodium ions in clays as ground water percolates through, or flows along, clay layers. Because of differences with respect to topography, the chemical quality of water in the bedrock aquifers cannot be easily mapped on an areal basis. Wells in one topographic setting may yield water of a chemical quality very different from water in nearby wells in another topographic setting (Ferrell, 1988).

Ground-water quality is also affected by human activities and can be degraded as a result of industrial waste disposal, coal mining, oil and gas drilling, agricultural activities, domestic or municipal waste disposal, transportation, and rural development. Studies by the USGS, other Federal agencies, various State agencies, and academic institutions have documented many such changes (Kozar and Brown, 1995).

Approach to Statistical Analysis of Water-Quality Data

In this report, "total concentrations" refer to concentrations of particular water-quality constituents determined by analysis of a whole, unfiltered water sample. "Dissolved concentrations" refer to concentrations of particular water-quality constituents determined by analysis of a water sample that has been filtered through a 0.45-micrometer filter. The data discussed in this report are based on two data sets. The first data set consists of concentrations of dissolved constituents from wells listed in the U.S. Geological Survey's National Water Information System (NWIS) data base. A second, much smaller ambient ground-water-quality data set consists primarily of concentrations of total constituents in samples collected from wells and springs by the USGS and the WVDEP-OWR. The data from both data sets discussed in this report are for raw untreated water. U.S. Environmental Protection Agency (USEPA) drinking water standards mentioned in this report are for treated drinking water. Primary standards or maximum contaminant levels (MCL's) are enforceable; secondary maximum contaminant levels (SMCL's) are unenforceable Federal guidelines.

Water-quality data collected at the 28 sites in the ambient ground-water-quality network (fig. 4) and for all wells in the USGS NWIS data base were input into spreadsheets from which simple statistics were computed. Censored data (concentration values reported as less than a detection limit) were set to zero for one set of computations and to the upper detection limit for each property or constituent for another set of computations. A comparison of the statistics computed by each method of treatment of censored data indicated no significant difference in value for most properties or constituents. The computations used in this report are from the second set of computations, in which the censored values were all set to the detection limit. The ambient data were grouped and analyzed by geologic unit (bedrock age), topographic setting, and season. The data from the NWIS data base were grouped and analyzed by geologic unit, topographic setting, and well depth. Tables that summarize the simple statistics for 10 selected water-quality properties and constituents for the ambient network and for the NWIS data base are presented at the back of this report. These tables illustrate the effects of geology, topography, and well depth on ground-water quality and allow comparisons of water-quality data between seasons and between the NWIS data base and the ambient network. Also presented at the back of the report are a table listing simple statistics for additional water-quality constituents for the ambient network and a table listing organic constituents sampled for the ambient network.

Statistical Analysis of Water-Quality Data from National Water Information System Data Base

Data for all wells in the USGS NWIS data base were grouped by geologic unit, topographic setting, and well depth. Simple statistical descriptors such as mean, median, maximum, minimum, standard deviation, and 10th and 90th percentiles were computed for each grouping (tables 1-3 at back of report). Median concentrations describe central tendency—half of the values in the data set are above the median and half are below the median. For 10th and 90th percentiles, 10 and 90 percent of the samples, respectively, are less than this value. Water-quality properties and constituents for which samples were analyzed included pH, fecal coliform, dissolved iron, dissolved manganese, dissolved sulfate, hardness, dissolved nitrate plus nitrite, dissolved chloride, dissolved fluoride, and dissolved solids.

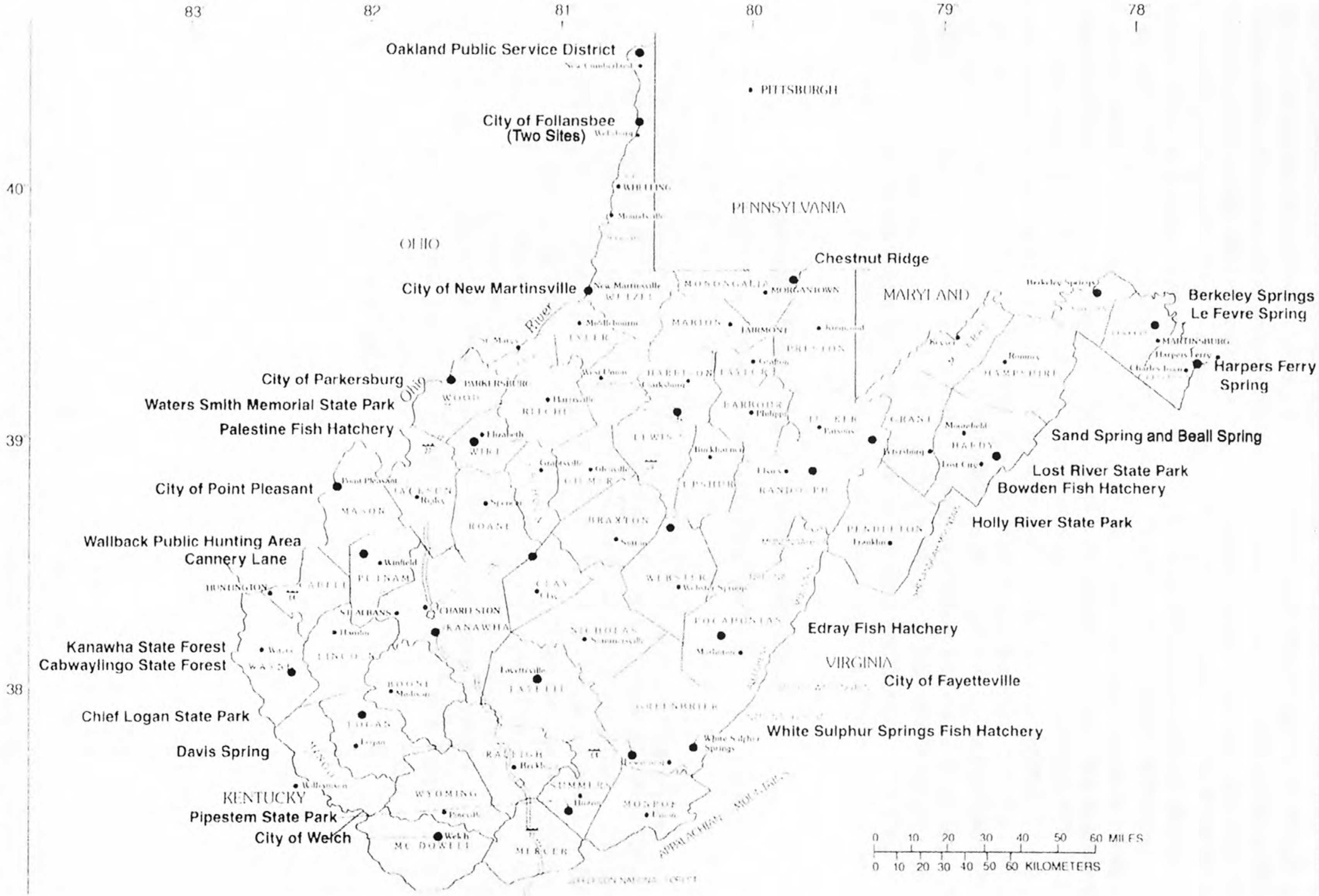


Figure 4. Location of ground-water-quality-monitoring sites in West Virginia.

Spatial Analysis by Geologic Unit

Wells from the NWIS data base were analyzed by geologic unit. Wells were grouped by Cambrian, Ordovician, Silurian, Devonian, Mississippian, Lower Pennsylvanian (Pottsville Group), Middle Pennsylvanian (Allegheny Formation), Upper Pennsylvanian (Monongahela and Conemaugh Groups), Permian (Dunkard Group), and Quaternary alluvium geologic units. Simple statistics were then computed for each of the 10 properties and constituents listed previously; these are summarized in table 1 and figure 5 (at back of report). Table 1 is discussed in the following paragraphs. Figure 5 is a graphic representation in boxplot format of the distribution of pH, dissolved iron, dissolved manganese, dissolved sulfate, hardness, dissolved nitrate plus nitrite, and dissolved chloride for each of the above geologic units in the NWIS data base. Distribution of pH is similar for all geologic units; most samples have pH in the near-neutral (pH 7.0) range. Dissolved iron and manganese concentrations tend to be greatest in samples from the Quaternary alluvium, Devonian, and Pennsylvanian geologic units. Dissolved sulfate and chloride show only minor variation in distribution among geologic units. Hardness and dissolved nitrate plus nitrite tend to be greatest in samples from the Cambrian and Ordovician geologic units.

Most of the fecal coliform data in the NWIS data base—239 of 252 analyses—are for sites in only four geologic units: Cambrian, Ordovician, Mississippian, and Lower Pennsylvanian (table 1). There are no fecal coliform data in the NWIS data base for the Quaternary alluvium, and there is only one analysis each for the Permian and Silurian rocks. Fecal coliform values that exceed 100 col/100 ml were measured in samples from wells in the Cambrian, Ordovician, Devonian, and Lower Pennsylvanian units.

Median dissolved iron concentration exceeds U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level of 300 μg/L in samples from sites in the Lower and Middle Pennsylvanian and the Devonian geologic units, and median dissolved manganese concentration exceeds USEPA secondary maximum contaminant level of 50 μg/L in samples from sites in the Quaternary alluvium; Upper, Middle, and Lower Pennsylvanian; and Devonian geologic units (table 1). Concentrations of dissolved iron at the 90th percentile exceed 300 μg/L in samples from all geologic units except the Cambrian and Silurian, and concentrations of dissolved manganese at the 90th percentile exceed 50 μg/L in samples from all geologic units except the Silurian. Dissolved iron concentrations exceed 300 μg/L in 61 percent of samples from the Lower Pennsylvanian, 54 percent from the Devonian, and 54 percent from the Middle Pennsylvanian geologic units. Dissolved manganese concentrations exceed 50 μg/L in 78 percent of the samples from the Lower Pennsylvanian, 65 percent from the Middle Pennsylvanian, 66 percent from the Devonian, 58 percent from the Quaternary alluvium, and 57 percent from the Upper Pennsylvanian geologic units.

Median concentrations of dissolved sulfate and concentrations at the 90th percentile do not exceed 250 mg/L in samples from any geologic unit. The Quaternary alluvium found along the Ohio and Kanawha Rivers has the highest median sulfate concentration (47 mg/L) of the geologic units (table 1).

At least one sample in each geologic unit is classified as very hard water (hardness in excess of 180 mg/L; table1). Median hardness values are greatest in samples from the Cambrian and Ordovician geologic units with their numerous limestone formations. Median hardness for samples from each of the geologic units as classified by Durfor and Becker (1964) are as follows:

Very hard - greater than 180 mg/L; Cambrian, Ordovician

Hard - 121-180 mg/L; Silurian, Permian, Quaternary alluvium

Moderately hard - 61-120 mg/L; Devonian, Mississippian, Pennsylvanian

Soft - 0-60 mg/L; none

Median concentrations of dissolved nitrate plus nitrite do not exceed the USEPA maximum contaminant level (10 mg/L as nitrogen) in samples from any geologic unit. Concentrations of dissolved nitrate plus nitrite at the 90th percentile exceed 10 mg/L as nitrogen in samples from the Cambrian and Ordovician geologic units (table 1). About 27 percent of the samples from the Cambrian and about 12 percent of the samples from the Ordovician geologic units exceed this contaminant level. Cambrian and Ordovician units are present in the agricultural areas of the Eastern Panhandle, and both contain karst formations that are highly susceptible to contamination from land surface.

Median dissolved chloride concentrations and concentrations at the 90th percentile do not exceed secondary maximum contaminant level of 250 mg/L in samples from any geologic units (table 1). This is somewhat surprising because saltwater underlies the entire State at varying depth and can easily flow into deeper wells or wells located where the saltwater is close to the surface. Improperly cased and abandoned oil and gas wells can provide routes for saltwater to reach shallow aquifers.

Median dissolved fluoride concentration and dissolved fluoride concentration at the 90th percentile do not exceed either the maximum contaminant level of 4 mg/L or the secondary maximum contaminant level of 2 mg/L in samples from any geologic unit (table 1).

Median concentration of dissolved solids does not exceed the secondary maximum contaminant level of 500 mg/L in samples from any geologic unit. Concentrations of dissolved solids at the 90th percentile exceed the secondary maximum contaminant level of 500 mg/L in samples from the Cambrian, Ordovician, Middle and Upper Pennsylvanian, Permian, and Quaternary alluvium.

Spatial Analysis by Topographic Setting

Wells from the NWIS data base were grouped by topographic setting into hilltop, hillside, and valley categories. Simple statistics were computed for the 10 selected properties and constituents previously grouped by geologic unit. These statistics are summarized in table 2 at the back of the report. Greatest median concentrations of dissolved iron and manganese are found in samples from valley wells, intermediate median concentrations in samples from hillside wells, and lowest median concentrations in samples from hilltop wells. Hardness appears to have the opposite trend, with the highest median concentration in samples from hilltop wells and the lowest median concentration in samples from valley wells. The other seven properties and constituents do not show any distinct patterns with respect to topographic setting.

Spatial Analysis by Well Depth

Wells from the NWIS data base were grouped by well depth into categories of 0-100 ft, 101-300 ft, and greater than 300 ft deep. Simple statistics were computed for the 10 selected properties and constituents and are summarized in table 3 at the back of the report. Samples from shallow wells have much higher median concentrations of dissolved iron and manganese than samples from deep wells. Median concentration of dissolved iron in samples from wells 0-100 ft deep is 300 µg/L, from wells 101-300 ft deep is only 60 µg/L, and from wells more than 300 ft deep is only 35 µg/L. Likewise, median concentration for dissolved manganese in samples from wells 0-100 ft deep is 130 µg/L, from wells 101-300 ft deep is only 47 µg/L, and from wells more than 300 ft deep is only 9 µg/L. The only other characteristic that shows any consistent variation with well depth is median concentration of dissolved solids, which increases with increasing well depth.

Statistical Analysis of Water-Quality Data From Ambient Network

Data for all 28 sites in the ambient ground-water-quality network were sorted by geologic unit, topographic setting, and season (summer (June-October) and winter (November-May)). Simple statistics such as mean, median, maximum, minimum, standard deviation, and 10th and 90th percentiles were computed for pH, fecal coliform, total iron, total manganese, dissolved sulfate, hardness, total nitrate plus nitrite, dissolved chloride, total fluoride, and dissolved solids. The statistics computed for each characteristic are presented in tables 4-6 at the back of the report.

Spatial Analysis by Geologic Unit

Sites from the ambient network were grouped by geologic unit into Cambrian, Ordovician, Devonian, Mississippian, Lower Pennsylvanian, Upper Pennsylvanian, Permian, and Quaternary alluvium data sets. (No samples were collected from the Silurian and Middle Pennsylvanian units.) Simple statistics were then computed, and these are summarized in table 4 at the back of the report. Because the data set for ambient network is much smaller than the data set from the NWIS data base, trends and relations in the data are not as distinct nor as statistically reliable (thus, the reason for the inclusion of the NWIS data-base analysis in this report). Nevertheless, patterns in the ambient network data are similar to those for the NWIS data base.

The highest median concentration of total iron (1,100 μg/L) is in samples from the Lower Pennsylvanian geologic unit (table 4). The NWIS data base (table 1) also shows that samples from the Lower Pennsylvanian have the highest median concentration of dissolved iron (790 μg/L). Lower Pennsylvanian geologic units are found mainly in the low-sulfur coal fields of southern West Virginia. Median total iron concentration exceeds secondary maximum contaminant levels (300 μg/L) in samples from the Upper and Lower Pennsylvanian geologic units. Total iron concentrations at the 90th percentile exceed 300 μg/L in samples from the Lower and Upper Pennsylvanian and Quaternary alluvium. The greatest median concentration of total manganese (135 μg/L) is in samples from the Quaternary alluvium, and the second greatest median concentration (100 μg/L) is in samples from the Lower Pennsylvanian; this differs from the pattern of the larger data set in that the greatest median dissolved manganese concentration (170 μg/L) in wells from the NWIS data base is in samples from the Lower Pennsylvanian. Median total manganese concentration exceeds the secondary maximum contaminant level of 50 μg/L in samples from the Quaternary alluvium and the Lower Pennsylvanian geologic units, and total manganese concentration at the 90th percentile exceeds this level in samples from the Quaternary alluvium, Upper and Lower Pennsylvanian, and Devonian geologic units.

The highest median dissolved sulfate concentration (53 mg/L) is in samples from the Quaternary alluvium, and the highest median hardness (339 mg/L) and total nitrate plus nitrite concentrations (3.2 mg/L) are in samples from the Cambrian geologic unit (table 4). No significant trends were found for chloride, fluoride, or dissolved solids for the ambient sites.

Spatial Analysis by Topographic Setting

Sites from the ambient network included only topographic settings of valley and hillside, and analysis and discussion of data patterns relating to topographic setting are incomplete. Simple statistics were computed for data grouped as valley or hillside and are summmarized in table 5 at the back of the report.

Temporal Analysis by Season

Sites from the ambient network were grouped by season. Only two periods were analyzed, summer (June-October) and winter (November-May). Simple statistics were computed for both periods (table 6). Most ground-water recharge occurs during winter and spring, and very little recharge occurs during the summer. Median values do not appear to be significantly different for these two periods for any property or constituent.

Additional Water-Quality Constituents

Table 7 summarizes statistics computed for additional water-quality constituents for the ambient network: total calcium, magnesium, potassium, sodium, aluminum, antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, beryllium, and zinc. Median concentrations of these constituents do not exceed any maximum or secondary maximum contaminant levels. Concentrations of these constituents at the 90th percentile exceed maximum contaminant levels for antimony (6 mg/L) and lead (15 mg/L) and the secondary maximum contaminant level for aluminum (50 mg/L).

Water-quality data were also collected for several organic constituents for the ambient network. In almost all cases, values for the data did not exceed detection limits. For the period 1994-97, only four organic constituents exceeded detection limits at any site: 1,1,1-trichloroethane (maximum 14 μg/L), trichloroethene (maximum 31.3 μg/L), 1,1,2,2-tetrachloroethane (maximum 6.2 μg/L), and cis-1,2-dichloroethene (maximum 22.3 μg/L). All organic concentrations exceeding detection limits were in samples collected at the Point Pleasant and Follansbee well fields. None of the organic constituents detected exceed any water-quality standards. Table 8 is a list of organic constituents sampled for the ambient network.

Comparison of Data from National Water Information System and Ambient Network

Comparisons of median values from the NWIS and ambient network data bases show that for most of the properties and constituents, medians are not significantly different. The exceptions are fecal coliform, iron, and manganese. Median concentrations of these three constituents are several times greater for samples from wells and springs in the ambient network. Some of the difference for the iron and manganese concentrations can be explained by the fact that NWIS data are for dissolved iron and manganese and ambient data are for total iron and manganese. Some of the variation could be attributed to the much smaller number of samples collected for the ambient network than collected for the NWIS data base.

Future Sampling Needs and Considerations

Prior attempts to document seasonal variation in ground-water quality in West Virginia have produced no statistically significant results (Kozar and others, 1991; Kozar, 1996; and Shultz and others, 1995). Similarly, no statistically significant seasonal trends were detected in samples from the ambient ground-water-quality network. Thus, future ambient ground-water-quality sampling would probably be more cost effective and could benefit from sampling a larger number of sites only once for a broad suite of constituents including common ions, trace metals, bacteria, and radon, rather than sampling the same sites repeatedly. Pesticides and volatile organic compounds (VOC's) were not detected at most sites sampled as part of the ambient ground-water-monitoring network or the Kanawha/New River studies of the USGS National Water-Quality Assessment program. Therefore, pesticide and VOC samples would not need to be collected at all sites in the ambient ground-water-monitoring network. As few as 20 percent of sites sampled for pesticides and possibly 30 to 50 percent of sites sampled for VOC's would probably be sufficient to describe the occurrence and distribution of these constituents. Sampling only 30 different sites a year over a period of 10 years could provide a valuable data base of more than 300 sites sampled for a broad suite of constituents, which could be used to assess the ambient ground-water resources of West Virginia. In addition, analysis of existing ambient monitoring sites has revealed that none of the sites are located on hilltops or in Silurian or Middle Pennsylvanian aquifers. The statistical validity of the ambient network could be improved by sampling additional sites, especially those for underrepresented aquifers in the data set.

SUMMARY

Data for both the NWIS data base and the ambient network showed the highest median iron concentration in samples from the Lower Pennsylvanian units, the highest median sulfate concentration in samples from the Quaternary alluvium, and the highest hardness and highest median nitrate plus nitrite concentrations in samples from the Cambrian and Ordovician units. NWIS data showed that median dissolved iron and manganese concentrations are greater in samples from valley wells and from shallow wells and that hardness is greatest in samples from hilltop wells. Ambient-network data did not show any significant seasonal variation of ground-water quality.

On the basis of the NWIS data, median dissolved iron concentrations exceed the 300-μg/L USEPA secondary maximum contaminant level in samples from the Lower and Middle Pennsylvanian and Devonian geologic units. Median dissolved manganese concentrations exceed the 50–μg/L secondary maximum contaminant level in samples from the Lower, Middle, and Upper Pennsylvanian, the Devonian, and the Quaternary alluvium geologic units. Median dissolved sulfate, chloride, fluoride, and nitrate plus nitrite concentrations do not exceed contaminant levels in samples from any geologic units. Dissolved iron concentration exceeds the secondary contaminant level of 300 μg/L in 61 percent of the samples from the Lower Pennsylvanian, 54 percent of the samples from the Middle Pennsylvanian, and 54 percent of the samples from the Devonian geologic units. Dissolved manganese exceeds the secondary contaminant level of 50 μg/L in 78 percent of the samples from the Lower Pennsylvanian, 65 percent from the Middle Pennsylvanian, 66 percent from the Devonian, 57 percent from the Upper Pennsylvanian, and 58 percent from the Quaternary alluvium. Dissolved nitrate plus nitrite exceeds the maximum contaminant level of 10 mg/L in 27 percent of the samples from the Cambrian and 12 percent of the samples from the Ordovician geologic units.

Data from the ambient network show that antimony, lead, and aluminum concentrations at the 90th percentile exceed contaminant levels. For most of the samples analyzed for organic constituents, concentrations are below detection limits.

NWIS and ambient ground-water-quality data were similar for most properties and constituents except fecal coliform, iron, and manganese. Differences for these constituents could be explained by differences in state of the constituent (dissolved as opposed to total iron and manganese) and differences in size of data sets (ambient data set is much smaller than NWIS data set).

Examination of both the ambient network and NWIS data base pointed out some gaps in available ground-water-quality data for West Virginia. Bacteria data in the NWIS data base, excluding the ambient data, are mostly for samples from four geologic units (Cambrian, Ordovician, Mississippian, and Lower Pennsylvanian). Excluding the ambient data, there were no bacteria data for samples from the Quaternary alluvium in the NWIS data base. The ambient network did not include any samples from hilltop ground-water sites nor from the Silurian or Middle Pennsylvanian geologic units.

The representativeness of the data for the ambient network would be increased by sampling more sites with a greater diversity of geologic and topographic conditions. Wells in the Silurian and Middle Pennsylvanian as well as hilltop wells could be added to improve geologic and topographic diversity, and fecal coliform and other bacteria data could be collected at all sites to improve the representation of these constituents. A sampling program of 30 different ambient sites sampled each year for 10 years could provide a more complete ambient data base than has resulted from the current sampling approach.

REFERENCES CITED

Appel, D.H., 1986, West Virginia surface-water resources, *in* Moody, D.W., Chase, E.B., and Aronson, D.A., comps., National Water Summary 1985—Hydrologic events and surface-water resources: U.S. Geological Survey Water-Supply Paper 2300, p. 479-484.

Bieber, P.P., 1961, Ground-water features of Berkeley and Jefferson Counties, West Virginia: West Virginia Geological and Economic Survey Bulletin 21, 81 p.

Cardwell, D.H., Erwin, R.B., and Woodward, H.P., comps., 1968, Geologic map of West Virginia: West Virginia Geological and Economic Survey, scale 1:250,000.

Carlston, C.W., and Graeff, G.D., Jr., 1955, Ground-water resources of the Ohio River Valley in West Virginia, pt. III of Geology and economic resources of the Ohio River Valley in West Virginia, 1956: West Virginia Geological and Economic Survey, v. 22, p. 1-131.

Durfor, C.N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States, 1962: U.S. Geological Survey Water-Supply Paper 1812, 364 p.

Ehlke, T.A., Bader, J.S., Puente, Celso, and Runner, G.S., 1982, Hydrology of area 12, Eastern Coal Province, West Virginia: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-902, 75 p.

Ferrell, G.M., 1988, West Virginia ground-water quality, *in* Moody, D.W., Carr, J., Chase, E.B., and Paulson, R.W., comps., National Water Summary 1986—Hydrologic events and ground-water quality: U.S. Geological Survey Water-Supply Paper 2325, p. 523-530.

Heath, R.C., 1983, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.

Hobba, W.A., Jr., Friel, E.A., and Chisholm, J.L., 1973, Ground-water hydrology of the Potomac River basin, West Virginia: West Virginia Geological and Economic Survey, scale 1:250,000.

Kozar, M.D., 1996, Geohydrology and ground-water quality of southern Canaan Valley, Tucker County, West Virginia: U.S. Geological Survey Water-Resources Investigations Report 96-4103, 67 p.

Kozar, M.D., and Brown, D.P., 1995, Location and site characteristics of the ambient ground-water-quality-monitoring network in West Virginia: U.S. Geological Survey Open-File Report 95-130, 48 p.

Kozar, M.D., Hobba, W.A., Jr., and Macy, J.A., 1991, Geohydrology, water availability, and water quality of Jefferson County, West Virginia, with emphasis on the carbonate area: U.S. Geological Survey Water-Resources Investigations Report 90-4118, 93 p.

Puente, Celso, 1985, West Virginia ground-water resources, *in* National Water Summary, 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, p. 439-446.

Shultz, R.A., Hobba, W.A., Jr., and Kozar, M.D., 1995, Geohydrology, ground-water availability, and ground-water quality of Berkeley County, West Virginia, with emphasis on the carbonate-rock area: U.S. Geological Survey Water-Resources Investigations Report 93-4073, 88 p.

Wyrick, G.G., and Borchers, J.W., 1981, Hydrologic effects of stress-relief fracturing in an Appalachian valley: U.S. Geological Survey Water-Supply Paper 2177, 51 p.

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age
[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	pH (units)							Number of samples used for analysis
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	
Quaternary Alluvium	4.7	----	7.0	8.6	6.1	7.7	----	190
Permian	6.2	----	7.6	9.2	7.1	8.6	----	242
Upper Pennsylvanian	2.6	----	7.4	9.0	6.7	8.4	----	400
Middle Pennsylvanian	4.5	----	6.9	8.6	6.0	8.0	----	74
Lower Pennsylvanian	4.1	----	6.7	9.1	5.7	7.5	----	773
Mississippian	4.0	----	7.5	9.8	6.4	8.0	----	126
Devonian	4.0	----	7.0	9.5	6.0	8.1	----	81
Silurian	6.2	----	7.4	8.4	6.5	8.2	----	11
Ordovician	5.6	----	7.0	8.0	6.7	7.5	----	114
Cambrian	5.9	----	7.2	8.0	6.7	7.5	----	148

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Fecal coliform (colonies per 100 milliliters)							Number of samples used for analysis
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	
Quaternary Alluvium		NO	DATA	FOR	THIS	CATEGORY		0
Permian	----	----	----	<1	----	----	----	1
Upper Pennsylvanian	<1	1	<1	3	----	----	1	5
Middle Pennsylvanian	<1	<1	<1	<1	----	----	0	3
Lower Pennsylvanian	<1	34	<1	1,300	<1	1	208	39
Mississippian	<1	2	<1	60	<1	<1	8	55
Devonian	<1	235	5	700	----	----	402	3
Silurian	----	----	----	2	----	----	----	1
Ordovician	<1	9	<1	210	<1	4	34	70
Cambrian	<1	15	<1	230	<1	47	37	75

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued
[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

	Dissolved iron (µg/L)							
Geologic age	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	<3	3,604	110	58,000	7	10,000	9,738	121
Permian	<3	385	17	16,000	3	595	1,612	120
Upper Pennsylvanian	<3	1,460	80	77,000	7	3,000	5,893	303
Middle Pennsylvanian	<3	2,253	420	26,000	19	6,300	4,450	67
Lower Pennsylvanian	<3	4,433	790	180,000	12	11,000	11,733	743
Mississippian	<3	219	10	3,700	<3	453	676	82
Devonian	<3	6,822	430	80,000	8	17,200	15,673	29
Silurian	9	12	12	13	----	----	2	4
Ordovician	<3	308	12	4,700	3	1,280	726	72
Cambrian	<3	92	10	1,600	3	185	282	77

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Dissolved manganese (µg/L) Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	<1	453	125	5,300	1	1,290	706	122
Permian	<1	128	7	3,100	1	285	377	102
Upper Pennsylvanian	<1	237	70	3,900	7	640	460	278
Middle Pennsylvanian	<1	215	100	1,400	14	546	288	65
Lower Pennsylvanian	<1	408	170	22,000	10	826	1,135	755
Mississippian	<1	76	5	1,800	<1	185	230	88
Devonian	<1	251	110	1,300	<1	648	348	29
Silurian	<1	2	2	4	----	----	1	4
Ordovician	<1	140	3	1,300	<1	470	238	71
Cambrian	<1	27	1	610	<1	55	90	75

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Dissolved sulfate (mg/L)							
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	<1	101	47	2,400	10	140	270	141
Permian	<1	37	25	330	4	73	50	136
Upper Pennsylvanian	<1	52	17	2,100	2	88	158	341
Middle Pennsylvanian	<1	24	9	170	<1	64	35	74
Lower Pennsylvanian	<1	29	10	1,200	<1	56	80	780
Mississippian	<1	27	12	980	3	32	96	126
Devonian	<1	155	12	6,000	<1	79	725	86
Silurian	<1	19	11	48	2	36	17	11
Ordovician	3	51	25	490	10	93	86	97
Cambrian	4	41	34	340	10	61	43	92

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Hardness (mg/L)							
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	5	208	170	1,700	38	400	227	141
Permian	2	156	150	530	10	330	123	135
Upper Pennsylvanian	2	172	110	6,900	12	330	409	346
Middle Pennsylvanian	2	96	81	490	18	170	85	74
Lower Pennsylvanian	3	83	64	1,700	20	150	105	777
Mississippian	1	126	110	580	21	230	94	126
Devonian	1	260	99	6,400	22	322	807	79
Silurian	6	144	155	270	19	261	101	10
Ordovician	61	305	310	680	146	430	122	87
Cambrian	25	344	350	680	200	470	126	111

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; μg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Dissolved nitrate plus nitrite (mg/L)							
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	<0.1	1.7	0.4	19	<0.1	4.9	2.9	107
Permian	<0.1	1.2	0.1	16	<0.1	3.3	2.4	99
Upper Pennsylvanian	<0.1	0.4	<0.1	6.7	<0.1	1.1	0.9	153
Middle Pennsylvanian	<0.1	0.2	<0.1	1.4	<0.1	0.3	0.3	40
Lower Pennsylvanian	<0.1	0.4	<0.1	11	<0.1	1.4	1.1	475
Mississippian	<0.1	0.4	0.2	4.1	<0.1	0.9	0.6	88
Devonian	<0.1	0.6	<0.1	4.4	<0.1	1.7	1.1	17
Silurian	0.3	1.2	1.0	2.4	----	----	0.9	4
Ordovician	<0.1	4.3	2.7	23	<0.1	11	5.2	73
Cambrian	<0.1	8.0	5.0	63	0.2	20	9.8	88

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Dissolved chloride (mg/L)							
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	<1	89	23	4,400	5	89	416	141
Permian	<1	81	14	1,500	4	98	237	116
Upper Pennsylvanian	<1	109	13	9,500	3	175	547	376
Middle Pennsylvanian	<1	63	5	1,400	2	59	226	74
Lower Pennsylvanian	<1	34	5	3,100	<1	51	179	781
Mississippian	<1	13	4	730	<1	18	66	125
Devonian	<1	143	5	3,700	<1	70	593	84
Silurian	<1	7	5	39	1	11	11	11
Ordovician	<1	21	10	420	3	37	45	108
Cambrian	1	22	12	270	3	46	32	121

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued
[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Dissolved fluoride (mg/L)							
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	<0.1	0.2	0.1	2.0	<0.1	0.3	0.3	127
Permian	<0.1	0.5	0.2	4.4	<0.1	1.2	0.7	137
Upper Pennsylvanian	<0.1	0.7	0.3	8.8	0.1	1.6	1.0	230
Middle Pennsylvanian	<0.1	0.6	0.2	12	<0.1	0.8	1.8	55
Lower Pennsylvanian	<0.1	0.2	0.1	2.6	<0.1	0.3	0.2	516
Mississippian	<0.1	0.3	0.1	8.4	<0.1	0.4	0.8	126
Devonian	<0.1	0.3	0.2	3.9	<0.1	0.4	0.5	70
Silurian	<0.1	0.1	0.1	0.3	----	----	0.1	9
Ordovician	<0.1	0.2	0.2	3.0	0.1	0.4	0.3	92
Cambrian	<0.1	0.4	0.3	4.5	0.2	0.7	0.5	91

Table 1. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Dissolved solids (mg/L)							
	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Quaternary Alluvium	47	521	329	9,120	122	680	1,019	117
Permian	134	474	379	3,270	228	725	415	116
Upper Pennsylvanian	95	527	367	6,790	180	884	690	167
Middle Pennsylvanian	24	392	204	3,390	86	624	582	46
Lower Pennsylvanian	4	199	136	3,530	44	321	303	463
Mississippian	5	144	138	307	44	244	76	75
Devonian	21	288	168	3,050	74	319	546	29
Silurian	58	235	241	355	----	----	115	5
Ordovician	104	349	333	929	163	522	155	70
Cambrian	65	425	402	1,230	284	546	168	75

Table 2. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to topographic setting
[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Topographic setting	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
				pH (units)				
Hilltop	4.1	----	7.1	9.5	5.5	7.7	----	472
Hillside	2.6	----	7.1	9.8	5.9	7.9	----	816
Valley	4.0	----	7.3	9.4	6.3	8.2	----	991
				Fecal coliform (colonies per 100 milliliters)				
Hilltop	<1	15	<1	700	<1	4	84	71
Hillside	<1	26	<1	1,300	<1	5	151	83
Valley	<1	6	<1	160	<1	2	23	51
				Dissolved iron (µg/L)				
Hilltop	<3	1,443	30	160,000	4	1,700	9,914	281
Hillside	<3	2,277	130	180,000	7	5,500	9,661	551
Valley	<3	3,154	180	80,000	7	9,340	8,136	627
				Dissolved manganese (µg/L)				
Hilltop	<1	244	40	22,000	<1	411	1,406	270
Hillside	<1	270	90	8,900	<1	750	591	491
Valley	<1	340	110	11,000	4	887	788	584
				Dissolved sulfate (mg/L)				
Hilltop	<1	50	12	6,000	2	69	324	365
Hillside	<1	51	13	2,300	2	74	184	726
Valley	<1	40	14	2,400	1	75	144	872

Table 2. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to topographic setting--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Topographic setting	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Hardness (mg/L)								
Hilltop	2	306	130	42,000	15	370	2,133	415
Hillside	<1	145	90	4,400	22	310	242	769
Valley	<1	124	82	2,600	20	250	176	864
Dissolved nitrate plus nitrite (mg/L)								
Hilltop	<0.1	2.0	0.4	23	<0.1	5.7	3.8	249
Hillside	<0.1	0.9	<0.1	39	<0.1	1.9	3.0	349
Valley	<0.1	0.7	<0.1	19	<0.1	1.8	1.6	437
Dissolved chloride (mg/L)								
Hilltop	<1	355	6	110,000	1	40	5,570	413
Hillside	<1	56	6	22,000	1	35	795	781
Valley	<1	73	9	4,400	1	92	319	890
Dissolved fluoride (mg/L)								
Hilltop	<0.1	0.3	0.1	8.4	<0.1	0.4	0.7	273
Hillside	<0.1	0.3	0.2	12	<0.1	0.5	0.8	437
Valley	<0.1	0.4	0.2	8.8	<0.1	0.9	0.7	612
Dissolved solids (mg/L)								
Hilltop	4	245	185	1,390	30	513	227	232
Hillside	7	252	176	3,390	56	463	327	323
Valley	12	399	249	9,120	91	714	667	478

Table 3. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to well depth

[>, greater than; ----, not available; <, less than; µg/l, micrograms per liter; mg/L, milligrams per liter]

Well depth (feet)	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
				pH (units)				
Depth 0-100	3.8	----	7.0	9.4	6.0	7.9	----	1,819
Depth 101-300	2.6	----	7.2	9.5	6.2	8.1	----	924
Depth >300	4.3	----	7.3	9.8	6.6	8.5	----	160
				Fecal coliform (colonies per 100 milliliters)				
Depth 0-100	<1	9	<1	230	<1	12	35	67
Depth 101-300	<1	18	<1	1,300	<1	5	116	142
Depth >300	<1	35	<1	700	<1	60	130	31
				Dissolved iron (µg/L)				
Depth 0-100	<3	3,069	300	80,000	10	8,880	7,069	1,213
Depth 101-300	<3	1,743	60	180,000	5	3,660	9,123	575
Depth >300	<3	2,274	35	160,000	4	590	16,988	89
				Dissolved manganese (µg/L)				
Depth 0-100	<1	351	130	11,000	6	889	736	1,062
Depth 101-300	<1	183	47	4,700	<1	470	433	509
Depth >300	<1	359	9	22,000	<1	194	2,504	77
				Dissolved sulfate (mg/L)				
Hilltop	<1	50	12	6,000	2	69	324	365
Hillside	<1	51	13	2,300	2	74	184	726
Valley	<1	40	14	2,400	1	75	144	872

Table 3. Summary statistics for West Virginia ground-water data retrieved from the U.S. Geological Survey National Water Information System water-quality data base with respect to well depth--Continued

[>, greater than; ----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Well depth (feet)	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
				Hardness (mg/L)				
Depth 0-100	<1	132	82	6,900	24	280	235	1,666
Depth 101-300	1	165	99	6,400	18	360	276	843
Depth >300	<1	165	110	670	12	360	139	151
				Dissolved nitrate plus nitrite (mg/L)				
Depth 0-100	<0.1	1.0	<0.1	39	<0.1	3.0	2.8	742
Depth 101-300	<0.1	2.0	0.1	63	<0.1	4.9	5.3	402
Depth >300	<0.1	1.6	0.2	14	<0.1	5.5	2.7	68
				Dissolved chloride (mg/L)				
Depth 0-100	<1	41	7	9,500	1	54	286	1,675
Depth 101-300	<1	57	8	3,100	1	75	224	865
Depth >300	<1	131	9	3,700	1	160	483	159
				Dissolved fluoride (mg/L)				
Depth 0-100	<0.1	0.3	0.2	3.6	<0.1	0.5	0.4	926
Depth 101-300	<0.1	0.4	0.2	12	<0.1	0.8	0.9	498
Depth >300	<0.1	0.7	0.3	8.4	0.1	1.7	1.2	105
				Dissolved solids (mg/L)				
Depth 0-100	6	310	212	9,120	72	516	532	751
Depth 101-300	4	362	258	6,090	58	654	527	381
Depth >300	4	450	354	1,390	106	810	340	76

Table 4. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to bedrock age

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
				pH (units)				
Quaternary Alluvium	6.4	---	6.9	8.0	6.4	7.5	----	41
Permian	7.2	---	8.4	8.6	7.4	8.5	----	10
Upper Pennsylvanian	6.1	---	7.3	8.6	6.4	8.4	----	37
Lower Pennsylvanian	6.0	---	6.9	8.0	6.3	7.6	----	68
Mississippian	5.2	---	7.0	8.3	6.5	7.7	----	54
Devonian	6.1	---	6.9	8.4	6.2	8.0	----	33
Ordovician	6.6	---	6.8	7.3	6.8	7.0	----	11
Cambrian	6.6	---	6.8	7.4	6.7	7.3	----	10
				Fecal coliform (colonies per 100 milliliters)				
Quaternary Alluvium	1	1	1	1	1	1	0	20
Permian	1	1	1	1	----	----	0	5
Upper Pennsylvanian	1	69	1	900	1	101	223	17
Lower Pennsylvanian	1	1	1	1	1	1	0	31
Mississippian	1	39	4	310	1	104	77	25
Devonian	1	3	1	18	1	6	4	15
Ordovician	1	14	4	57	----	----	24	5
Cambrian	1	9	6	25	----	----	11	4

Table 4. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Total iron (µg/L)								
Quaternary Alluvium	4	161	130	545	26	354	141	43
Permian	10	83	35	470	20	105	131	11
Upper Pennsylvanian	15	582	355	5,100	60	1,071	958	37
Lower Pennsylvanian	5	2,218	1,100	10,000	85	6,370	2,679	69
Mississippian	15	135	82	885	30	230	152	52
Devonian	3	169	45	3,700	20	109	635	33
Ordovician	8	38	38	90	14	63	24	10
Cambrian	5	98	65	225	32	189	77	10
Total manganese (µg/L)								
Quaternary Alluvium	10	483	135	1,580	28	1,200	522	43
Permian	5	11	5	48	5	10	13	11
Upper Pennsylvanian	5	57	30	240	14	136	58	37
Lower Pennsylvanian	5	174	100	2,300	40	363	284	69
Mississippian	<1	18	5	230	5	45	34	52
Devonian	<1	105	8	1,600	2	250	289	32
Ordovician	<1	5	5	10	5	6	2	10
Cambrian	<1	6	5	15	5	10	4	10

Table 4. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
				Dissolved sulfate (mg/L)				
Quaternary Alluvium	9	64	53	253	24	111	45	43
Permian	14	26	29	37	17	33	7	11
Upper Pennsylvanian	<1	28	4	364	1	53	61	37
Lower Pennsylvanian	<1	14	4	151	1	35	30	66
Mississippian	2	11	8	52	3	16	9	52
Devonian	4	69	16	400	8	199	104	30
Ordovician	10	18	17	29	14	27	6	10
Cambrian	15	25	24	44	17	37	9	10
				Hardness (mg/L)				
Quaternary Alluvium	134	215	206	336	159	279	48	43
Permian	10	20	18	46	11	28	10	11
Upper Pennsylvanian	<1	88	52	490	4	180	95	37
Lower Pennsylvanian	<1	73	64	180	36	120	36	69
Mississippian	8	90	76	230	41	196	57	52
Devonian	26	161	144	442	64	317	105	33
Ordovician	234	313	314	370	288	338	35	10
Cambrian	130	320	339	506	227	372	96	10

Table 4. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Total nitrate plus nitrite (mg/L)								
Quaternary Alluvium	<0.1	2.3	2.8	6.2	0.1	5.6	2.3	43
Permian	<0.1	0.1	<0.1	1.0	<0.1	<0.1	0.3	11
Upper Pennsylvanian	<0.1	0.1	<0.1	0.8	<0.1	0.4	0.2	36
Lower Pennsylvanian	<0.1	<0.1	<0.1	0.4	<0.1	0.2	<0.1	68
Mississippian	<0.1	0.6	0.5	2.5	<0.1	2.2	0.7	52
Devonian	<0.1	0.1	0.1	0.4	<0.1	0.3	<0.1	33
Ordovician	1.7	2.1	2.0	3.0	1.8	2.3	0.4	10
Cambrian	0.8	3.1	3.2	4.5	2.1	4.3	1.0	10
Dissolved chloride (mg/L)								
Quaternary Alluvium	<1	43	31	134	15	96	34	43
Permian	12	13	13	15	13	14	<1	11
Upper Pennsylvanian	1	84	90	211	16	180	65	37
Lower Pennsylvanian	1	28	18	130	4	76	30	68
Mississippian	<1	10	4	39	1	31	12	52
Devonian	1	4	4	8	1	7	2	33
Ordovician	12	14	14	16	12	16	2	10
Cambrian	9	14	15	18	10	16	3	10

Table 4. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to bedrock age--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Geologic age	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
				Total fluoride (mg/L)				
Quaternary Alluvium	<0.1	0.2	0.2	0.7	0.1	0.5	0.2	43
Permian	0.1	0.6	0.5	0.8	0.5	0.7	0.2	11
Upper Pennsylvanian	<0.1	0.3	0.2	0.7	0.1	0.5	0.2	37
Lower Pennsylvanian	<0.1	0.2	0.2	0.8	<0.1	0.6	0.2	68
Mississippian	<0.1	<0.1	0.1	0.2	<0.1	0.1	<0.1	52
Devonian	<0.1	0.1	0.1	0.4	<0.1	0.3	0.1	33
Ordovician	0.1	0.1	0.1	0.2	0.1	0.2	<0.1	10
Cambrian	0.3	0.3	0.3	0.4	0.3	0.4	<0.1	10
				Dissolved solids (mg/L)				
Quaternary Alluvium	219	330	283	548	253	454	92	43
Permian	324	338	339	349	325	346	8	11
Upper Pennsylvanian	67	355	385	935	204	513	157	37
Lower Pennsylvanian	36	295	166	838	67	746	255	68
Mississippian	18	135	91	273	53	242	81	52
Devonian	51	195	164	610	96	385	130	33
Ordovician	314	346	346	372	328	359	16	10
Cambrian	294	358	370	398	298	396	38	10

Table 5. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to topographic setting
[----, not available; <, less than; μg/l, micrograms per liter; mg/L, milligrams per liter]

Topographic setting	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
pH (units)								
Hillside	6.0	---	6.8	8.4	6.2	7.6	----	57
Valley	5.2	---	6.9	8.6	6.5	8.0	----	208
Fecal coliform (colonies per 100 milliliters)								
Hillside	1	53	1	900	1	73	184	25
Valley	1	11	1	310	1	10	41	98
Total iron (μg/L)								
Hillside	5	644	140	5,100	28	1,600	1,096	57
Valley	3	764	130	10,000	30	1,319	1,806	209
Total manganese (μg/L)								
Hillside	<1	168	55	2,300	5	298	365	57
Valley	<1	143	26	1,580	5	380	303	208
Dissolved sulfate (mg/L)								
Hillside	1	27	8	364	3	62	56	56
Valley	<1	32	15	400	1	76	52	204

Table 5. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to topographic setting--Continued

[----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Topographic setting	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Hardness (mg/L)								
Hillside	26	84	74	490	38	124	64	57
Valley	<1	142	130	506	20	304	106	209
Total nitrate plus nitrite (mg/L)								
Hillside	<0.1	0.2	0.1	0.9	<0.1	0.7	0.3	57
Valley	<0.1	0.9	0.1	6.2	<0.1	3.3	1.6	207
Dissolved chloride (mg/L)								
Hillside	1	16	6	178	1	42	27	57
Valley	<1	34	15	211	2	96	43	208
Total fluoride (mg/L)								
Hillside	<0.1	0.2	0.1	0.8	<0.1	0.6	0.2	57
Valley	<0.1	0.2	0.1	0.8	<0.1	0.5	0.2	208
Dissolved solids (mg/L)								
Hillside	51	306	120	935	72	760	294	57
Valley	18	262	258	610	72	429	127	208

Table 6. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to season

[Summer, June-October; Winter, November-May; ----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Season	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation for analysis	Number of samples used
				pH (units)				
Summer	6.0	---	7.2	8.6	6.6	8.0	----	140
Winter	5.2	---	6.8	8.6	6.3	7.6	----	125
				Fecal coliform (colonies per 100 milliliters)				
Summer	1	24	1	900	1	24	111	74
Winter	1	12	1	250	1	7	48	49
				Total iron (µg/L)				
Summer	5	806	155	9,100	30	1,800	1,752	136
Winter	3	668	125	10,000	30	1,410	1,601	130
				Total manganese (µg/L)				
Summer	<1	153	45	1,600	5	361	304	135
Winter	<1	144	29	2,300	5	335	331	130
				Dissolved sulfate (mg/L)				
Summer	<1	33	14	364	1	77	56	134
Winter	<1	29	14	400	1	74	50	126

Table 6. Summary statistics for data from the West Virginia ambient ground-water-quality network with respect to season--Continued

[Summer, June-October; Winter, Novembeer-May; ----, not available; <, less than; µg/L, micrograms per liter; mg/L, milligrams per liter]

Season	Minimum	Mean	Median	Maximum	10th percentile	90th percentile	Standard deviation	Number of samples used for analysis
Hardness (mg/L)								
Summer	<1	134	105	490	34	292	100	136
Winter	<1	124	96	506	26	271	102	130
Total nitrate plus nitrite (mg/L)								
Summer	<0.1	0.7	<0.1	6.0	<0.1	2.8	1.4	135
Winter	<0.1	0.8	0.2	6.2	<0.1	3.0	1.4	129
Dissolved chloride (mg/L)								
Summer	1	31	15	211	2	93	41	136
Winter	<1	28	13	211	2	89	40	129
Total fluoride (mg/L)								
Summer	<0.1	0.2	0.2	0.8	<0.1	0.5	0.2	136
Winter	<0.1	0.2	0.1	0.7	0.1	0.5	0.2	129
Dissolved solids (mg/L)								
Summer	41	288	254	935	86	509	182	135
Winter	18	255	240	808	62	453	171	130

Table 7. Summary statistics for total metals data from the West Virginia ambient ground-water-quality network
[<, less than; μg/L, micrograms per liter; mg/L, milligrams per liter]

Concentration	Median	Statistics for total concentrations, with values less than the detection limit set to the detection limit					
		Maximum	10th percentile	90th percentile	Standard deviation	Number of samples less than detection limit	Total number of samples
Calcium (mg/L)	24	175	5	100	38	3	266
Magnesium (mg/L)	6	44	1	16	7	1	266
Potassium (mg/L)	2	238	<1	3	15	7	266
Sodium (mg/L)	8	460	2	165	80	2	266
Aluminum (μg/L)	50	4,300	15	115	361	124	266
Antimony (μg/L)	2	120	2	100	42	218	226
Arsenic (μg/L)	<1	100	<1	6	7	145	232
Barium (μg/L)	50	4,400	50	458	530	119	266
Cadmium (μg/L)	2	5	<1	2	1	136	221
Chromium (μg/L)	25	70	25	25	4	208	224
Copper (μg/L)	10	130	10	15	11	178	224
Lead (μg/L)	1	50	<1	50	18	133	266
Mercury (μg/L)	<1	<1	<1	<1	<1	189	224
Nickel (μg/L)	20	50	20	20	4	199	224
Selenium (μg/L)	1	2	1	2	<1	218	224
Silver (μg/L)	5	10	<1	5	2	204	224
Beryllium (μg/L)	2	10	<1	2	2	107	114
Zinc (μg/L)	10	490	2	40	47	28	266

Table 8. Organic constituents for which water samples from the West Virginia ambient ground-water-quality network were analyzed

Constituent	Detection limit (micrograms per liter, µg/L)	Detection limit excceded?
Chloromethane	5, 10	No
Bromomethane	5, 10	No
Vinyl chloride	5, 10	No
Chloroethane	5, 10	No
Methylene chloride	5, 10	No
1,1-Dichloroethene	5, 10	No
1,1-Dichloroethane	5, 10	No
trans-1,2-Dichloroethene	5, 10	No
Chloroform	5, 10	No
1,2-Dichloroethane	5, 10	No
1,1,1-Trichloroethane	5, 10	Yes - 14 µg/L - maximum
Carbon tetrachloride	5, 10	No
Bromodichloromethane	5, 10	No
1,2-Dichloropropane	5, 10	No
trans-1,3-Dichloropropene	5, 10	No
cis-1,3-Dichloropropene	5, 10	No
Trichloroethene	5, 10	Yes - 31.3 µg/L - maximum
Dibromochloromethane	5, 10	No
1,1,2-Trichloroethane	5, 10	No
Bromoform	5, 10	No
1,1,2,2-Tetrachloroethane	5, 10	Yes - 6.2 µg/L - maximum
Tetrachloroethene	5, 10	No
Benzene	5, 10	No
Toluene	5, 10	No
Ethylbenzene	5, 10	No
Chlorobenzene	5, 10	No
1,2-Dichlorobenzene	5, 10	No
1,3-Dichlorobenzene	5, 10	No
1,4-Dichlorobenzene	5, 10	No
Trichlorofluoromethane	10	No
Trichloromonofluoromethane	5	No
Dichlorodifluoromethane	5, 10	No
2,2-Dichloropropane	5, 10	No
cis-1,2-Dichloroethene	5, 10	Yes - 22.3 µg/L - maximum
Bromochloromethane	5, 10	No
1,1-Dichloropropene	5, 10	No
Dibromomethane	5, 10	No
1,3-Dichloropropane	5, 10	No

Table 8. Organic constituents for which water samples from the West Virginia ambient ground-water-quality network were analyzed--Continued

Constituent	Detection limit (micrograms per liter, μg/L)	Detection limit exceeded?
1,2-Dibromoethane	5, 10	No
m,p-Xylene	5, 10	No
o-Xylene	5, 10	No
Styrene	5, 10	No
Isopropylbenzene	5, 10	No
Bromobenzene	5, 10	No
1,1,1,2-Tetrachloroethane	5, 10	No
1,2,3-Trichloropropane	5, 10	No
n-Propylbenzene	5, 10	No
o-Chlorotoluene	5, 10	No
p-Chlorotoluene	5, 10	No
1,3,5-Trimethylbenzene	5, 10	No
tert-Butylbenzene	5, 10	No
1,2,4-Trimethylbenzene	5, 10	No
sec-Butylbenzene	5, 10	No
p-Isopropyltoluene	5, 10	No
n-Butylbenzene	5, 10	No
1,2-Dibromo-3-chloropropane	5, 10	No
1,2,3-Trichlorobenzene	5, 10	No
Hexachlorobutadiene	5, 10	No
Napthalene	5, 10	No
1,2,4-Trichlorobenzene	5, 10	No

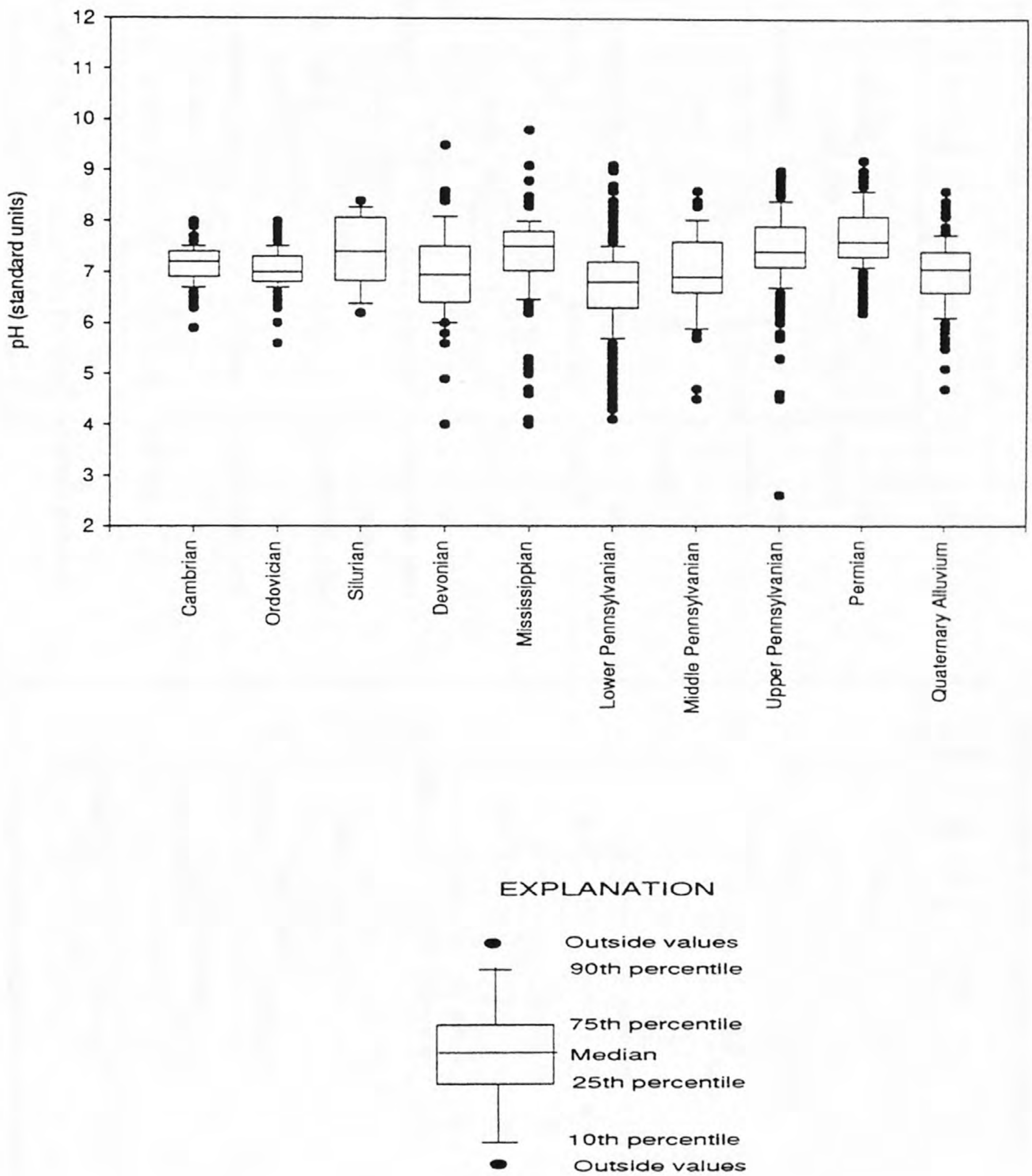


Figure 5.--Summary of selected water-quality properties and constituents for aquifers in West Virginia (from U.S. Geological Survey National Water Information System data base) (page 1 of 4).

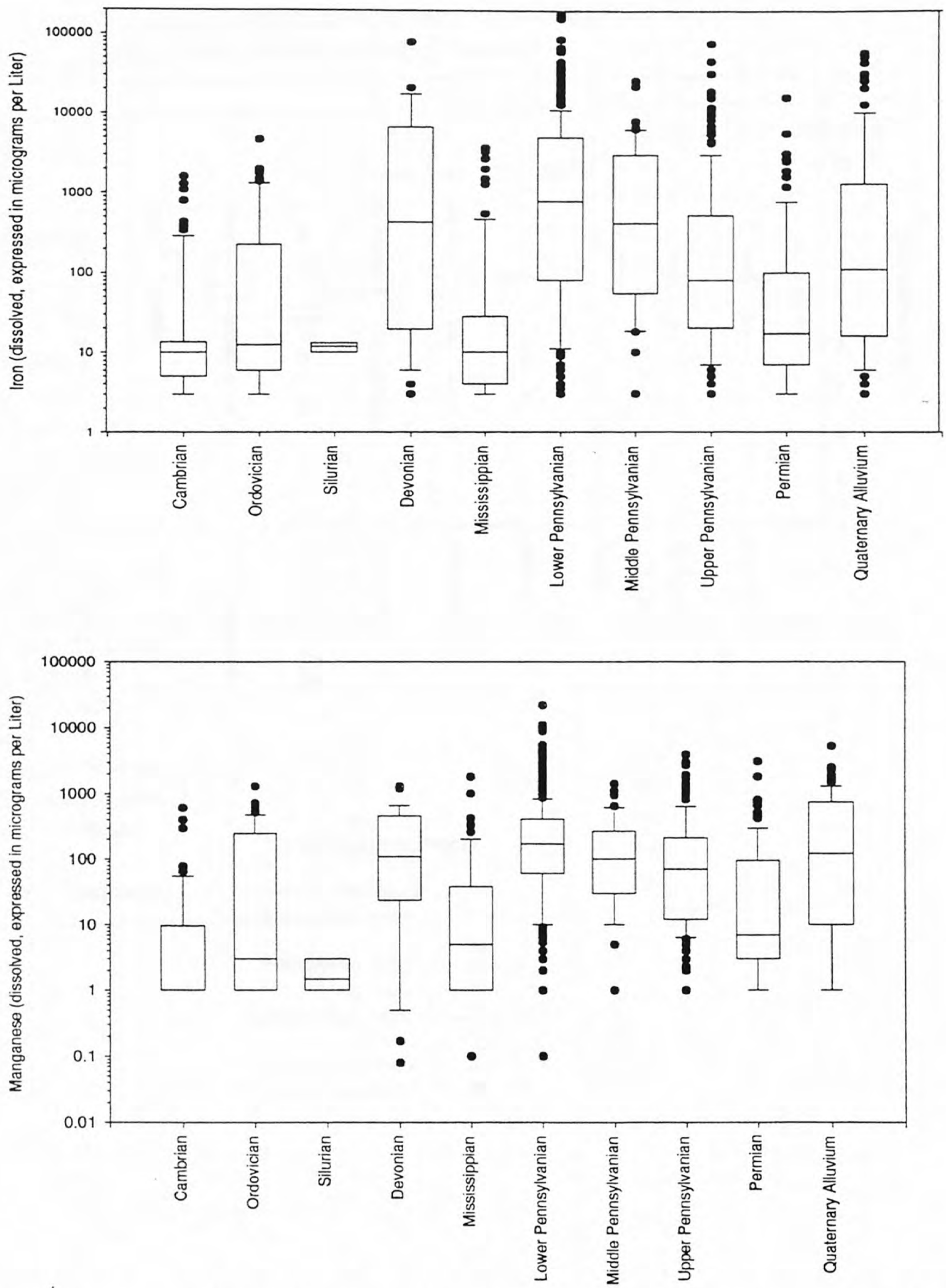


Figure 5.--Summary of selected water-quality properties and constituents for aquifers in West Virginia (from U.S. Geological Survey National Water Information System data base) (page 2 of 4).

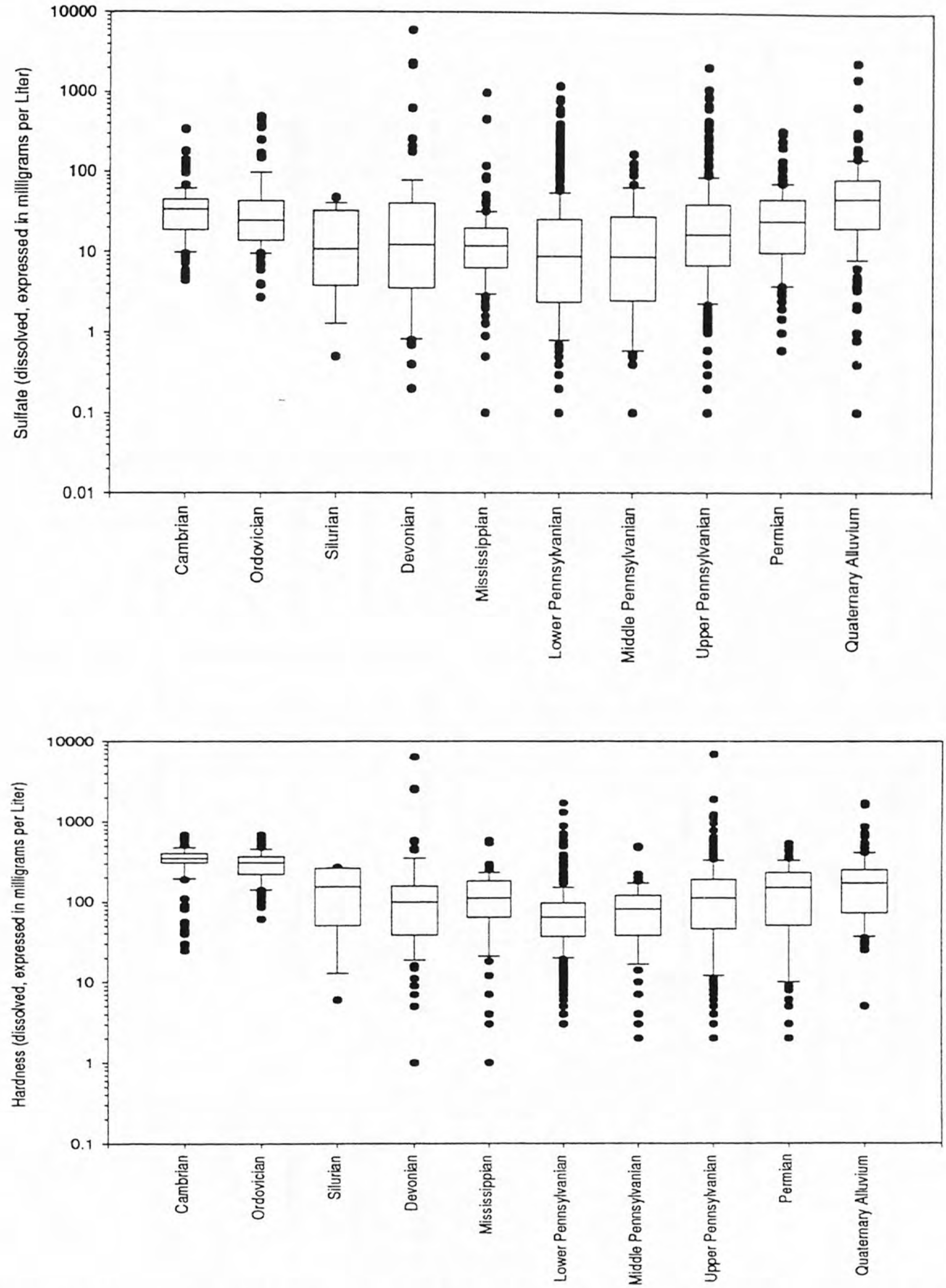
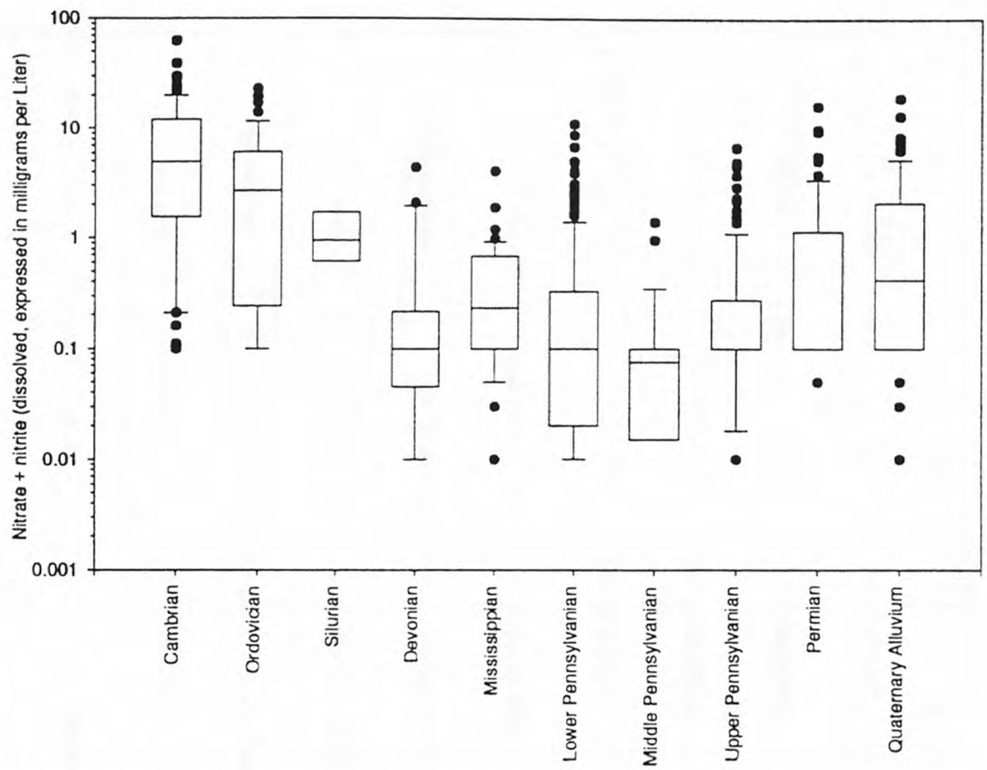


Figure 5.--Summary of selected water-quality properties and constituents for aquifers in West Virginia (from U.S. Geological Survey National Water Information System data base) (page 3 of 4).



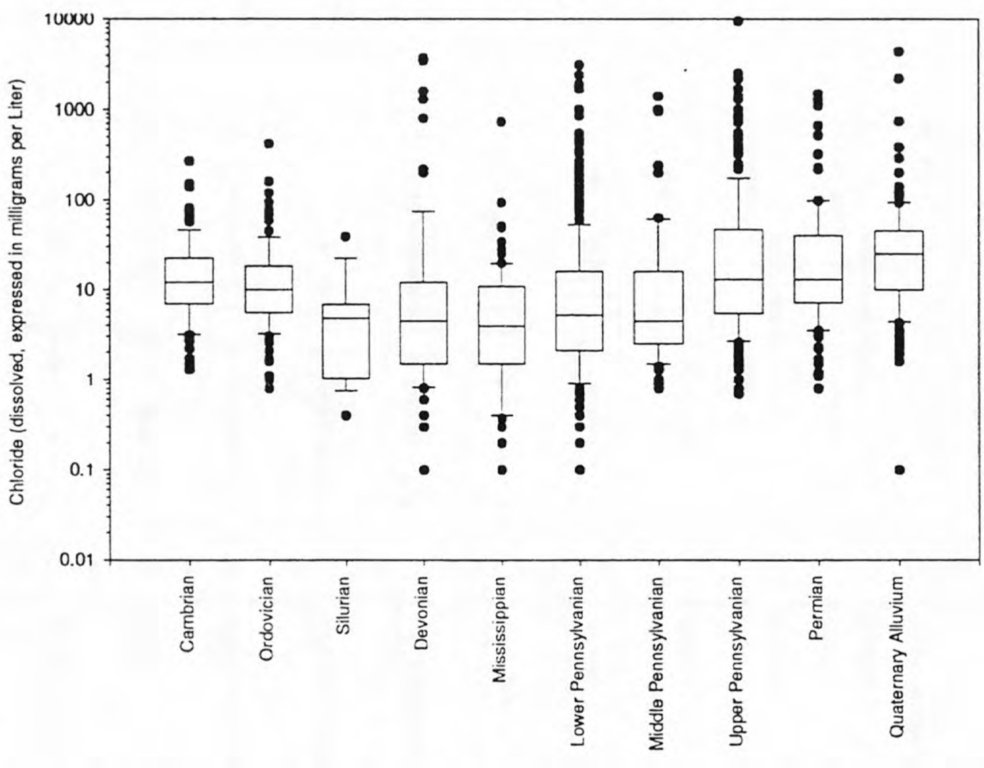


Figure 5.--Summary of selected water-quality properties and constituents for aquifers in West Virginia (from U.S. Geological Survey National Water Information System data base) (page 4 of 4).