Hydrogeologic Setting and Conceptual Hydrologic Model of the Spring Creek Basin, Centre County, Pennsylvania, June 2005

By John W. Fulton, Edward H. Koerkle, Steven D. McAuley, Scott A. Hoffman, and Linda F. Zarr

In cooperation with the ClearWater Conservancy

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[On CD-ROM in pocket]

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Conversion Factors and Datum

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [(Mgal/d)/mi^2]	1,461	cubic meter per day per square kilometer [(m^3/d)/km^2]
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
Specific capacity		
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s/m]
Transmissivity*		
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Temperature in degrees Celsius (˚C) may be converted to degrees Fahrenheit (˚F) as follows:

˚F = (1.8 x ˚C) + 32

Temperature in degrees Fahrenheit (˚F) may be converted to degrees Celsius (˚C) as follows:

˚C = (˚F - 32) / 1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88) except where noted in the text.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83) except where noted in the text.

Altitude, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (∝S/cm at 25˚C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (∝g/L).

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Abstract

The Spring Creek Basin, Centre County, Pa., is experiencing some of the most rapid growth and development within the Commonwealth. This trend has resulted in land-use changes and increased water use, which will affect the quantity and quality of stormwater runoff, surface water, ground water, and aquatic resources within the basin. The U.S. Geological Survey (USGS), in cooperation with the ClearWater Conservancy (CWC), Spring Creek Watershed Community (SCWC), and Spring Creek Watershed Commission (SCWCm), has developed a Watershed Plan (Plan) to assist decision makers in water-resources planning. One element of the Plan is to provide a summary of the basin characteristics and a conceptual model that incorporates the hydrogeologic characteristics of the basin.

The report presents hydrogeologic data for the basin and presents a conceptual model that can be used as the basis for simulating surface-water and ground-water flow within the basin. Basin characteristics; sources of data referenced in this text; physical characteristics such as climate, physiography, topography, and land use; hydrogeologic characteristics; and water-quality characteristics are discussed. A conceptual model is a simplified description of the physical components and interaction of the surface- and ground-water systems. The purpose for constructing a conceptual model is to simplify the problem and to organize the available data so that the system can be analyzed accurately. Simplification is necessary, because a complete accounting of a system, such as Spring Creek, is not possible. The data and the conceptual model could be used in development of a fully coupled numerical model that dynamically links surface water, ground water, and land-use changes. The model could be used by decision makers to manage water resources within the basin and as a prototype that is transferable to other watersheds.

Introduction

The Spring Creek Basin lies entirely within Centre County, Pa. (fig. 1), and drains an area of approximately 175 mi^2. The basin is undergoing rapid growth and development that is expected to continue in the future. As a result, land-use changes and increased demand for water will have an effect on the quality and quantity of water resources within the basin. To evaluate these effects, the U.S. Geological Survey (USGS), in cooperation with the ClearWater Conservancy (CWC) and with assistance from the Spring Creek Watershed Community (SCWC) and the Spring Creek Watershed Commission (SCWCm), has developed a Watershed Plan (Plan) to assist decision makers with water-resources planning and forecasting. This Plan includes future development of a fully coupled numerical model that dynamically links surface water, ground water, and land-use changes. The Plan includes completion of the following tasks before development of the numerical model: compilation and evaluation of existing data sets concerning the physical and hydrogeologic characteristics of the basin, development of a conceptual hydrologic model of the basin, and formulation of suggestions for additional data collection and other future work.

Purpose and Scope

This report (1) provides a summary of available data describing the physical and hydrogeologic characteristics of the basin; (2) presents a conceptual model of the surface-water and ground-water system; and (3) identifies additional data needs and tasks to define the interaction of surface water and ground water within the basin. Basin characteristics such as climate, physiography, topography, land use, soils, and geology are presented; surface-water and ground-water systems are described; and a summary of surface- and ground-water-quality characteristics is presented. The conceptual model is presented as a simplified representation of the hydrologic system and is illustrated with block diagrams, generalized cross sections, and schematic illustrations.

Description of Study Area

The study area includes the combined area of the Spring Creek surface-water and ground-water basins (fig. 1). Although surface-water and ground-water basins may coincide in some basins, this is not the case for the Spring Creek Basin. In this

Figure 1. Location of Spring Creek Basin, Centre County, Pennsylvania.

report, the term “Spring Creek Basin” refers to the area encompassed by both the ground-water and surface-water basins. The ground-water basin refers to the 175-mi^2 area delineated by the ground-water divide. The surface-water basin occupies approximately 146 mi^2 and is delineated by the surface-water divide. The surface-water basin is further subdivided into eight surface-water subbasins that include Big Hollow, Buffalo Run, Cedar Run, Galbraith Gap Run, Logan Branch, Roaring Run, Slab Cabin Run, and Spring Creek (fig. 1).

The Spring Creek Basin lies entirely within Centre County and includes all or part of the Boroughs of Bellefonte, Centre Hall, Milesburg, and State College. The Spring Creek surface-water basin is part of Sub-basin 9C as defined by Pennsylvania's State Water Plan (Pennsylvania Department of Environmental Protection, 2003). Spring Creek discharges into Bald Eagle Creek, a tributary to the West Branch Susquehanna River. The region supports a wide range of land-use activities that makes this basin particularly susceptible to increased nonpoint-source pollution from stormwater runoff, construction activities, increased traffic, and degeneration of wetland sites.

The main stem of Spring Creek is designated as a Class A high quality, cold-water fishery (Commonwealth of Pennsylvania, 2001; Commonwealth of Pennsylvania, Fish and Boat Commission, 2005). Because ground-water discharges contribute approximately 86 percent of the streamflow to Spring Creek (Gannett Flemming, 2000), any changes in ground-water quantity and quality will be reflected to some degree in streams within the basin.

Physical Characteristics of Spring Creek Basin

This section summarizes the available data describing the physical and hydrologic characteristics of the Spring Creek Basin. Basin characteristics such as climate, physiography, topography, land use, soils, and geology are presented; surface-water and ground-water systems are described; and water-quality characteristics are summarized. To make the available data readily accessible from a single source, the data have been included as Appendixes 1 and 2 on a CD-ROM in a pocket at the back of the report. Appendix 1 contains spatial information on CD-ROM as Geographic Information System (GIS) data sets. GIS coverages for the basin include roads, streams, political subdivisions, and other geographic features that can be represented by spatial coordinates. Included in these coverages are interpreted data such as drainage-basin divides and subbasin slope that are derived from other sources such as aerial photography (table 1). Appendix 2 consists of a relational database containing data and other attributes for wells, springs, streams, meteorological stations, and miscellaneous geologic features. A description of the tables in the relational database is provided in table 2.

Table 1. GIS data sets provided on CD-ROM in Appendix 1.

[---, data not available on disk; ~, approximately]

Theme	Data provider	Source scale	Folder name	Data set name	File type
Athletic fields	Centre County Planning	1:2,400	ccp	---	
Black and white aerial photography	Centre County Planning	1:2,400	ccp	---	
Borough wells	State College Borough Water Authority	1:24,000	scbwa	---	
Building footprints	Centre County Planning	1:2,400	ccp	---	
Census blocks (1990)	U.S. Bureau of Census	1:100,000	census	census90	Coverage
Census blocks (2000)	U.S. Bureau of Census	1:100,000	census	census00	Coverage
Color aerial photography	Centre County Planning	1:2,400	ccp	---	
Depth to ground water	Pennsylvania State University	1:100,000	psu	gwdepth	Grid
Digital Elevation Model (DEM)	U.S. Geological Survey	1:24,000	usgs/dem		
Hydrologically enforced DEM				hydrodem	Grid
National Elevation Database (NED)				studydem30	Grid
Digital Ortho Quarter Quad (DOQQ)	U.S. Geological Survey	1:12,000	usgs/doqq		
Barrville				barrville_pa	Image
Bear Knob				bear_knob_pa	Image
Bellefonte				bellefonte_pa	Image
Centre Hall				centre_hall_pa	Image
Franklinville				franklinville_pa	Image
Julian				julian_pa	Image
McAlevys Fort				mcalevys_fort_pa	Image
Mingoville				mingoville_pa	Image
Pine Grove Mills				pine_grove_mills_pa	Image
Port Matilda				port_matilda_pa	Image
State College				state_college_pa	Image

Table 1. GIS data sets provided on CD-ROM in Appendix 1.—Continued

[---, data not available on disk; ~, approximately]

Theme	Data provider	Source scale	Folder name	Data set name	File type
Digital Raster Graphic (DRG)	U.S. Geological Survey	1:24,000	usgs/drg		
Barrville				barrville	Image
Bear Knob				bear_knob	Image
Bellefonte				bellefonte	Image
Centre Hall				centre_hall	Image
Franklinville				franklinville	Image
Julian				julian	Image
McAlevys Fort				mcalevys_fort	Image
Mingoville				mingoville	Image
Pine Grove Mills				pine_grove_mills	Image
Port Matilda				port_matilda	Image
State College				state_college	Image
Drainage basins	U.S. Geological Survey	1:24,000	usgs	swbasins	Coverage
Edge of pavement	Centre County Planning	1:2,400	ccp	---	
Faults	Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey	1:250,000	dcnr	faults	Coverage
Floodplains	Federal Emergency Management Agency	1:24,000	fema	floodp	Coverage
Fracture trace intersections	Pennsylvania State University, Nittany Geoscience, Inc.	1:24,000	psu	fti	Coverage
Geology	Centre County Planning	1:250,000	ccp	---	
	Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey	1:250,000	dcnr	geology	Coverage
Geology and physiography	Pennsylvania State University	1:250,000	psu	geolphys	Shapefile
Golf courses	Centre County Planning	1:2,400	ccp	---	
GWSI wells and springs	U.S. Geological Survey	1:24,000	usgs	gwsi	Shapefile
Hydrography	Centre County Planning	1:2,400	ccp	---	
	U.S. Geological Survey	1:24,000	usgs	cl_flow	Coverage
Hydrologic soil grouping	Natural Resources Conservation Service	1:250,000	nrcs	pa_hsgpct.dat	Info table
Land use	Centre County Planning	1:2,400	ccp	---	
	U.S. Geological Survey/U.S. Environmental Protection Agency	1:100,000	epa	mrlc	Grid
Mines and quarries	Centre County Planning	1:2,400	ccp	---	
National wetland inventory	U.S. Fish and Wildlife Service	1:24,000	usfw		
Barrville				barrville	Coverage
Bear Knob				bear_knob	Coverage
Bellefonte				bellefonte	Coverage
Centre Hall				centre_hall	Coverage
Franklinville				franklv	Coverage
Julian				julian	Coverage
McAlevys Fort				mcalev_fort	Coverage
Mingoville				mingoville	Coverage
Pine Grove Mills				pine_gr_mills	Coverage
Port Matilda				portmat	Coverage
State College				state_coll	Coverage
Obscured areas	Centre County Planning	1:2,400	ccp	---	
Parking areas	Centre County Planning	1:2,400	ccp	---	
Ponds, lakes, reservoirs	U.S. Geological Survey	1:24,000	usgs	lakepond	Coverage
Public water supply	Pennsylvania State University	1:24,000	psu	---	
Rain gages	National Weather Service	1:24,000	nws	rgage	Coverage

Table 1. GIS data sets provided on CD-ROM in Appendix 1.—Continued

[---, data not available on disk; ~, approximately]

Theme	Data provider	Source scale	Folder name	Data set name	File type
Sampling basins	ClearWater Conservancy	1:24,000	cwc		
Spring Creek above Axeman				axeman	Coverage
Spring Creek above Houserville				houser	Coverage
Lower Buffalo Run				lobuff	Coverage
Lower Cedar Run				locedar	Coverage
Lower Logan Branch				lologan	Coverage
Lower Slab Cabin Run				loslab	Coverage
Spring Creek above Milesburg				milesb	Coverage
Thompson Run				thompson	Coverage
Upper Buffalo Run				upbuff	Coverage
Upper Logan Branch				uplogan	Coverage
Upper Slab Cabin Run				upslab	Coverage
Upper Spring Creek				upspring	Coverage
Sampling locations	ClearWater Conservancy	1:24,000	cwc	s_sites	Coverage
Sewer lines	Centre County Planning	1:2,400	ccp	---	
Sewer service areas	Centre County Planning	1:2,400	ccp	---	
Siddiqui wells	S.H. Siddiqui	1:24,000	sid	sidiwell	Coverage
Sinkholes and closed depressions	Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey	1:24,000	dcnr	sinks	Coverage
Soils	Natural Resources Conservation Service	1:24,000	nrcs		
Available water capacity				awc	Coverage
Soil associations from Braker (1981)				braker	Coverage
Sand, silt, clay fraction				fract	Coverage
State Soil Geographic database				mupoly	Coverage
Mean permeability				perm	Coverage
Porosity				poros	Coverage
Soil Survey Geographic database				ssurgo	Coverage
Springs	Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey	1:24,000	dcnr	springs	Coverage
Study area	U.S. Geological Survey	1:24,000	usgs	studyarea	Coverage
Streamflow-gaging stations	U.S. Geological Survey	1:24,000	usgs	scgages	Coverage
Street centerlines	Centre County Planning	1:2,400	ccp	---	
Treatment plants	Pennsylvania State University	1:24,000	psu	treatplt	Shapefile
Water levels (1969)	C.R. Wood and Todd Giddings	~ 1:50,000	wg	wlevel69	Shapefile
Water levels (1997)	Susquehanna River Basin Commission	~ 1:24,000	srbc	watlev97	Coverage
Water lines	Pennsylvania State University	Unknown	psu	waterlns	Shapefile
Water users	Pennsylvania State University	1:24,000	psu	wudsal	Shapefile
Water-quality sites	U.S. Geological Survey	1:24,000	usgs	qw_sites	Shapefile
Well Water Inventory	Pa. Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey	1:24,000	dcnr	wwi	Coverage
Wooded areas	Centre County Planning	1:2,400	ccp	---	

Table 2. Tables included in the relational database provided on CD-ROM in Appendix 2.

[USGS, U.S. Geological Survey; DCNR, Department of Conservation and Natural Resources; PaDEP, Pennsylvania Department of Environmental Protection]

Table name	Table description
tblSCMain	Main table of Spring Creek database
tblLineData	Table consisting of line-data information
tblPointData	Table consisting of point-data information
tblPolyData	Spring Creek data consisting of municipalities, boroughs, basins, and watershed information
tblGWInv	Ground Water Inventory Data-USGS/DCNR/PaDEP
tblSPInv	Spring Inventory Data-USGS/DCNR
tblSWQWsites	USGS water-quality surface-water sites for Centre County
tblUSGSSpringPump	USGS Spring Pump – PaDEP Well Data
tblCConStations	ClearWater Conservancy monitoring stations data
tblCConaxe00	ClearWater Conservancy flow data for Axemann-Spring Creek
tblCConFlow	ClearWater Conservancy flow data for Spring Creek Watershed
tblCConSamples	ClearWater Conservancy stream sample information
tblCConParamData	ClearWater Conservancy parameter information
tblCConInstruments	ClearWater Conservancy instruments information
tblCConTemperature	ClearWater Conservancy temperature data
tblCConStorms	ClearWater Conservancy storm information
tblCConLabConc	ClearWater Conservancy sample information
tblCConStormLoads	ClearWater Conservancy storm load information
tblPumpage	Well pumpage data collected by College Township, Pennsylvania State University, and State College Borough Water Authority
tblSprFlowRates	Bellefonte Spring Data
tblReservoirWD	State College Water Authority Reservoir withdrawals
tblDataSource	Sources of data for Spring Creek database
tblSC_Gages	Spring Creek streamflow-gaging station data
tblUSGS_SWQWdata	USGS surface-water-quality data
tblWQN_QWdata	Water-quality data for Spring Creek near Axemann, Pa.
tblParamData-USGS	USGS parameter data from ClearWater Conservancy database
tblCCon-USGS	USGS water-quality data from ClearWater Conservancy database
tblParamcodes	Names and units of parameter codes
tblGWQW1, tblGWQW2, tblGWQW3	USGS ground-water-quality sites/data for Centre County
tblJulian	Sinkhole, depression, mine, cave locations in the Julian Quadrangle
tblPineGrove	Sinkhole, depression, mine, cave locations in the Pine Grove Quadrangle
tblStateCollege	Sinkhole, depression, mine, cave locations in the State College Quadrangle
tblPAMetData	Information on 23 meteorological stations in and near the Spring Creek Watershed
tblBeavertown1NEMet	Beavertown meteorological data
tblBellefonteMet	Bellefonte meteorological data
tblCampKlineMet	Camp Kline meteorological data
tblClarenceMet	Clarence meteorological data
tblClearfieldMet	Clearfield meteorological data
tblHuntingdonMet	Huntingdon meteorological data
tblJerseyShoreMet	Jersey Shore meteorological data
tblKarthausMet	Karthaus River meteorological data
tblLaureltonMet	Laurelton Center meteorological data
tblLewistownMet	Lewistown meteorological data
tblLockHavenMet	Lock Haven meteorological data
tblLockHavenSewageMet	Lock Haven Sewage Plant meteorological data
tblMaderaMet	Madera meteorological data
tblMapletonMet	Mapleton Depot meteorological data
tblMillheimMet	Millheim meteorological data
tblMilroy2Met	Milroy meteorological data
tblPhilipsburg8EMet	Philipsburg meteorological data
tblRaystownLk2Met	Raystown Lake meteorological data
tblRenovoMet	Renovo meteorological data

Table 2. Tables included in the relational database provided on CD-ROM in Appendix 2.—Continued

[USGS, U.S. Geological Survey; DCNR, Department of Conservation and Natural Resources; PaDEP, Pennsylvania Department of Environmental Protection]

Table name	Table description
tblStateCollegeMet	State College meteorological data
tblTyron4BaldEagleMet	Tyrone/Bald Eagle meteorological data
tblTyroneMet	Tyrone meteorological data
tblWilliamsburgMet	Williamsburg meteorological data
tblSPQWSites	Water-quality data for selected springs in the Spring Creek Basin

The physical characteristics of the Spring Creek Basin include climate, physiography, topography, land use, soils, and geology. Each of these topics is discussed below and is used in the conceptual model to describe evapotranspiration, direct runoff, and ground-water recharge in the basin.

Climate

The Spring Creek Basin has a temperate climate characterized by hot, humid summers and cold winters (Giddings, 1974). The climate on the floor of the basin typically is milder than the surrounding higher elevations but is influenced by cold air drainage from the bordering ridges, which contributes to reduced minimum temperatures (Giddings, 1974).

Climatologic data available for hydrologic modeling of Spring Creek Basin include precipitation, air temperature, humidity, solar radiation, and evaporation. These data are available from 18 meteorological stations in and within 15 mi of the basin (fig. 2). Descriptions of the stations and type of meteorological data available are summarized in table 3.

Precipitation

Precipitation is the ultimate source of water in the Spring Creek Basin; therefore, the volume and spatial distribution of precipitation are needed to develop an accurate hydrologic model.

Precipitation data are available from 18 meteorological stations in and near the Spring Creek Basin (fig. 2 and table 3). Sixteen stations currently are collecting data and two are discontinued. Ten stations report daily totals and have the longest periods of record. Eight stations report hourly totals but data collection began in 1995 and later. One of the hourly stations, the National Weather Service radar in Centre County (State College), reports areal estimates of rainfall. Daily snowfall is available for eight current and two discontinued stations. Data from one station (Rock Springs) also is available in 1-minute reporting intervals beginning in June 1999. On the basis of data from daily reporting stations in Centre County, the average annual precipitation for Centre County for the period 1961 through 1990 is 41.7 in. The average monthly precipitation is shown in figure 3. The average monthly snowfall for State College is shown in figure 4.

Radar-derived rainfall is reported for individual 4 km by 4 km cells. The cells are spatially fixed, and their locations are known, which allows input to the spatial dataset GIS. The radar cell network covering Spring Creek Basin is shown in figure 5. The spatial resolution of radar-derived rainfall is finer than can be derived from a typical network of rain gages. If each cell is considered a virtual rain gage, the equivalent network for the Spring Creek Basin would consist of 24 rain gages. Because the radar system is optimized for rainfall measurement, estimates of snowfall are not considered reliable (National Weather Service, 2002). Current radar-derived rainfall values use multisensor precipitation estimates (MPE) and are available for October 1999 to the present. Non-MPE radar-derived rainfall estimates are available for January 1996 to the present. The quality of the earlier data is highly variable (National Weather Service, 2002), and continuity is poor because of the large amount of missing data (up to 35 percent for the period of record).

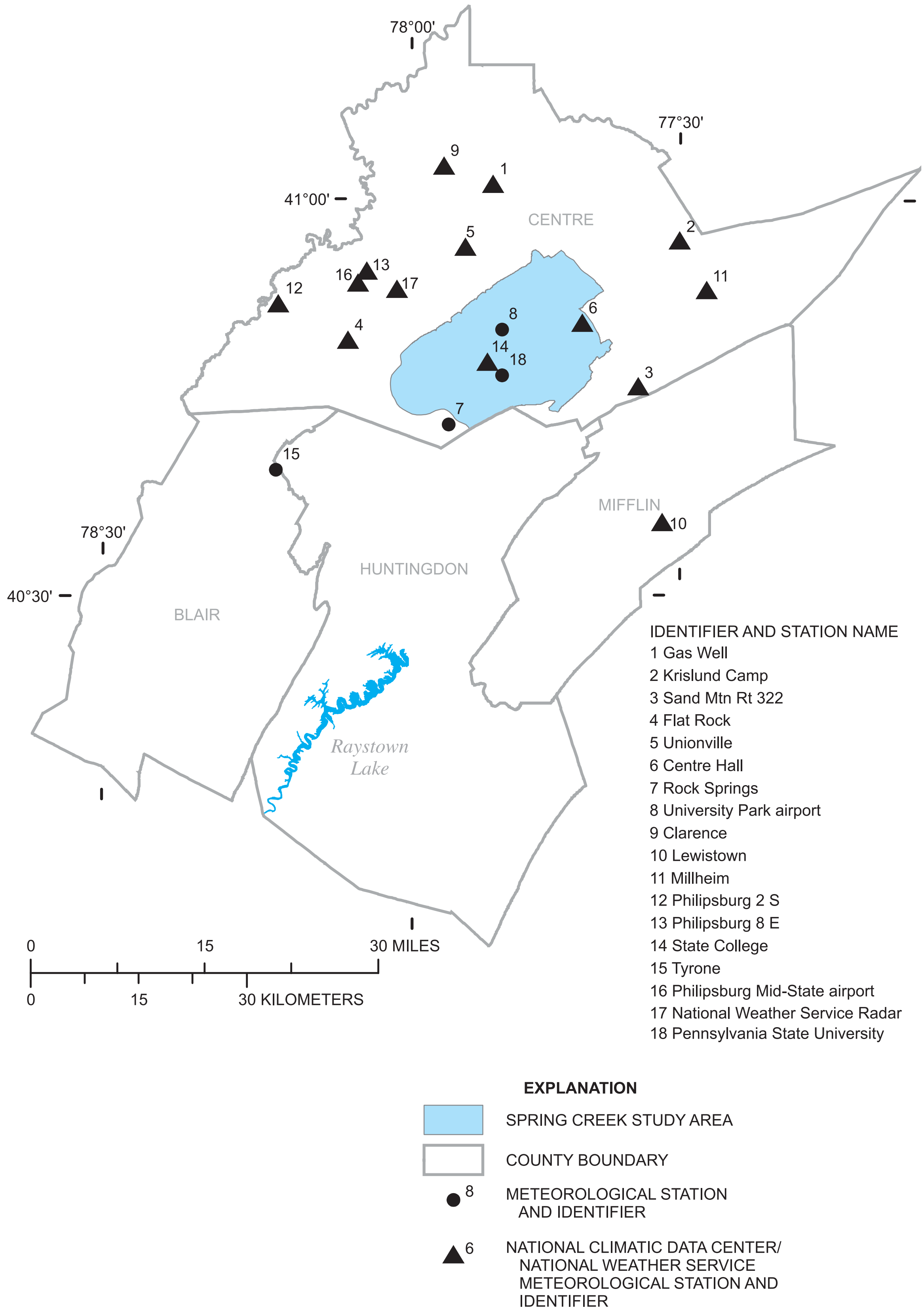


Figure 2. Location of meteorological data-collection stations in and within 15 miles of the Spring Creek Basin, Centre County, Pennsylvania.

Table 3. Meteorological data-collection stations in and within 15 miles of the Spring Creek Basin, Centre County, Pennsylvania.

[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988; na, not applicable; Y, yes; N, no; --, no data]

Station name	Latitude (degrees, minutes, seconds, NAD 83)	Longitude (degrees, minutes, seconds, NAD 83)	Elevation (feet above NAVD 88)	Period of record	Observation interval	Observation time	Rainfall	Snow	Air temperature	Humidity	Sky cover	Wind speed	Wind direction	Data source
Gas Well	410132	775131	2,050	1/1/2000 to present	Hourly	na	Y	N	N	N	N	N	N	IFLOWS[1]
Krislund Camp	405708	773246	1,270	1/1/2000 to present	Hourly	na	Y	N	N	N	N	N	N	IFLOWS
Sand Mtn Rt 322	404604	773700	1,780	1/1/2000 to present	Hourly	na	Y	N	N	N	N	N	N	IFLOWS
Flat Rock	404940	780600	1,600	1/1/2000 to present	Hourly	na	Y	N	N	N	N	N	N	IFLOWS
Unionville	405644	775417	1,500	1/1/2000 to present	Hourly	na	Y	N	N	N	N	N	N	IFLOWS
Centre Hall	405058	774236	2,150	1/1/2000 to present	Hourly	na	Y	N	N	N	N	N	N	IFLOWS
Rock Springs	404319.2	775555.2	1,210	9/10/1999 to present	Hourly	na	Y	N	Y	Y	Y	Y	Y	PSU[2]
University Park airport	405031.2	775034.8	1,239.8	1/1/2003 to present	Daily	na	Y	Y	Y	Y	Y	Y	Y	PACLIM[3]
Clarence	410300	775700	1,389.7	8/1/1950 to present	Daily	0700	Y	Y	N	N	N	N	N	NCDC[4]
Lewistown	403500	773400	459.9	5/1/1948 to present	Daily	0800	Y	Y	Y	N	N	N	N	NCDC
Millheim	405300	772800	1,119.8	6/1/1949 to present	Daily	0700	Y	Y	N	N	N	N	N	NCDC
Philipsburg 2 S	405200	781300	1,719.7	4/1/1998 to present	Daily	Unknown	Y	Y	Y	N	N	N	N	NCDC
Philipsburg 8 E	405500	780400	1,944.4	10/1/1986 to 1/31/1997	Daily	Unknown	Y	Y	Y	N	N	N	N	NCDC
State College	404800	775200	1,169.6	1/1/1926 to present	Daily	0700	Y	Y	Y	N	N	N	N	NCDC
Tyrone	404000	781300	889.9	9/1/1972 to present	Daily	0700	Y	Y	N	N	N	N	N	PACLIM
Philipsburg Mid-State airport	405400	780500	1,941.4	1/1948 to 8/1996	Daily	Unknown	Y	Y	Y	N	N	N	N	NCDC
National Weather Service radar	405500	780000	2,404.2	4/6/1995 to present	Hourly	na	Y	N	N	N	N	N	N	NHDS[5]
Pennsylvania State University	404735	755202	--	1/1/1896 to present	Daily	0700	Y	Y	Y	N	N	N	N	PSU

[1]National Weather Service, 2005.

[2]Pennsylvania State University, 2005.

[3]Pennsylvania State Climatologist, 2005.

[4]U.S. Department of Commerce, 2005.

[5]National Oceanic and Atmospheric Administration, 2005.

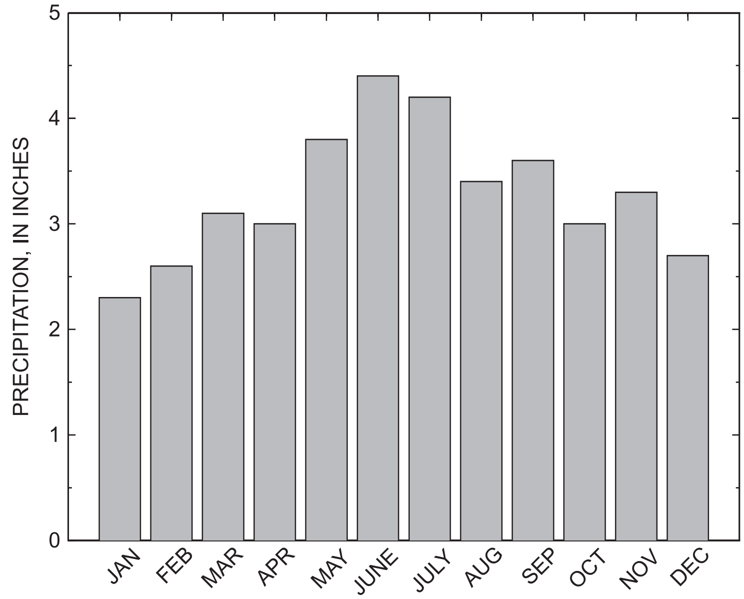


Figure 3. Average monthly precipitation for Centre County, Pennsylvania (1961 through 1990) (National Oceanic and Atmospheric Administration, 2003).

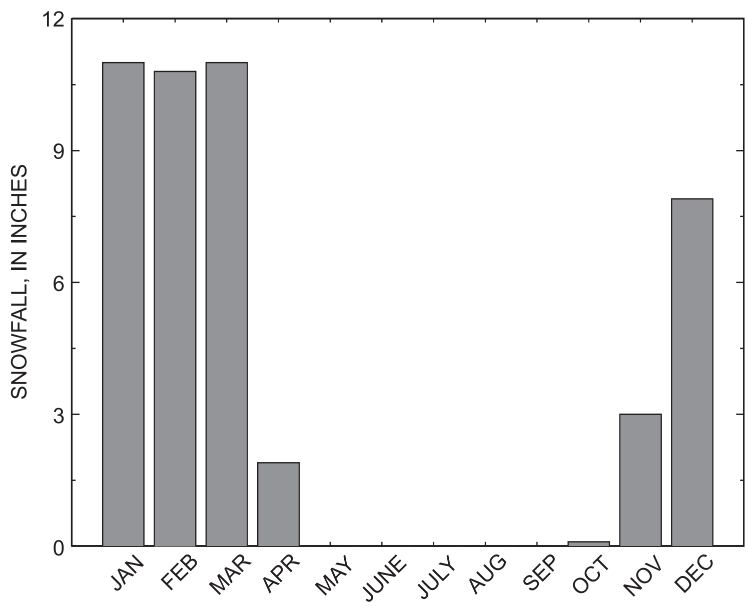


Figure 4. Average monthly snowfall at State College, Pennsylvania (1926 through 1994) (Pennsylvania State Climatologist, 2005).

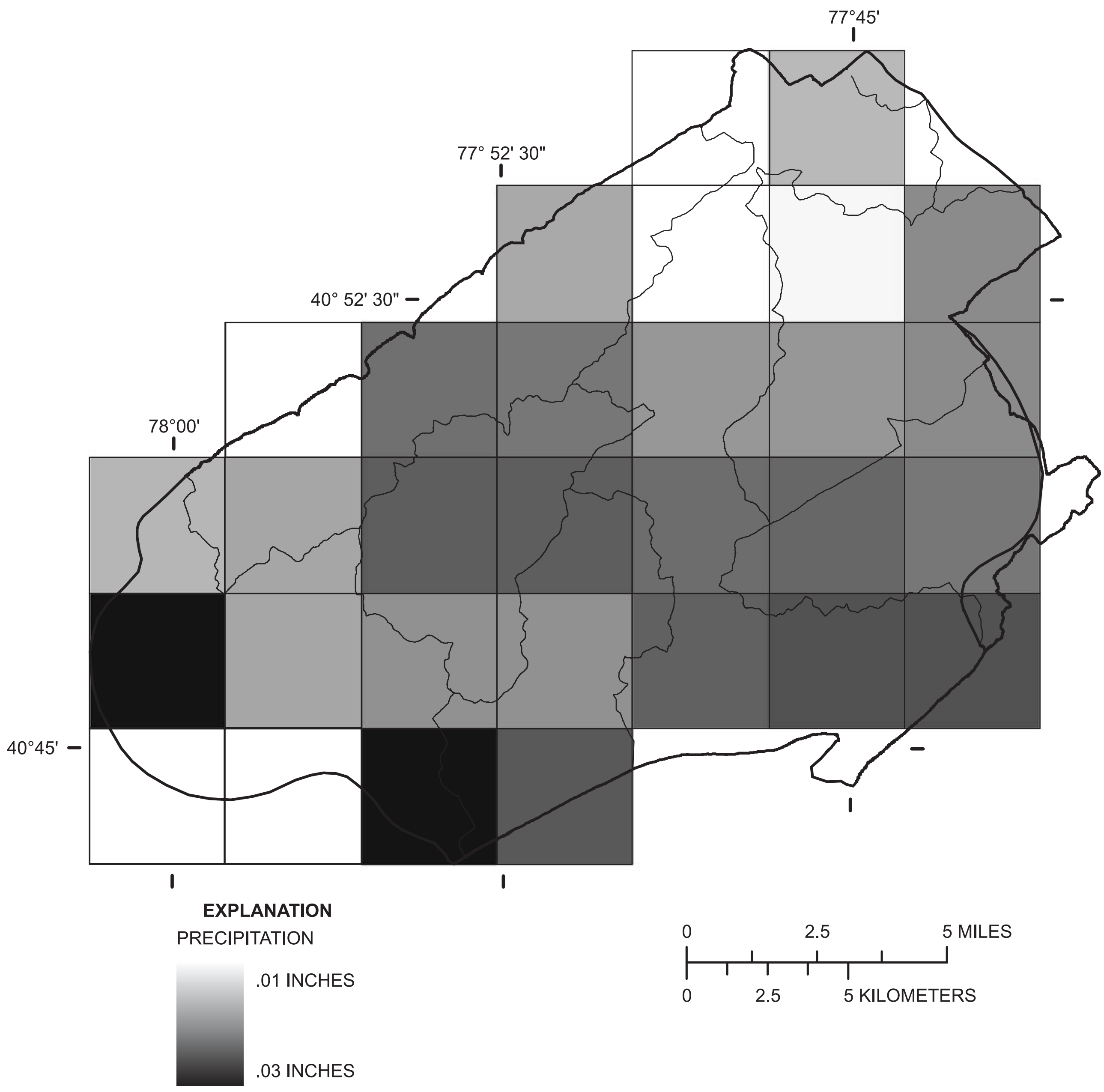


Figure 5. Example of a 4-kilometer square cell grid of radar-derived precipitation data for the Spring Creek Basin, Centre County, Pennsylvania.

Air Temperature

Air-temperature records are available for eight locations (fig. 2 and table 3). Seven of those locations record daily minimum and maximum temperatures, and one location records hourly temperature. The average annual air temperature in State College is 49.4°F. The highest monthly mean temperature is 71.7°F in July, and the lowest monthly mean temperature is 26.5°F in January (Pennsylvania State Climatologist, 2003). The average daily minimum and maximum temperatures for the period of record at State College are shown in figure 6.

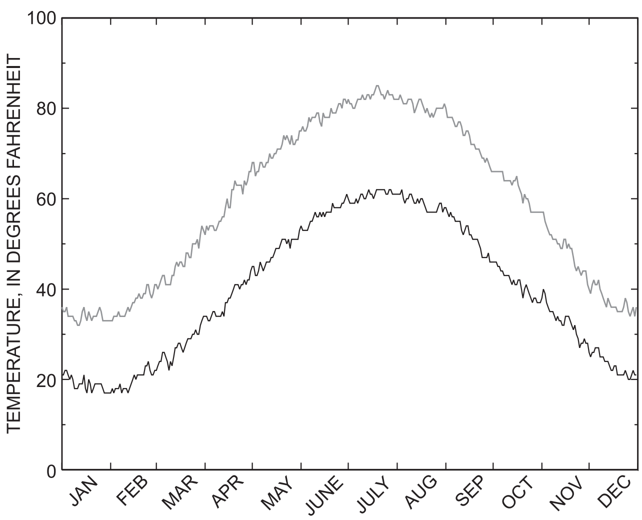


Figure 6. Average minimum and maximum daily air temperature at State College, Pennsylvania (Pennsylvania State Climatologist, 2005).

Humidity

Humidity is a measure of water vapor in the air, and water vapor is a significant source of latent heat. In the eastern United States, humidity levels can be high enough to be a substantial source of heat and, thus, warrant inclusion in a modeled snowmelt process (George Leavesley, U.S. Geological Survey, written commun., 2003). Hourly humidity data are available for one location and daily humidity data are available for one location within the Spring Creek Basin (table 3). The average annual relative humidity for Centre County is about 70 percent.

Solar Radiation

Modeling evapotranspiration (ET) and snowmelt generally requires estimates of energy inputs. In many instances, solar radiation is the desired energy form. However, the availability of measured solar-radiation data is limited to observations collected at airports in the vicinity of the basin.

Hourly solar-radiation data from the airport near Williamsport, Pa., about 60 mi northeast of State College, are available for the period January 1961 through December 31, 1990 (Pennsylvania State Climatologist, 2003). Solar-radiation data also were collected at the Pennsylvania State University from 1952 to about 1985 and are archived as paper copies (Pennsylvania State Climate Office, written commun., 2003). A new solar-radiation measurement site was established in 1998 at the Pennsylvania State University Rock Springs agricultural research farm as part of the National Oceanic and Atmospheric Administration (NOAA) SURFRAD Network (National Oceanic and Atmospheric Administration, 2003). Solar-radiation data for Rock Springs are available in 3-minute intervals for the period beginning June 24, 1998.

Evaporation

In hydrologic modeling, ET is a major component of the hydrologic budget. ET typically is either computed from other meteorological inputs or estimated from measured evaporation data. Pan evaporation is the most commonly collected type of evaporation data.

Average growing season (May through October) pan evaporation at Raystown Lake, Huntingdon County, 30 mi south-southwest of State College, Pa., is 30.8 in. (Pennsylvania State Climatologist, 2003). Total annual pan-evaporation values are somewhat greater than this value, although November through April values generally are reduced compared to values measured during the growing season. Average daily pan-evaporation data collected at Raystown Lake (fig. 2) for the May through October growing season are listed in table 4. The period of record for this data is from 1974 to 1984.

Computed daily evaporation data beginning May 2000 are available from the Rock Springs meteorological station (Pennsylvania State Climatologist, 2003). Rock Springs is in Ferguson Township, about 2 mi southwest of the Spring Creek Basin.

Free water surface (FWS) evaporation is considered a better estimate of potential ET than pan evaporation. FWS evaporation typically is estimated by application of a pan coefficient to pan-evaporation data. Farnsworth and others (1982) assigned a pan coefficient of 0.76 to the area near Spring Creek Basin. This coefficient is an average annual value. Monthly pan coefficients would be preferred for modeling purposes.

Table 4. Average daily pan evaporation for the growing season, in inches, at Raystown Lake, Huntingdon County, Pennsylvania.

[The period of record is from 1974 to 1984. --, no data]

Day	May	June	July	Aug.	Sept.	Oct.
1	--	0.22	0.23	0.17	0.15	0.15
2	0.19	.22	.18	.20	.13	.09
3	.24	.18	.21	.21	.15	.09
4	.18	.16	.23	.19	.18	.13
5	.21	.19	.17	.16	.16	.11
6	.23	.25	.18	.17	.15	.11
7	.16	.13	.21	.18	.18	.11
8	.19	.24	.25	.19	.15	.10
9	.26	.14	.16	.19	.18	.08
10	.17	.25	.19	.20	.15	.09
11	.21	.19	.18	.19	.19	.07
12	.17	.20	.21	.19	.18	.08
13	.19	.25	.20	.14	.15	.10
14	.18	.20	.19	.16	.13	.13
15	.19	.22	.23	.20	.17	.10
16	.16	.22	.20	.15	.10	.13
17	.17	.21	.19	.22	.15	.08
18	.12	.25	.19	.18	.14	.07
19	.20	.19	.26	.20	.12	.07
20	.16	.20	.20	.20	.18	.11
21	.20	.17	.20	.21	.12	.06
22	.18	.21	.22	.17	.11	.11
23	.24	.22	.20	.19	.11	.11
24	.23	.21	.19	.16	.14	.09
25	.18	.18	.23	.21	.11	.05
26	.15	.17	.19	.20	.12	.10
27	.19	.23	.20	.20	.16	.07
28	.19	.23	.21	.17	.11	.07
29	.18	.15	.16	.20	.10	.08
30	.14	.17	.17	.17	.11	.10
31	.15		.21	.16		.10
Total	5.61	6.05	6.24	5.73	4.28	2.94

Physiography

Spring Creek Basin is in the Ridge and Valley Physiographic Province of the Appalachian Mountains and is juxtaposed to the southern boundary of the Appalachian Plateaus Physiographic Province. Bald Eagle Mountain and Tussey Mountain form the northern and southern basin boundaries of the Nittany Valley (fig. 7). Nittany Mountain bisects the eastern half of Nittany Valley, which then becomes Penns Valley to the south (Giddings, 1974).

Topography

Bald Eagle, Tussey, and Nittany Mountain ridges are the most prominent topographic features in the basin (fig. 7). Relief between the ridge crests and valley floor ranges from 600 to 1,000 ft. The Gatesburg Ridge adds 200 ft of relief to the Nittany Valley floor. Stream channels have cut as deep as 300 ft into the valley floor (Giddings, 1974). Topographic statistics are summarized by subbasin in table 5. Mean subbasin slope was calculated as the average of the set of grid cell slopes taken from a 30-m digital elevation model. Mean aspect is the average downslope direction calculated from the set of steepest downslope directions for each grid cell in a 30-m digital elevation model. The mean channel slope is the slope that is measured between the 10-percent and 85-percent length of the channel.

Nittany and Penns Valley are characterized by karst topography. The valley floors contain numerous features such as surface depressions and sinkholes. These features and others such as swallets or swallow holes capture surface-water runoff. Swallets are openings to the subsurface conduit system. They may occur in sinkholes or stream channels and provide direct points of recharge to the underlying carbonate aquifers. As a result, recharge to the unsaturated zone in the valley floor could be bypassed. It is anticipated that recharge from swallets is not perched but moves rapidly through mature karst terrain to prescribed discharge points. The degree of hydraulic connection between the swallets and valley-floor aquifers is minimal. David Yoxtheimer (Water Resources Monitoring Project, Spring Creek Watershed Community Project, written commun., 2003) provided a summary of features for the Julian, Pine Grove, and State College quadrangles compiled by Kochanov (1992). The GIS database (Appendix 1) includes coordinates for four karst features—surface depressions, sinkholes, caves, and surface mines. The complete data set is contained in Appendix 1. A subset of the data is presented in table 6. The Julian, Pine Grove, and State College quadrangles contain 4,906, 2,768, and 3,660 features, respectively.

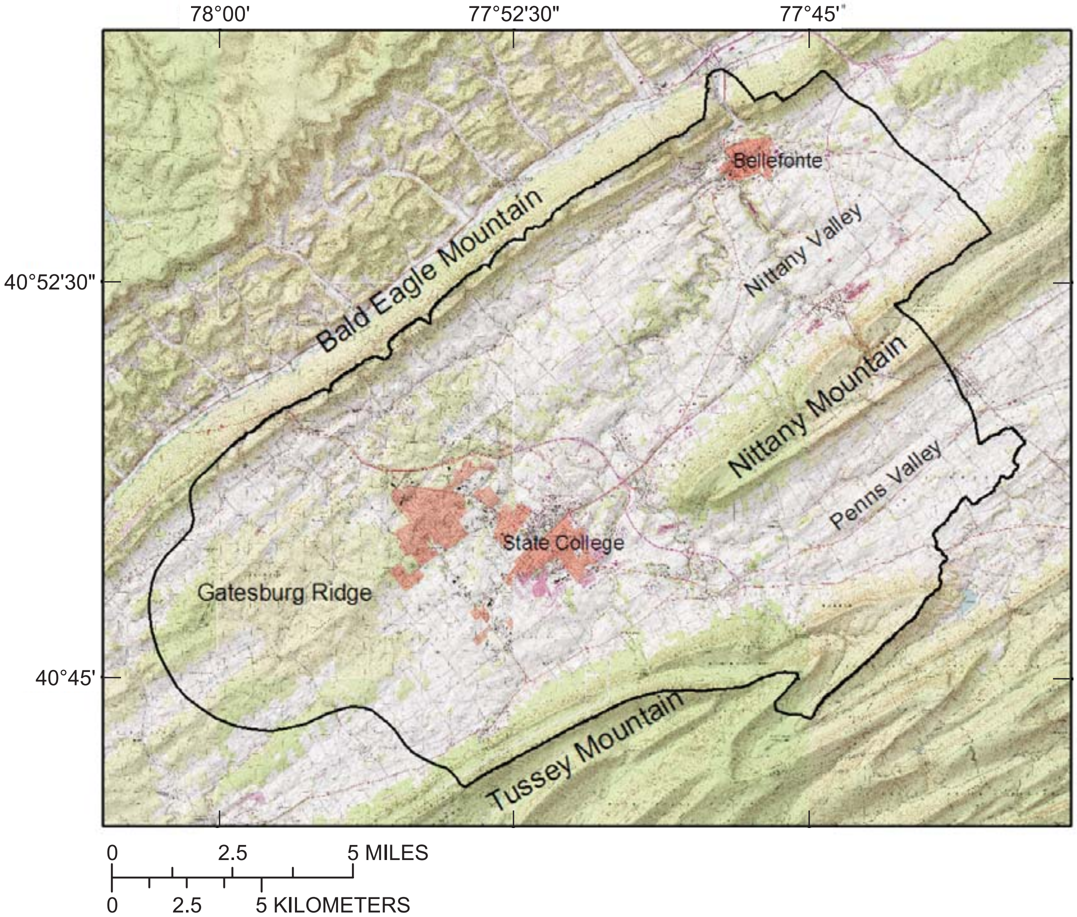


Figure 7. Topography of Spring Creek Basin, Centre County, Pennsylvania.

Table 5. Elevation, slope, and aspect, by subbasin, of the Spring Creek surface-water basin, Centre County, Pennsylvania.

[na, not applicable]

Subbasin	Drainage area (square miles)	Mean elevation (feet)	Mean subbasin slope (percent)	Maximum subbasin slope (percent)	Main channel length (miles)	Mean channel slope (percent)	Mean aspect (azimuth degrees)
Big Hollow	17.1	1,201	2.3	12.6	7.2	0.7	166
Buffalo Run	27.3	1,245	6.0	35.5	13	.8	182
Cedar Run	17.5	1,321	3.8	28.2	3.2	.5	185
Galbraith Gap Run	5.13	1,767	9.3	27.4	4	3.1	199
Logan Branch	22.5	1,308	5.9	33.8	9.2	2.1	218
Roaring Run	4.72	1,580	8.2	29.7	4.2	3.3	242
Slab Cabin Run	16.8	1,240	3.8	26.2	9.9	1.5	199
Spring Creek - main channel	34.9	1,120	4.9	30.8	24.5	.4	202
Spring Creek - total surface-water basin	146	1,262	5.0	35.5	75.2	na	195

Table 6. Selected data for surface depressions, sinkholes, caves, and surface mines reported for the Julian quadrangle, Spring Creek Basin, Centre County, Pennsylvania.

[Feature number is an arbitrary number assigned to a given surface depression, sinkhole, or surface mine in tblJulian in Appendix 2]

Feature number	Coordinates, in decimal degrees		Type
	Latitude	Longitude	
4821	-77.96700	40.82557	surface depression
4822	-77.96750	40.82700	surface depression
4823	-77.99110	40.81429	surface depression
4890	-77.93790	40.82632	sinkhole
4896	-77.88280	40.84131	sinkhole
4897	-77.88400	40.84384	sinkhole
4898	-77.87960	40.77607	surface mine
4901	-77.91550	40.76786	surface mine
4902	-77.98110	40.79649	surface mine
4903	-77.94620	40.80212	surface mine
4904	-77.99530	40.80707	cave
4905	-77.96280	40.82701	cave
4906	-77.93200	40.84132	cave

Land Use

Land-use patterns are influenced heavily by the physiography of the basin. Bald Eagle, Tussey, and Nittany Mountain ridges are forested, and the basin valley floor is predominantly agriculture and urban (fig. 8). The headwaters area and extended ground-water basin in the southwest part of the basin also are primarily forested with limited agriculture or urban land use. A summary of land cover derived from the USGS/U.S. Environmental Protection Agency Multi-Resolution Land Characteristics 1992 (MRLC1992) (U.S. Geological Survey, 1992) GIS data set (fig. 8) is presented by subbasin in table 7. The scale of MRLC1992 is 1:100,000.

Higher-resolution GIS data are being developed by the Centre County Planning Commission. These data, mapped at a scale of 1:24,000, are based on digital orthophotography completed for Centre County in 1995 and 2001. Land-cover classes in this data set are not identical to those in the MRLC1992. This new data set will feature improved overall accuracy and definition of land cover.

Land-cover classes can be used as a primary guide for assigning specific hydrologic/hydraulic characteristics to the spatial framework of a hydrologic model. Not included in the listed land-cover classifications is an accounting of pervious and impervious areas. Models that simulate runoff/infiltration from rainfall input typically apply rainfall to delineated pervious and impervious areas, allowing no infiltration in the impervious areas. However, this approach may not adequately simulate situations where runoff from impervious areas is directed to pervious areas. In the Spring Creek Basin, runoff from impervious areas commonly infiltrates into the subsurface.

Table 7. Summary of multiresolution land-cover classes, by subbasin, in Spring Creek surface-water basin, Centre County, Pennsylvania.

[na, not applicable]

Multiresolution land-characteristic class	Big Hollow		Buffalo Run		Cedar Run		Galbraith Gap Run		Logan Branch		Roaring Run		Slab Cabin Run		Spring Creek		Total all subbasins	
	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]	Square miles	Percent[1]
Bare: quarries	na	na	0.019	0.1	na	na	na	na	0.237	1.1	na	na	0.004	0	0.07	0.2	0.329	0.2
Bare: transitional	na	na	.014	.1	0.015	0.1	na	na	.169	.7	na	na	.009	.1	.012	0	.219	.2
Deciduous forest	4.677	27.4	11.488	42.2	3.213	18.4	3.282	64	9.028	40.1	2.708	57.4	3.5	20.8	9.348	26.8	47.412	32.5
Emergent herbaceous wetland	.006	0	.072	.3	.014	.1	.008	.1	.009	0	na	na	.028	.2	.029	.1	.165	.1
Evergreen forest	.474	2.8	.735	2.7	.11	.6	.82	16	1.121	5	.433	9.2	.417	2.5	.762	2.2	4.877	3.3
Hay/pasture	1.37	8	1.541	5.7	2.163	12.4	.031	.6	1.032	4.6	.208	4.4	1.498	8.9	2.817	8.1	10.656	7.3
High-intensity commercial/ industrial	.346	2	.042	.2	.006	0	.002	0	.384	1.7	.001	0	.328	1.9	.49	1.4	1.596	1.1
High-intensity residential	.188	1.1	.023	.1	.001	0	na	na	.029	.1	na	na	.381	2.3	.222	.6	.844	.6
Low-intensity developed	1.704	10	.238	.9	.043	.2	na	na	.747	3.3	.021	.4	2.238	13.3	2.352	6.7	7.33	5
Mixed forest	1.028	6	1.269	4.7	.377	2.2	.803	15.7	1.034	4.6	.476	10.1	.892	5.3	1.369	3.9	7.266	5
Other grass	.321	1.9	na	na	.021	.1	na	na	na	na	na	na	.223	1.3	.161	.5	.728	.5
Row crops	6.935	40.6	11.714	43	11.457	65.6	.139	2.7	8.645	38.4	.871	18.5	7.324	43.5	16.934	48.5	64.011	43.9
Water	.018	.1	.025	.1	.016	.1	.017	.3	.095	.4	.001	0	.006	0	.297	.8	.473	.3
Woody wetland	.004	0	.023	.1	.001	0	.001	0	na	na	na	na	0	0	.013	0	.044	0

[1]Total percent of land-cover classes for an individual subbasin may not equal 100 percent because of rounding.

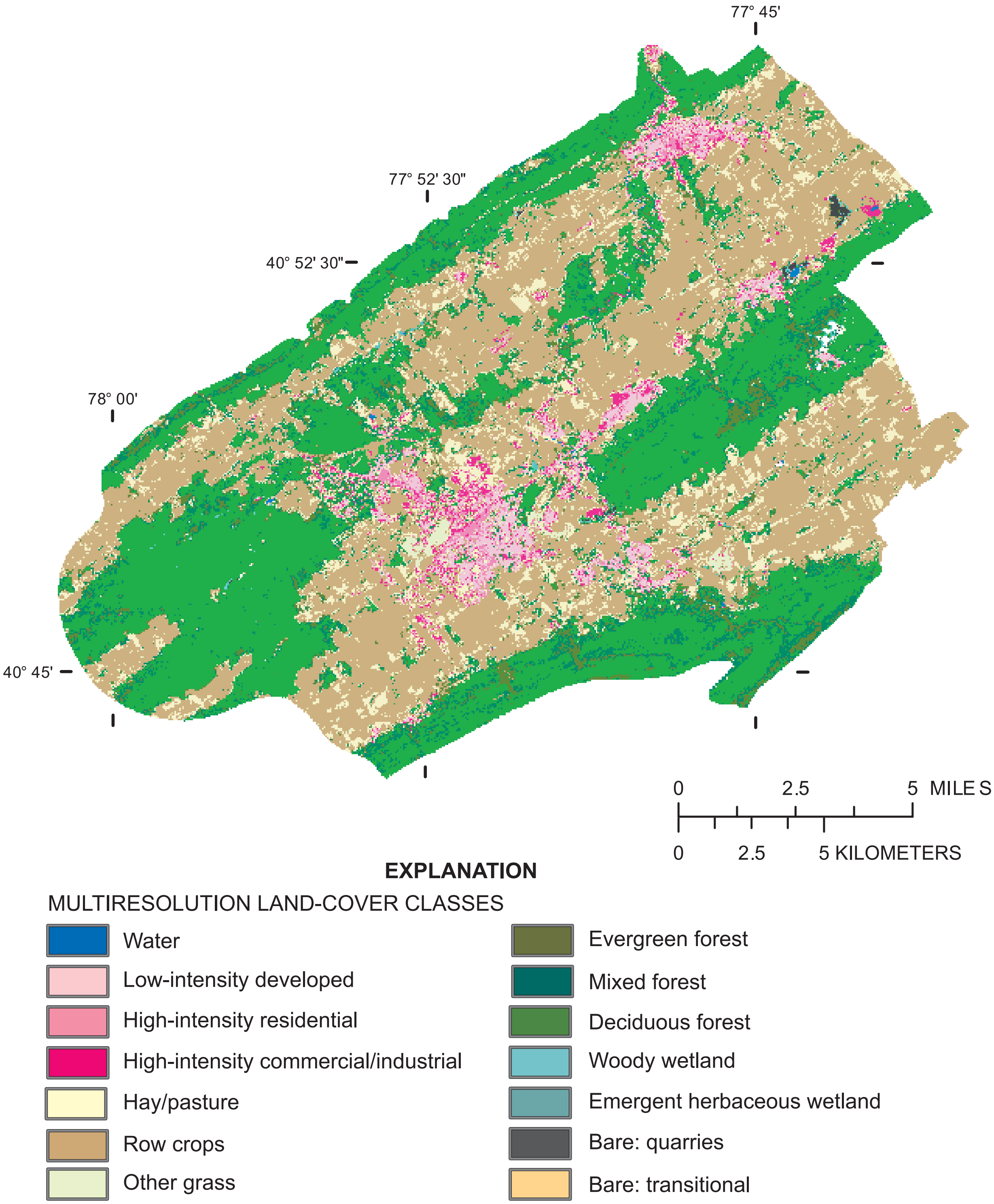


Figure 8. Land use in the Spring Creek Basin, Centre County, Pennsylvania (U.S. Geological Survey, 1992).

Hydrogeologic Setting of Spring Creek Basin

Soils

Soils in Spring Creek Basin can be classified into two generic groups on the basis of their origin. Residual soils are those that have been formed in place, and transported soils are those deposited some distance from their point of origin (Parizek, 1984). Within these two broad classifications, numerous subdivisions known as soil types or series exist (Braker, 1981). The occurrence and range of individual soil series in the Spring Creek Basin are exceedingly complex. However, by grouping soils of similar origin and characteristics, a generalized map of soils can be produced (fig. 9) (Braker, 1981). These groups, called associations, tend to have uniformity in their pattern of distribution but may exhibit considerable variation in their characteristics (Braker, 1981).

The Berks-Weikert association consists of soils formed in residual material weathered from shale of the Ridge and Valley Physiographic Province. The Hagerstown-Opequon-Hublerburg, Morrison, Opequon-Hagerstown, and Murrill associations consist of soils formed in residual and colluvial materials weathered primarily from limestone. The Hazleton-Laidig-Andover and Ungers associations consist of soils formed in residual and colluvial material weathered from sandstone. The extents of the associations are listed by subbasin in table 8. Together the Hagerstown-Opequon-Hublerburg and Hazleton-Laidig-Andover associations cover 78 percent of the Spring Creek Basin. Soils in the ground-water drainage basin, which extends outside the surface-water basin, are listed in table 9.

In hydrologic modeling, soil properties and conditions affect infiltration rates and soil-moisture storage capacity. A listing of selected hydrologic properties and particle-size distributions of the soil associations in the Spring Creek Basin is shown in table 10. These characteristics are summarized from the Conterminous United States (CONUS-soil) (Miller and White, 1998) data set. The CONUS-soil data comprise a GIS data set that contains data from the Natural Resources Conservation Service State Soil Geographic (STATSGO) database (U.S. Department of Agriculture, Natural Resources Conservation Service, 1994) structured for use in hydrologic and climate models.

The STATSGO database was released in 1992 for use in river basin, multi-county, and state resource planning. STATSGO consists of georeferenced digital maps and attribute data. Maps were compiled using USGS 1:250,000 topographic quadrangles. The CONUS-soil data is a multi-layer soil-characteristics database that provides soil physical and hydraulic properties for soil layers extending 2.5 meters below the surface and includes soil-texture class and particle-size fractions, bulk density, porosity, depth to bedrock, rock-fragment volume, rock-fragment class, available water capacity, permeability, plasticity, pH, K-factor (erosion), hydrologic soil group, and curve number (Experimental Climate Prediction Center, 2005). Soil temperature and moisture data collected at the Pennsylvania State University Rock Springs Agricultural Research Farm by the Natural Resources Conservation Service are available starting November 1999 (Natural Resources Conservation Service, 2003).

Geology

The geology of Spring Creek Basin has been described in numerous studies. Key studies related to the geology and hydrogeology of carbonate rocks include those by Butts and Moore (1936), Caruccio (1963), Landon (1963), Clark (1965), Flueckinger (1967), Konikow (1969), and Meiser (1971). Detailed stratigraphic and petrologic information is available in studies by Tuttle (1939), Pelto (1942), Folk (1952), Rones (1955), Donaldson (1959), Thomson (1961), Smith (1966), Parizek and others (1971), and Rauch (1972).

The Spring Creek Basin is underlain by 6,000 to 8,000 ft of interbedded limestone, dolomite, and sandstone of Cambrian, Ordovician, Silurian, and Devonian age (table 11). The strata are folded into anticlines and synclines, and numerous normal, thrust, and strike-slip faults have offset the rocks in several places. The Birmingham Thrust Fault is the major fault extending through much of Nittany Valley. The geologic units and location of major faults as mapped by Berg and others (1980) are shown in figure 10.

Geologic sections across the Spring Creek Basin show lithologic control on the topography of the basin. The resistant quartzite of the Tuscarora Formation and the sandstone of the Bald Eagle Formation form the double ridges of Bald Eagle Mountain and the less-resistant Juniata Formation underlies the small valleys between the double ridges (figs. 11 and 12). The Nittany and Penns Valleys formed on less resistant carbonate rocks of Cambrian and Ordovician age. The sections (figs. 11 and 12) show that the valleys formed on anticlines and the mountains on synclinal structures.

The rocks in the Spring Creek Basin have been fractured by many forces, principally those that formed the Appalachian Mountains. Fractures include cleavage, bedding-plane partings, joints, and faults. Some major fractures are expressed topographically and are referred to as fracture traces or lineaments. Fracture traces are natural linear features consisting of topographic, vegetation, or soil-tonal alignments that are visible primarily on aerial photographs, are greater than 1,000 ft in length, and are less than 1 mi in length. Maps of fracture traces in the State College area by Lattman and Parizek (1964) and Parizek and Drew (1966) suggest that fracture traces are abundant and tend to have north-south and east-west strikes, giving rise to large, irregular, rectangular blocks. Areas of high-density fracture traces are shown in figure 13. The location of the traces is important because wells drilled on fracture traces in Spring Creek Basin generally have higher yields than those drilled off fracture traces (Lattman and Parizek, 1964; Parizek and Drew, 1966; Siddiqui, 1969).

Many fractures in the carbonate rocks beneath the valleys of Spring Creek Basin have been enlarged by dissolution. These enlarged fractures (vugs, solution cavities, sinkholes, and conduits) have a significant influence on the rate and direction of ground-water flow.

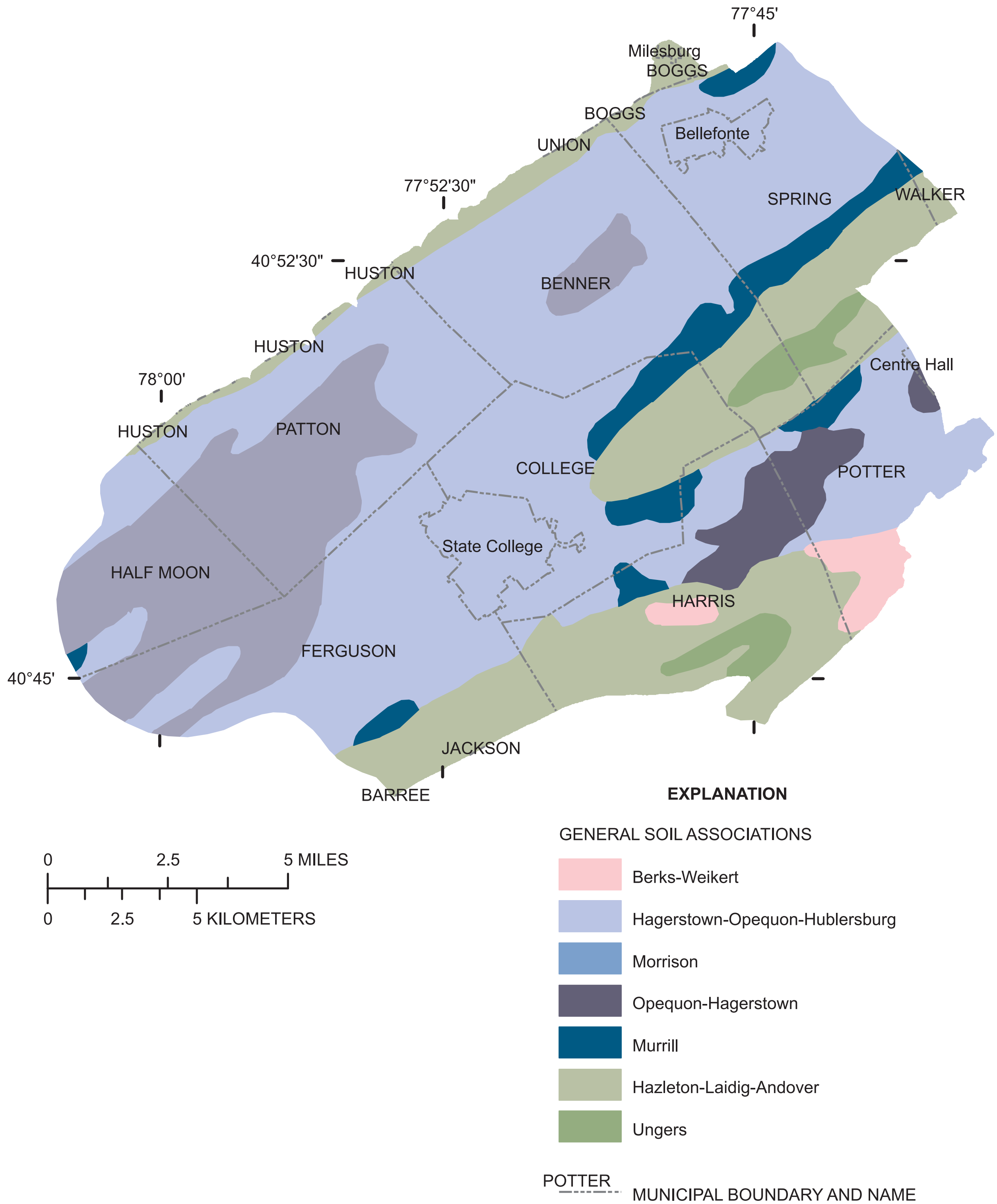


Figure 9. Soil associations in the Spring Creek Basin, Centre County, Pennsylvania (Braker, 1981). (Note: Soil associations have been extended to the ground-water divide.)

Table 8. Inventory and extent of soil associations, by subbasin, in Spring Creek surface-water basin, Centre County, Pennsylvania (from Braker, 1981).

[—, no data]

Subbasin	Berks-Weikert		Hagerstown-Opequon-Hublersburg		Morrison		Opequon-Hagerstown		Murrill		Hazleton-Laidig-Andover		Ungers	
	Square miles	Percent of subbasin	Square miles	Percent of subbasin	Square miles	Percent of subbasin	Square miles	Percent of subbasin	Square miles	Percent of subbasin	Square miles	Percent of subbasin	Square miles	Percent of subbasin
Big Hollow	—	—	13.8	81	3.28	19	—	—	—	—	—	—	—	—
Buffalo Run	—	—	17.9	66	6.04	22	—	—	—	—	3.27	12	—	—
Cedar Run	0.67	4	10.5	60	—	—	4.66	26	1.33	8	.32	2	—	—
Galbraith Gap Run	.61	12	—	—	—	—	.02	0	—	—	3.21	63	1.29	25
Logan Branch	—	—	5.6	25	—	—	—	—	3.56	16	11.4	50	2.03	9
Roaring Run	—	—	.47	10	—	—	—	—	—	—	3.96	84	.29	6
Slab Cabin Run	—	—	11.7	69	—	—	—	—	.3	2	4.88	29	—	—
Spring Creek (main channel)	1.49	4	20.4	59	2.01	6	.74	2	3.04	9	6.81	20	.13	1
Total all subbasins	2.77	2	80.4	55	11.3	8	5.42	4	8.23	6	33.8	23	3.74	2

Table 9. Inventory and extent of soil associations in the ground-water drainage basin for Spring Creek, Centre County, Pennsylvania (from Braker, 1981).

[—, no data]

	Berks-Weikert		Hagerstown-Opequon-Hublersburg		Morrison		Opequon-Hagerstown		Murrill		Hazleton-Laidig-Andover		Ungers	
	Square miles	Percent of ground-water basin	Square miles	Percent of ground-water basin	Square miles	Percent of ground-water basin	Square miles	Percent of ground-water basin	Square miles	Percent of ground-water basin	Square miles	Percent of ground-water basin	Square miles	Percent of ground-water basin
Ground-water basin outside of surface-water basin	0.22	1	12.5	39	17.1	53	—	—	0.63	2	1.48	5	—	—
Total ground-water basin	2.99	2	92.9	52	28.4	16	5.42	3	8.86	5	35.3	20	3.74	2

Table 10. Selected physical properties of soil associations in Spring Creek Basin, Centre County, Pennsylvania (from Miller and White, 1998).

[—, no data]

Association	Proportion (percent)[1]	Available water capacity (inch per inch)		Permeability (inches per hour)		Porosity		Sand fraction (percent)			Silt fraction (percent)			Clay fraction (percent)		
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum	Median
Berks-Weikert	51-13-36	0.04	0.14	0.4	3.6	0.13	0.5	27	34	32	47	58	51	15	19	17
Hazleton-Laidig-Andover	28-23-16-33	.04	.2	4.8	8.5	.33	.5	46	53	49	34	38	34	13	20	15
Hagerstown-Opequon-Hublersburg	53-12-12-23	.1	.2	1.2	2.2	.45	.52	16	20	18	38	70	40	13	44	42
Morrison	80-20	.06	.16	3.7	5.0	.46	.51	51	55	54	33	35	34	12	14	13
Murrill	82-18	.08	.14	.6	2.0	—	—	—	—	—	—	—	—	—	—	—
Opequon-Hagerstown	35-23-42	.1	.2	.6	2.0	—	—	—	—	—	—	—	—	—	—	—
Ungers	73-27	.06	.16	.6	6.0	—	—	—	—	—	—	—	—	—	—	—

[1]Proportion of soil type listed in same order as named in association except last value which refers to other unnamed soil types in that association. For example, the proportions 51-13-36 for the Berks-Weikert soil association suggests that the Berks soil is equivalent to 51 percent, the Weikert soil is equivalent to 13 percent, and unnamed soils are equivalent to 36 percent.

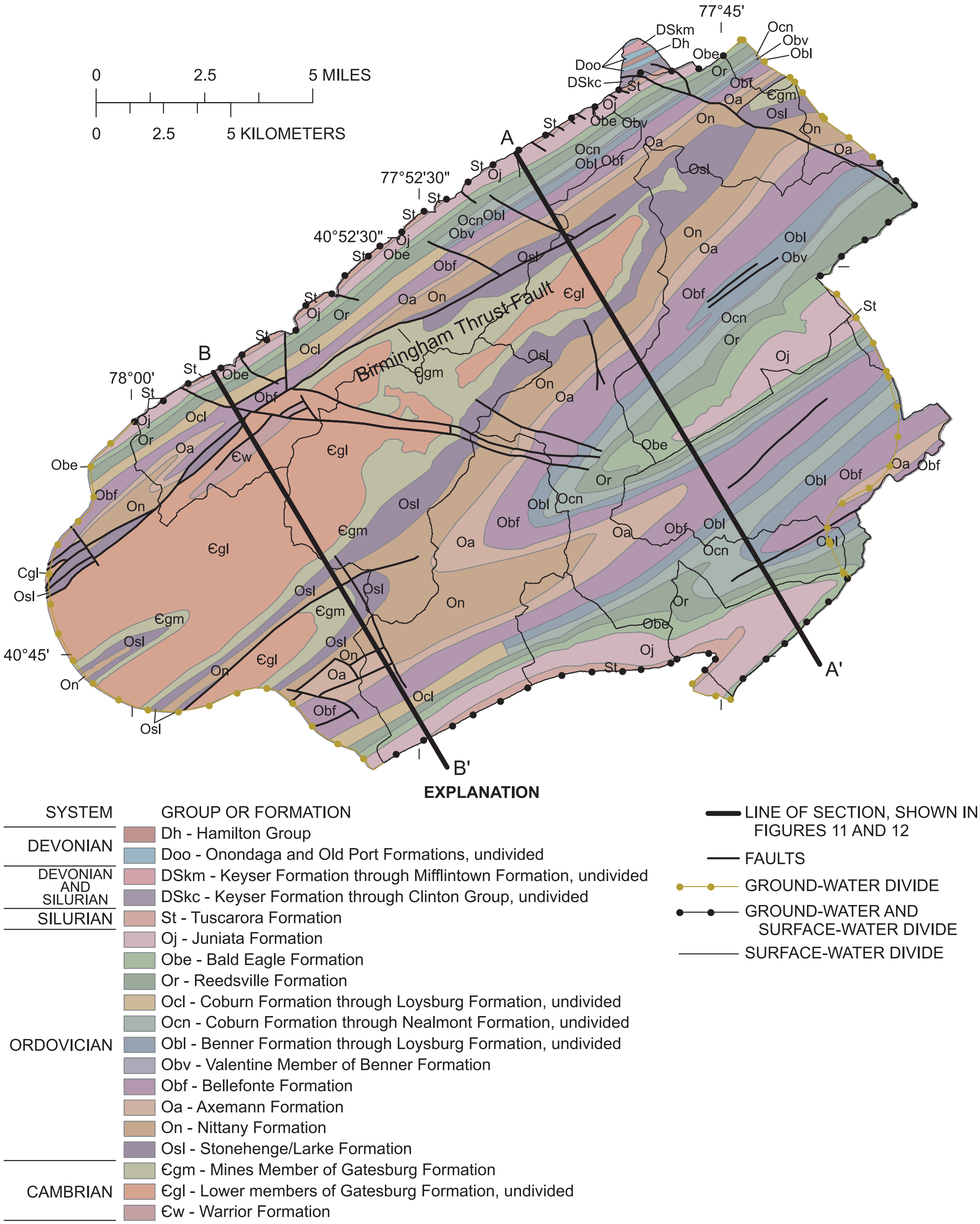


Figure 10. Geologic map of Spring Creek Basin, Centre County, Pennsylvania (modified from Berg and others, 1980).

Table 11. Stratigraphy and aquifer types for the Spring Creek Basin (modified from Siddiqui, 1969).

System	Geologic unit	Thickness (feet)	Lithologic description	Aquifer type
Devonian	Hamilton Group:			Fracture-dominated siliciclastic
	Mahantango Formation	610	Olive-green shale; thin fine-grained sandstone; 0 to 50 feet of gray limestone and shale at top (Tully Member)	Fracture-dominated siliciclastic
	Marcellus Formation	100	Black-fissile shale	Fracture-dominated siliciclastic
	Onondaga Formation	0-50	Greenish-blue shale and dark-blue to black, medium-bedded limestone	Fracture-dominated siliciclastic
	Old Port Formation:	225-280		Fracture-dominated siliciclastic
	Ridgeley Member		Coarse-grained, calcareous, brown to white, fossiliferous sandstone	Fracture-dominated siliciclastic
	Shriver Member		Thin-bedded siliceous limestone, shale, calcareous sandstone, and chert	Fracture-dominated siliciclastic
	Corriganville Member		Medium-gray limestone and light-gray chert	Fracture-dominated siliciclastic
	New Creek Member		Coarsely crystalline, medium-dark-gray, massive-bedded limestone	Fracture-dominated siliciclastic
Devonian and Silurian	Keyser Formation	150	Dark-gray, thick-bedded, crystalline to nodular limestone, thin-bedded and shaly near the top	Fracture-dominated siliciclastic
	Tonoloway Formation	400	Dark, thin-bedded limestone	Fracture-dominated siliciclastic
	Wills Creek Formation	400	Olive-gray and yellow, calcareous shale	Fracture-dominated siliciclastic
	Bloomsburg Formation	40-400	Red and gray shale	Fracture-dominated siliciclastic
	Mifflintown Formation	400	Olive-gray and yellowish-brown shale, interbedded with medium-gray top dark-gray limestone; interbedded sandstone and limestone at base	Fracture-dominated siliciclastic
	Clinton Group		Fossiliferous sandstone and hematitic, oolitic sandstone and shale	Fracture-dominated siliciclastic
Silurian	Rose Hill Formation	800	Olive-gray shales weathering pale yellowish brown; interbedded thin sandstone and limestone	Fracture-dominated siliciclastic
	Tuscarora Formation	550	Hard, thick-bedded, white or gray quartzitic sandstone	Fracture-dominated siliciclastic

Table 11. Stratigraphy and aquifer types for the Spring Creek Basin (modified from Siddiqui, 1969).—Continued

System	Geologic unit	Thickness (feet)	Lithologic description	Aquifer type
Ordovician	Juniata Formation	500-1,000	Dominately red, fine-grained sandstone, siltstone, and shale	Fracture-dominated siliciclastic (except Oswego Sandstone of the Bald Eagle Formation, which has intergranular permeability)
	Bald Eagle Formation	700-800	Brown to gray, fine- to coarse-grained sandstone	
	Reedsville Formation[1]	900-1,400	Dark-gray to brownish-gray shale; somewhat calcareous near the base; sandy near the top	Fracture-dominated siliciclastic
	Coburn Formation	300	Thin-bedded limestone containing shale interbeds	Conduit-dominated carbonate
	Salona Formation	180-300	Thin-bedded limestone containing shale partings	Conduit-dominated carbonate
	Nealmont Formation	70	Thin to thick impure limestone	Conduit-dominated carbonate
	Benner Formation:	150	Dark-gray laminated, thick- to thin-bedded limestone	Conduit-dominated carbonate
	Valentine Member[1]		Dark-gray laminated, thick- to thin-bedded limestone	Conduit-dominated carbonate
	Snyder Formation	80	Medium-bedded limestone and dolomite	Conduit-dominated carbonate
	Hatter Formation	75	Medium-bedded limestone and laminated, argillaceous and arenaceous dolomite	Conduit-dominated carbonate
	Loysburg Formation	50-450	Laminated, medium- to thin-bedded limestone and dolomite	Conduit-dominated carbonate
	Bellefonte Formation	1,400	Light-gray, thick-bedded dolomite; some chert; sandstone bed in upper part	Fracture-dominated carbonate
	Axemann Formation[1]	400-700	Blue, thin-bedded limestone; some dolomite layers	Conduit-dominated carbonate
	Nittany Formation[1]	1,200	Blue, thick-bedded, coarsely crystalline dolomite	Fracture-dominated carbonate
	Stonehenge Formation	250-600	Blue, thin-bedded limestone; some dolomite	Conduit-dominated carbonate
Cambrian	Gatesburg Formation:	1,800		Conduit-dominated carbonate
	Mines Member[1]		Dark-gray, coarse-grained dolomite and subordinate light-gray fine-grained dolomite; abundant oolitic chert	Fracture-dominated carbonate
	upper sandy member[1]		Dolomite and interbedded orthoquartzite and sandy dolomite	Diffuse-flow-dominated carbonate aquifer
	Ore Hill Member[1]		Dark-gray dolomite	Diffuse-flow-dominated carbonate aquifer
	lower sandy member		Dolomite and interbedded orthoquartzite and sandy dolomite	Diffuse-flow-dominated carbonate aquifer
	Warrior Formation	1,300	Blue, impure limestone and dolomite; thin sandy partings	Fracture-dominated carbonate

[1]Indicates geologic name not currently used by the U.S. Geological Survey. Conforms to usage by the Pennsylvania Geological Survey.

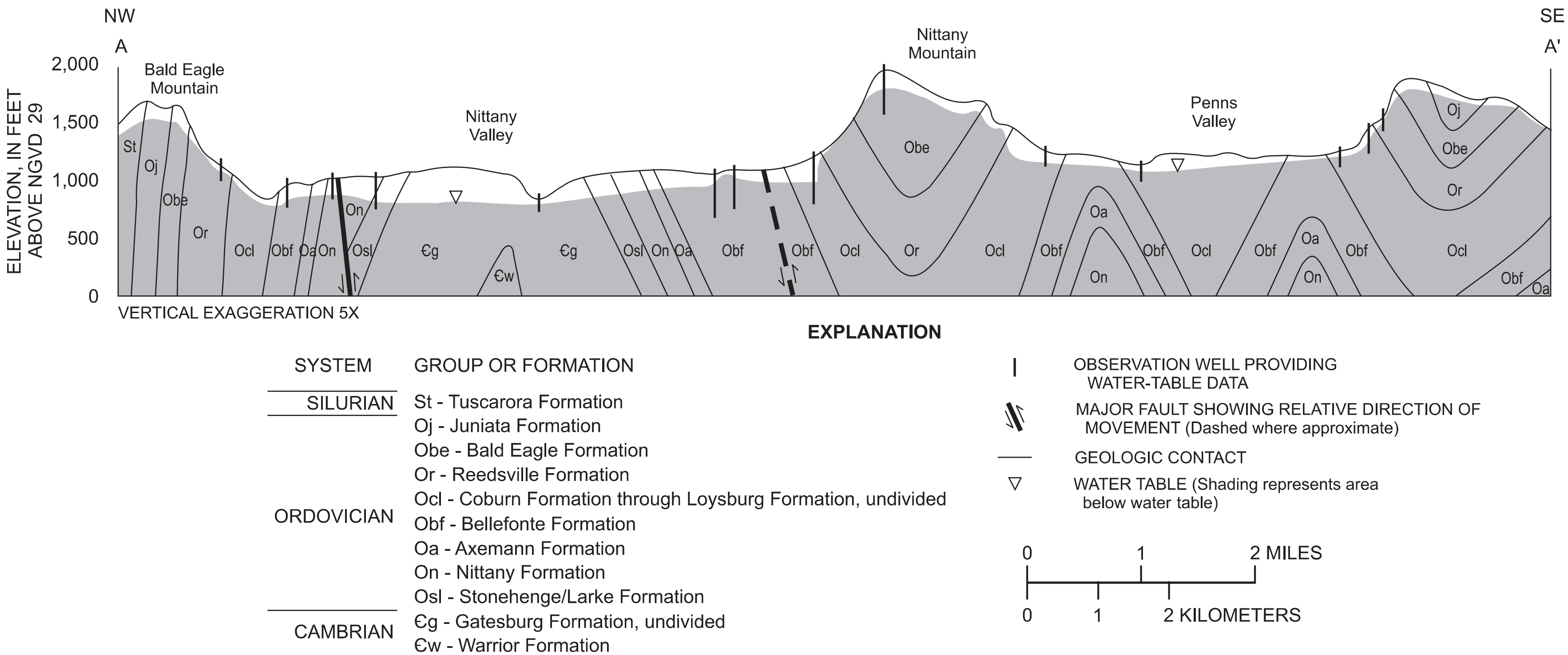


Figure 11. Geologic section and generalized water table through line A-A′, Spring Creek Basin and adjacent area (modified from Giddings, 1974; geology by Butts and Moore, 1936). Approximate location of section A-A′ is shown on figure 10. Some contacts differ between figures 10 and 11 because different geologic mapping sources were used.

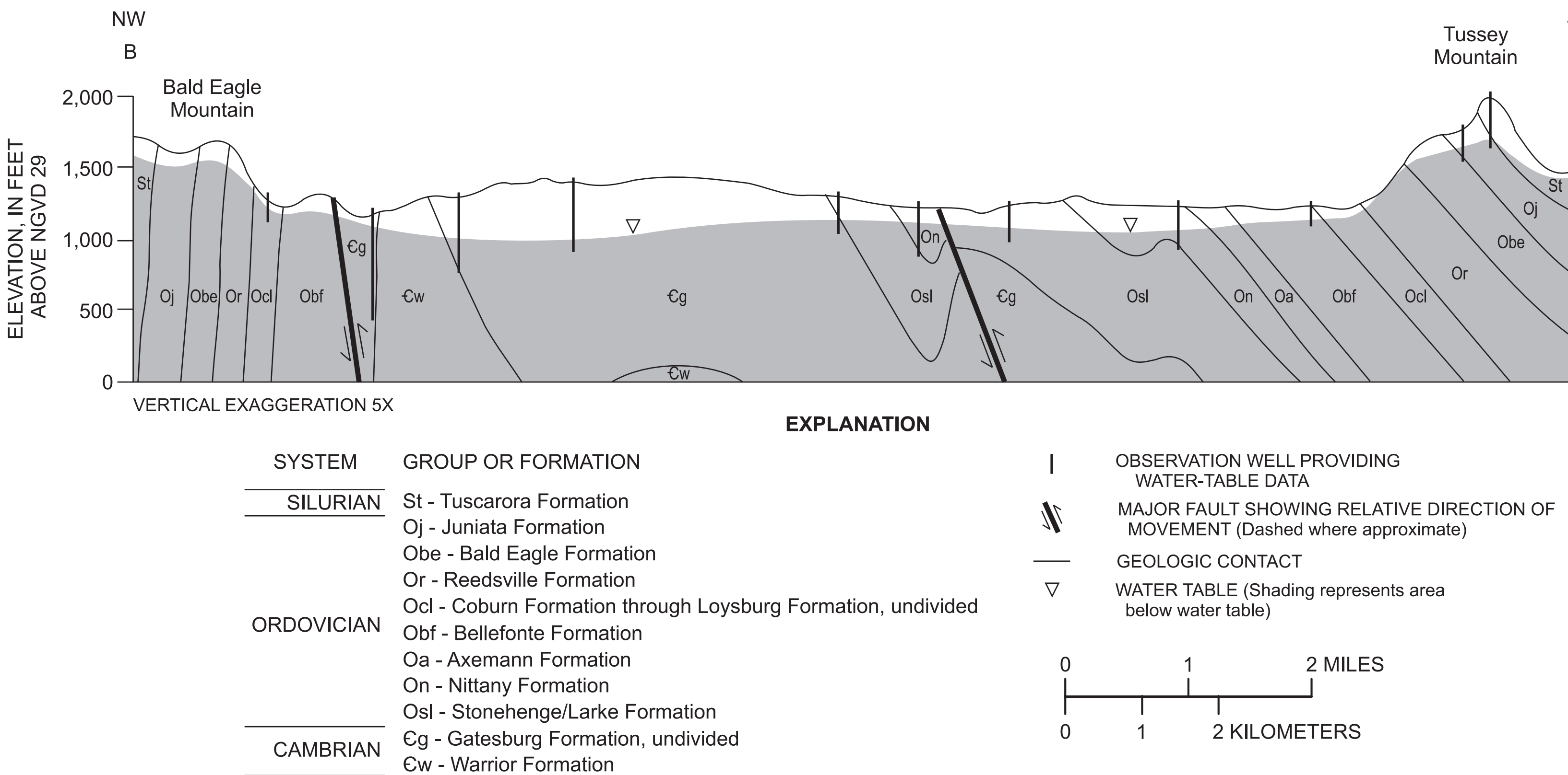


Figure 12. Geologic section and generalized water table through line B-B′, Spring Creek Basin and adjacent area (modified from Giddings, 1974; geology by Butts and Moore, 1936). Approximate location of section B-B′ is shown on figure 10. Some contacts differ between figures 10 and 12 because different geologic mapping sources were used.

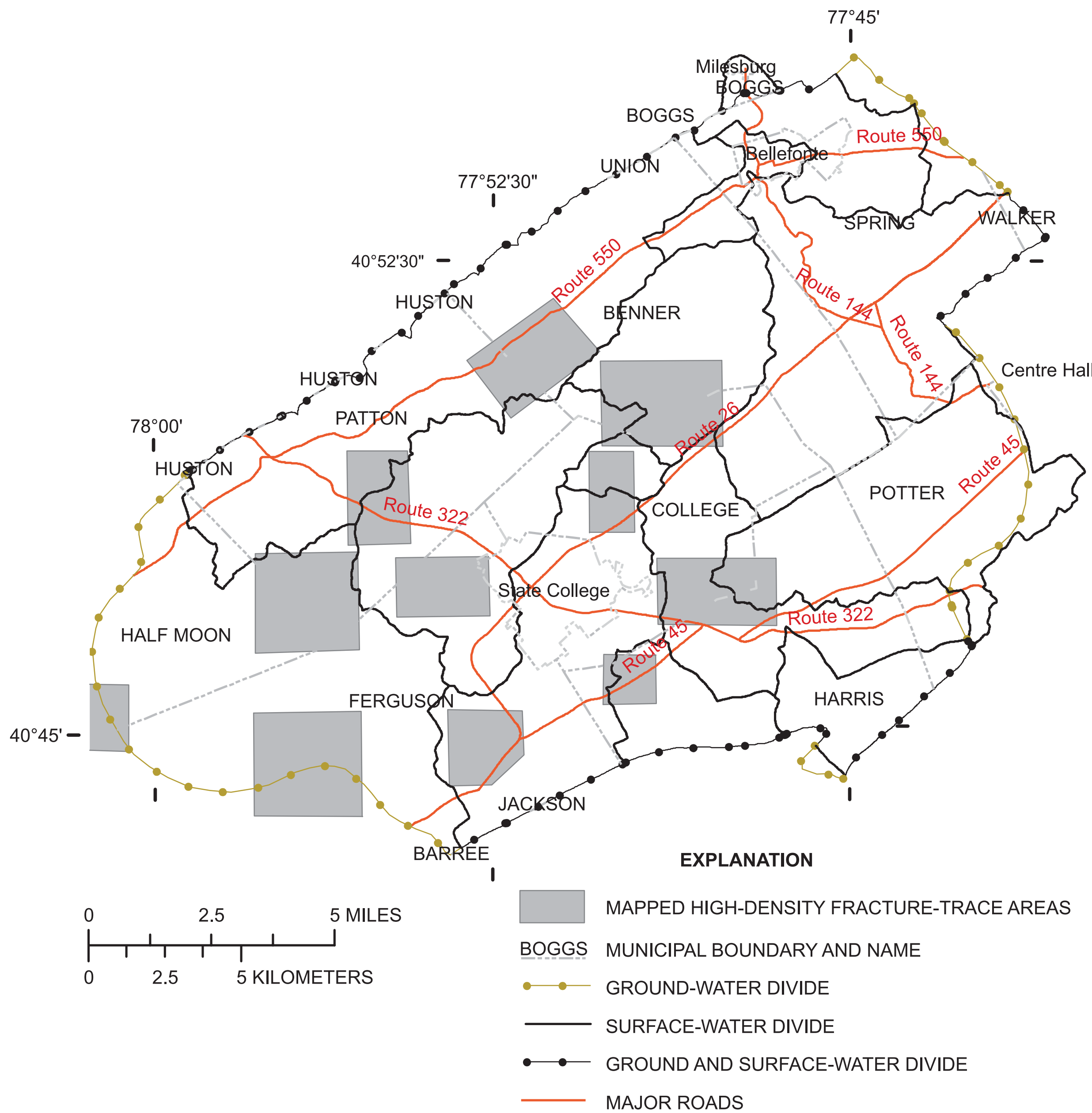


Figure 13. Areas of high-density fracture traces in the Spring Creek Basin, Centre County, Pennsylvania (from Nittany Geoscience, Inc., 1989).

Surface Water

The Spring Creek surface-water basin drains 146 mi^2 via Spring Creek and seven major named tributaries (fig. 14). The surface-water drainage areas of the tributary subbasins range in size from 4.72 to 34.9 mi^2. Springs, many of which are large, are the primary source of streamflow in the basin. A number of small tributaries carry mountain runoff into basin-valley streams. However, during low to moderate flow conditions, most or all of this runoff enters sinkholes and fractures near the base of the ridges that delimit Spring Creek Basin (Giddings, 1974). This lost runoff is discharged to surface waters through the numerous springs on the valley floor of the basin. Spring Creek flows northeast and discharges to Bald Eagle Creek, north of Bald Eagle Mountain. Surface water in the extended ground-water basin drains southwest into Spruce Creek, west of Big Hollow and Slab Cabin Run subbasins.

Areas of Spring Creek Basin are subject to variable-source hydrologic conditions. These areas, generally downslope of areas with high infiltration rates and underlying bedrock of reduced permeability, become sources rather than sinks of surface-water runoff during sufficiently saturated soil conditions. Snowmelt runoff is also an important contributor to surface runoff.

Streamflow in Spring Creek Basin is recorded continuously at three USGS streamflow-gaging stations, three Pennsylvania Cooperative Fish and Wildlife Research Unit streamflow-gaging stations, and six SCWCm streamflow-gaging stations (fig. 14; table 12). At the USGS streamflow-gaging stations, stream stage is recorded every 15 minutes. From the stage values, a daily mean streamflow is determined and is stored in the USGS National Water Information System (NWIS) database, which is available through the World-Wide Web (*http://waterdata.usgs.gov/pa/nwis?*). Stream stage at the Pennsylvania Cooperative Fish and Wildlife Research Unit streamflow-gaging stations are recorded hourly and computed streamflows are stored in electronic format (R. Carline, Pennsylvania Cooperative Fish and Wildlife Research Unit, oral commun., June 17, 2003). At the SCWCm streamflow-gaging stations, stream stage is recorded every 30 minutes and computed streamflows are stored in electronic format (K. Ombalski, ClearWater Conservancy, oral commun., April 2003).

Streamflow in Spring Creek has a large base-flow component. Base flows at the three USGS streamflow-gaging stations on Spring Creek were computed using the local-minimum method hydrograph-separation technique (Pettyjohn and Henning, 1979; Sloto and Crouse, 1996). Period-of-record statistics (table 13) show the greatest mean annual streamflow and mean base-flow yield at the most downstream streamflow-gaging station, Spring Creek at Milesburg. Base-flow yields increase more than 40 percent from Axemann to Milesburg (fig. 14). This large increase in base-flow yield has been attributed to large springs that drain the high-yielding Gatesburg Formation (Taylor, 1997) and to a total ground-water drainage area approximately 19 percent larger than the surface-water drainage area at Milesburg (Giddings, 1974). The large percentage of total streamflow contributed by base flow (table 13) remains unusually constant over time. Taylor (1997) reported a minimum base-flow percentage of 79 percent and a maximum of 93 percent for Spring Creek at Milesburg for the 27-year period from 1968 to 1994.

A flow-duration plot (from October 1, 1968, through September 30, 2002) comparing base flow at the Milesburg streamflow-gaging station (drainage area = 142 mi^2) to base flow for a similar size watershed at Beech Creek at Monument, Pa. (drainage area = 152 mi^2), shows greater constancy of base flow at Milesburg (fig. 15). Daily mean base flows are between 100 and 200 ft^3/s (0.70 to 1.41 $(ft^3/s)/mi^2$) about 70 percent of the time. During the same time period, base flows at Beech Creek at Monument, Pa., ranged from 10 to about 280 ft^3/s (0.07 to 1.84 $(ft^3/s)/mi^2$) about 70 percent of the time. In addition, high base flows are lower at Milesburg, further reducing variation in base flow compared to Beech Creek at Monument.

An inventory of permitted surface-water withdrawals and discharges (as of November 30, 2003) is presented in table 14. In the Spring Creek Basin, the total volume of surface-water discharges exceeds surface-water withdrawals, because ground-water withdrawals supply the majority of facilities having surface-water discharges. Records of withdrawal volumes are available for most facilities. Records of discharge volumes generally do not exist. Small residential and commercial facilities are not required to monitor discharge volumes. In many instances, these facilities are permitted on the basis of an expected volume for the stated type of discharge. Continuous or partial records for some facilities (mostly larger dischargers) are available from either the U.S. Environmental Protection Agency Envirofacts Database or the facilities themselves.

Active and historic surface-water impoundment structures in Spring Creek Basin include three dams and four reservoirs—Milesburg Dam, McCoy Dam, Markles Gap Reservoir, McBrides Gap Reservoir, Musser Gap Reservoir, Shingletown Gap Reservoir, and Benner Spring Dam. Two impoundments, the McBrides Gap and Shingletown Gap Reservoirs, currently are used to supplement public water supplies. Markles Gap and Musser Gap Reservoirs were formerly used as water-supply sources but currently (2003) are out of service.

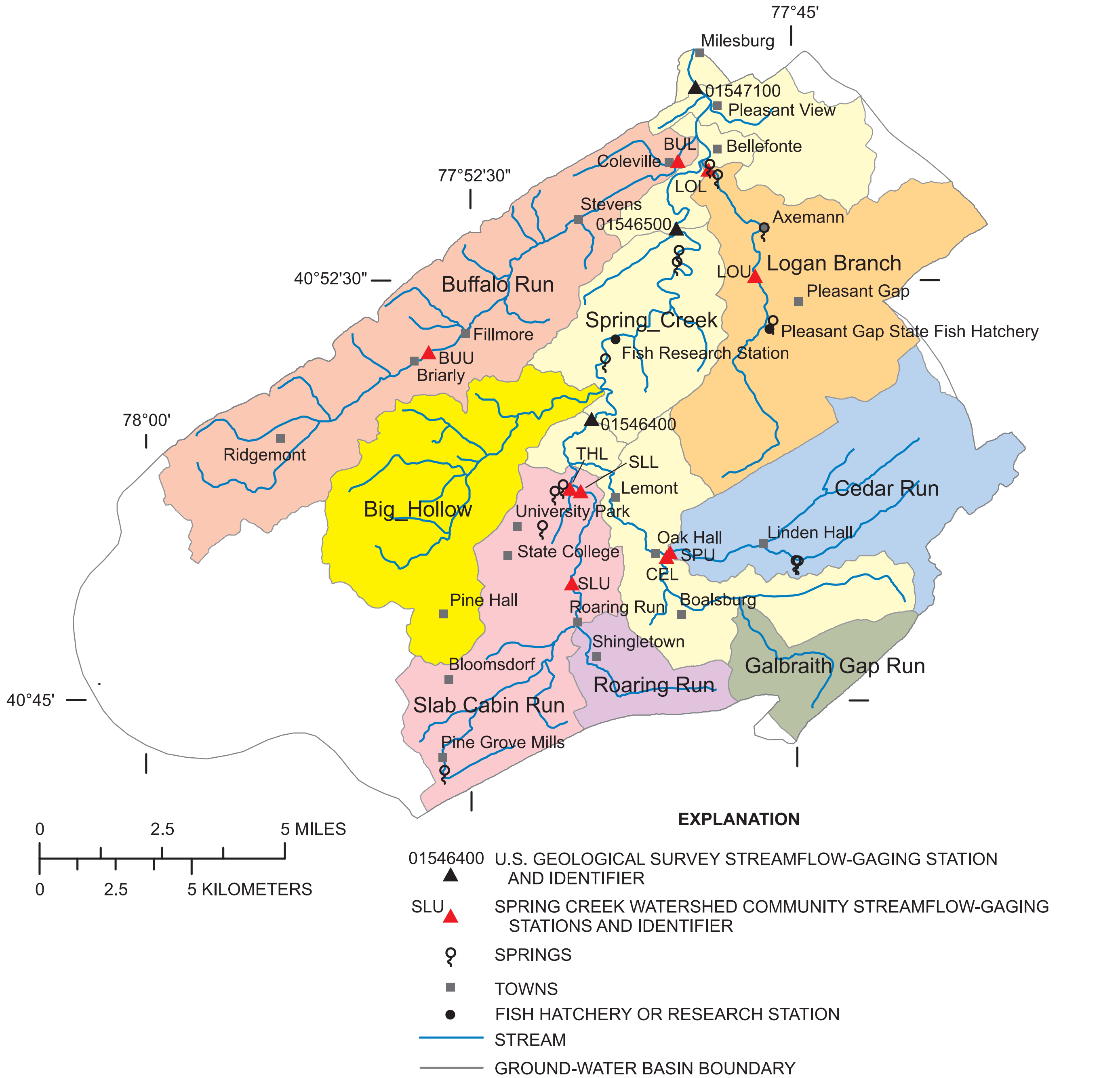


Figure 14. Location of streamflow-gaging stations and springs in the Spring Creek surface-water basin, Centre County, Pennsylvania.

Table 12. Active streamflow-gaging stations in the Spring Creek Basin, Centre County, Pennsylvania.

[NAD 83, North American Datum of 1983; NAVD 88, North American Vertical Datum of 1988; na, not available]

U.S. Geological Survey streamflow-gaging station number	Station abbreviation	Station name	Annual mean discharge (cubic feet per second)	Drainage area (square miles)	Latitude (degrees, minutes, seconds, NAD 83)	Longitude (degrees, minutes, seconds, NAD 83)	Elevation (feet in NAVD 88)	Mean drainage area slope (percent)	Maximum drainage area slope (percent)	Period of record
405435007747301	BUL	Lower Buffalo Run	na	14.2	405435	774738	748	6.3	35.5	August 1999 to present
405112007753301	BUU	Upper Buffalo Run	na	12.6	405112	775328	1,003	5.4	25.3	August 1999 to present
404739007747501	CEL	Lower Cedar Run	na	17.5	404739	774750	1,036	3.8	28.2	1990-1994, November 1998 to present
405426007746501	LOL	Lower Logan Branch	na	4.44	405426	774655	750	3.7	19.1	February 1999 to present
405233007745501	LOU	Upper Logan Branch	na	18.1	405233	774550	874	6.4	33.8	August 1999 to present
404844007749501	SLL	Lower Slab Cabin Run	na	1.96	404844	774955	944	2.8	9.5	June 1999 to present
404706007750101	SLU	Upper Slab Cabin Run	na	10	404706	775008	1,031	4.8	26.2	1990-1994, November 1998 to present
01546500	SPA	Spring Creek near Axemann	93.7	87.2	405324	774740	786	4.4	30.8	October 1940 to present
01546400	SPH	Spring Creek at Houserville	67.2	58.5	405002	774939	930	5.1	30.8	November 1984 to present
01547100	SPM	Spring Creek at Milesburg	230	142	405554	774711	706	5.0	35.5	May 1967 to present
404734007747501	SPU	Upper Spring Creek	na	13.1	404734	774755	1,038	7.1	30.8	1990-1994, November 1998 to present
404847007750101	THL	Lower Thompson Run	na	3.88	404847	775010	939	1.7	7.7	June 1999 to present

Table 13. Period-of-record statistics for streamflow and base flow at U.S. Geological Survey streamflow-gaging stations in Spring Creek Basin, Centre County, Pennsylvania.

U.S. Geological Survey streamflow-gaging station number	Station name	Drainage area (square miles)	Period of record	Mean annual stream-flow (cubic feet per second)	Mean annual base flow (cubic feet per second)	Mean annual base flow (percent of total stream-flow)	Mean base-flow yield (cubic feet per second per square mile)	Mean base-flow yield for common period (cubic feet per second per square mile)[1]
01546400	Spring Creek at Houserville, Pa.	58.5	November 1984 to present	65.6	50.2	76.5	0.86	0.86
01546500	Spring Creek near Axemann, Pa.	87.2	October 1940 to present	93.2	76.9	82.5	.90	.93
01547100	Spring Creek at Milesburg, Pa.	142	May 1967 to present	228	194	85.1	1.34	1.32

[1]Common period: November 8, 1984, to September 30, 2002.

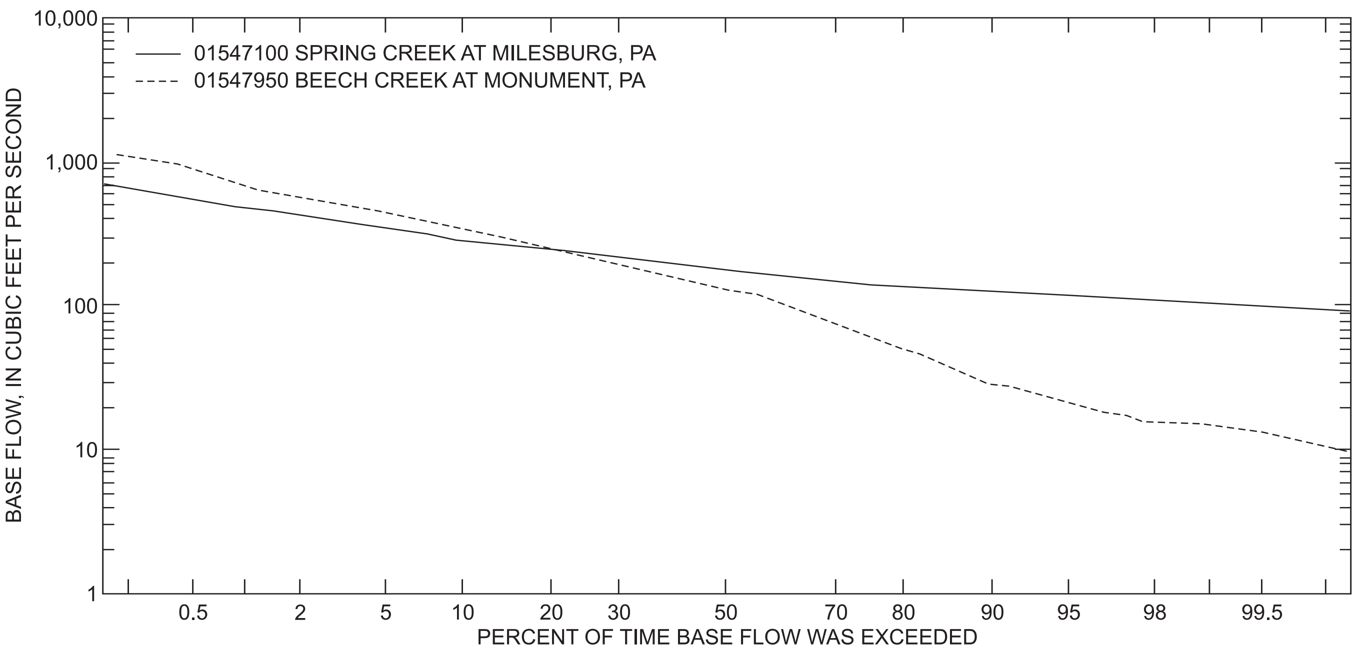


Figure 15. Stream base-flow exceedence probabilities at streamflow-gaging stations 01547100, Spring Creek at Milesburg, Pa., and 01547950, Beech Creek at Monument, Pa., for October 1, 1968, through September 30, 2002.

Table 14. Inventory of permitted surface-water withdrawals and discharges to Spring Creek Basin, Centre County, Pennsylvania (as of November 30, 2003).

[Mgal/d, million gallons per day; ND, no data; STP, sewage treatment plant; INDWW, industrial wastewater; STMW, stormwater; GWC, ground-water cleanup; CAFO, concentrated animal-feeding operation; TRTD GW, treated ground water]

Type	Name	Use	Stream location	Status	Permitted volume (Mgal/d)	Records available
Withdrawal	Oak Hall Water System, Markles Gap Reservoir	Public Supply	Tributary to Spring Creek	Inactive	ND	Unknown
Withdrawal	Rockview, Mcbrides Gap Reservoir	Commercial	Logan Branch	Active	ND	Yes
Withdrawal	State College Borough Water Authority, Shingletown Gap Reservoir	Public Supply	Roaring Run	Active	ND	Yes
Withdrawal	Pleasant Gap Fish Culture Station	Commercial	Logan Branch	Active	ND	Yes
Withdrawal	Upper Spring Creek Fish Culture Station	Commercial	Spring Creek	Active	ND	Yes
Discharge	Al Mar Acres Mobile Home Park	STP	Spring Creek	Active	0.0105	Unknown
Discharge	Atotech USA, Inc.	INDWW	Tributary to Big Hollow Run	Active	ND	Unknown
Discharge	Bellefonte Borough	STP	Spring Creek	Active	2.4	Yes
Discharge	Bellefonte Fish Culture Station	INDWW	Spring Creek	Active	3.07	Yes
Discharge	Burns, Pat	STMW	Buffalo Run	Active	.005	No
Discharge	Centre Concrete Co.	STMW	Spring Creek	Active	ND	No
Discharge	Centre City Solid Waste Authority	ND	Tributary to Logan Branch	Active	ND	Unknown
Discharge	Cerro Metal Products	INDWW,STMW, GWC	Logan Branch	Active	.225	Unknown
Discharge	Cerro Metal Products, Plant 5	ND	Spring Creek	Active	ND	Unknown
Discharge	Con-lime, Inc.	Quarry discharge	Buffalo Run	Active	ND	Unknown
Discharge	Corning Asahi Video Products Co.	INDWW	Tributary to Logan Branch	Active	1.97	Unknown
Discharge	Daniel R. Hawbaker	STP	Tributary to Buffalo Run	Active	.0004	No
Discharge	Gensimore Trucking, Inc.	ND	Tributary to Logan Branch	Active	ND	Unknown
Discharge	Graybec Lime, Inc. (Graymont)	INDWW	Buffalo Run	Active	ND	Unknown
Discharge	Gray's Vehicle Clinic	STMW	Logan Branch	Active	ND	No
Discharge	H.R. Bierly Auto Service	STMW	Tributary to Gap Run	Active	ND	No
Discharge	Hesser, Petronella	STP	Tributary to Spring Creek	Active	.0004	No
Discharge	Hodes Industries, Inc.	STMW	Tributary to Logan Branch	Active	ND	No
Discharge	Milestone Materials, Neidighs Quarry	Quarry discharge	Spring Creek	Active	ND	Unknown
Discharge	Mowery Jr., Wayne	STP	Halfmoon Creek	Active	.0005	No
Discharge	Murata Erie	INDWW	Tributary to Big Hollow Run	Active	ND	Unknown
Discharge	Pennsylvania Air National Guard Station	STMW	Tributary to Big Hollow Run	Active	ND	Unknown
Discharge	Pennsylvania Fish & Boat Commission-Benner Spring	INDWW	Spring Creek	Active	9.216	Yes
Discharge	Pennsylvania State University	INDWW	Tributary to Slab Cabin Run	Active	ND	Unknown

Table 14. Inventory of permitted surface-water withdrawals and discharges to Spring Creek Basin, Centre County, Pennsylvania (as of November 30, 2003).—Continued

[Mgal/d, million gallons per day; ND, no data; STP, sewage treatment plant; INDWW, industrial wastewater; STMW, stormwater; GWC, ground-water cleanup; CAFO, concentrated animal-feeding operation; TRTD GW, treated ground water]

Type	Name	Use	Stream location	Status	Permitted volume (Mgal/d)	Records available
Discharge	Pennsylvania State University	GWC	Big Hollow Run	Active	0.0072	Unknown
Discharge	Pennsylvania State University	CAFO	Buffalo Run/spring Creek	Active	ND	Unknown
Discharge	Pleasant Gap Fish Culture Station	INDWW	Logan Branch	Active	5.508	Yes
Discharge	Potter Township	STP	Cedar Run	Active	.035	Unknown
Discharge	Ruetgers-nease Organics Corp.	TRTD GW	Tributary to Spring Creek	Active	.072	Unknown
Discharge	Science Prk Recreation Association	INDWW	Tributary to Big Hollow Run	Active	ND	Unknown
Discharge	Smithbauer, Lawrence	STP	Tributary to Spring Creek	Active	.0004	No
Discharge	Sms Sutton, Inc.	STMW	Spring Creek	Active	ND	Unknown
Discharge	Stewart Auto Parts	STMW	Tributary to Spring Creek	Active	ND	Unknown
Discharge	Superior Services of Pa., Inc.	STMW	Tributary to Spring Creek	Active	ND	Unknown
Discharge	Tolan, William	STP	Tributary to Buffalo Run	Active	.0004	No
Discharge	University Area Joint Authority, Spring Creek Pollution Control Facility	STP	Spring Creek	Active	6	Yes
Discharge	United Parcel Service, Inc.	STMW	Tributary to Spring Creek	Active	ND	Unknown
Discharge	University Park Airport	STMW	Spring Creek and Buffalo Run	Active	ND	Unknown
Discharge	Upper Spring Creek Fish Culture Station	INDWW	Spring Creek	Active	.576	Yes

Ground Water

Ground water is important in the Spring Creek Basin because it is the source of most water supplies and it sustains the high-quality cold-water streamflow in Spring Creek. Wells and springs where characteristics of the ground-water system have been collected are shown in figure 16. The available data include drilling logs, water levels, and water-quality data, which have been partly compiled in Appendixes 1 and 2.

Aquifer Properties

Values for transmissivity and storativity were calculated from aquifer tests in the Spring Creek Basin. References for the aquifer-test data include Siddiqui (1969), Parizek and others (1971), Nittany Geoscience Inc. (1988a, 1988b, 1990, 1991a, 1991b, 1991c, 1992a, and 1992b), Parizek (2000), and several internal papers from the Pennsylvania State University Office of Physical Plant (John Gaudlip, written commun., 2003).

Transmissivity and storativity values are presented in figure 17 and table 15 for wells where sufficient documentation of the aquifer test was available. The range of transmissivity values for the Gatesburg Formation, the most productive carbonate-rock aquifer, is from about 40 to 35,000 ft^2/d. The transmissivity values determined for the Bellefonte and Nittany Formations range from about 2 to 4,800 ft^2/d, which are generally less than values of the Gatesburg Formation. Only two transmissivity values are presented in table 15 for the siliciclastic-rock aquifer, 9 and 30 ft^2/d, which are from the Reedsville Formation.

Insight into the anisotropic conditions in the carbonate-rock aquifers was provided by Siddiqui (1969) using analysis of boundary conditions and image-well calculations for many of the aquifer tests. Anisotropy with respect to hydraulic conductivity caused by fractures and faults oriented along the strike of beds is probably a major influence on the area of influence and source of water to wells withdrawing water from the carbonate-rock aquifers in the valleys. The hydraulic conductivity along strike in the valleys has been estimated to be three to eight times greater than the hydraulic conductivity in the dip direction (Giddings and Associates, 1995).

Well yields and specific-capacity data can be used to provide estimates of aquifer hydraulic conductivity and insights into factors affecting its magnitude. Siddiqui (1969) and Siddiqui and Parizek (1971) related well yields in the Spring Creek Basin to six hydrogeologic factors: bedrock lithology, dip of strata, topographic setting, depth of water table, proximity of wells to anticlinal or synclinal axes, and location of the wells with respect to fracture traces or concentrations of fracture zones. The researchers evaluated productivity of the wells, defined as adjusted specific capacity per foot of prepumping saturated thickness. Results showed that wells on or near fracture traces were more productive than wells removed from fracture traces. The median productivity for wells near fracture traces was 0.079 (gal/min)/ft compared to a median productivity of 0.0014 (gal/min)/ft for wells removed from fracture traces. Wells completed in sandy and coarse-grained dolomites, such as the Gatesburg Formation, were the best producers (median productivity was 0.12 (gal/min)/ft for the upper sandy member of the Gatesburg Formation); wells tapping the Nittany Formation had the second highest productivity (0.068 (gal/min)/ft). Although no wells were analyzed that penetrated highly cavernous limestone beds, rocks with significant secondary and primary intergranular porosity and permeability, such as the sandy dolomite rocks, were the best producers.

Other conclusions indicated by the work of Siddiqui (1969) and Siddiqui and Parizek (1971) were:

- Wells in valley bottoms were more productive than wells in valley slopes or uplands. (The carbonate rocks of high primary and secondary permeability are all in the valleys.)
- Wells near anticlinal axes were more productive than wells near synclinal axes.
- Wells in bedrock that dip less than 15° had higher yields than wells in bedrock with steeper dips.
- Wells with varying depth to water table were not significantly different, but the highest well yields were associated with the deepest and shallowest water table. (Depth to the water table for wells open to the Gatesburg Formation commonly is greater than 100 ft and can be more than 400 ft.)

Few calculations of storage values have been made in the Spring Creek Basin. Storativity values reported from a few aquifer tests for State College Borough Water Authority wells ranged from 0.0003 to 0.00072 for wells open to the upper sandy member of the Gatesburg Formation. Specific yields were calculated as about 1.5 percent for the entire Spring Creek Basin that is underlain by 80 percent Cambro-Ordovician carbonate rocks and 20 percent Ordovician fine-grained limestones, sandstones, and shales (Giddings, 1974). The Gatesburg Formation alone is estimated to have a specific yield of 3 to 5 percent (Parizek and others, 1971). Specific yield for the Ordovician mostly fine-grained limestones, sandstones, and shales, including the residual soils, colluvium, and stream alluvium in the Nittany Valley area, was calculated by Konikow (1969) to range from 1 to 2.5 percent.

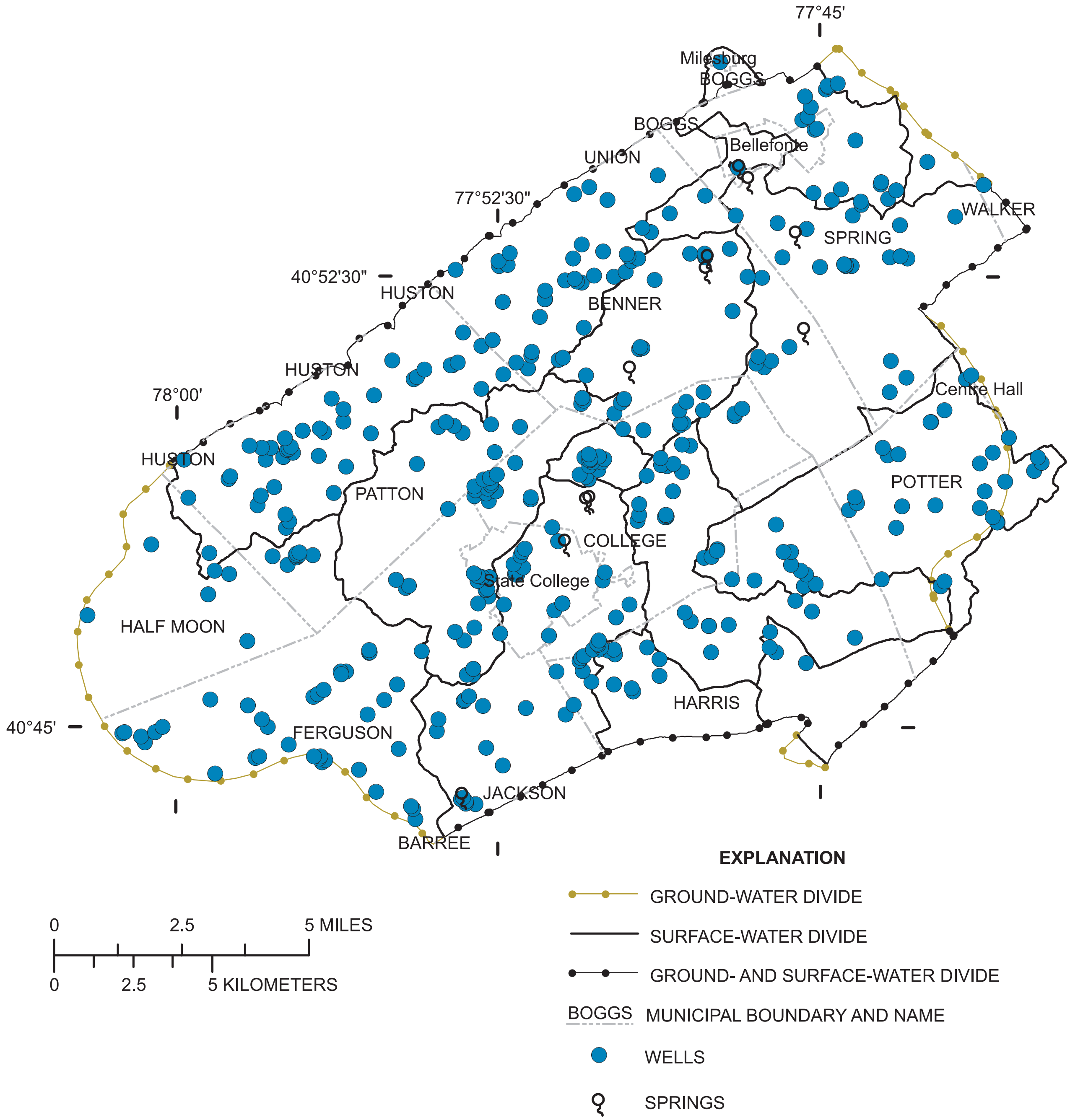


Figure 16. Locations of selected wells and springs in the Spring Creek Basin, Centre County, Pennsylvania.

Table 15. Transmissivity and storativity values for the carbonate- and siliciclastic-rock aquifers in the Spring Creek Basin, Centre County, Pennsylvania (from Siddiqui, 1969; Parizek and others, 1971; Nittany Geoscience Inc., 1988a, 1988b, 1990, 1991a, 1991b, 1991c, 1992a, 1992b; Parizek, 2000; and John Gaudlip, Pennsylvania State University, Office of Physical Plant, written commun., 2003)

[ft^2/d, feet squared per day; ---, more than one value; nd, no data; —, only one value; Note, anisotropy ratios (Kx/Ky) vary from 4 to 8]

Local well number	Aquifer	Transmissivity, (if only one value reported) (ft^2/d)	Transmissivity, minimum, (ft^2/d)	Transmissivity, maximum, (ft^2/d)	Storativity
434	Bellefonte Formation	---	275	549	nd
420	Bellefonte Formation	---	8	23	nd
421	Bellefonte Formation	---	26	66	nd
422	Bellefonte Formation	---	724	1,340	nd
432	Bellefonte Formation	---	637	1,206	nd
442-A	Bellefonte Formation	---	13	34	nd
433	Bellefonte Formation	---	2	8	nd
425	Bellefonte Formation	---	174	359	nd
426	Bellefonte Formation	---	39	96	nd
401	Nittany Formation	---	80	177	nd
402	Nittany Formation	---	19	49	nd
SC-22	Nittany Formation	4,783	—	—	nd
SC-24	Nittany Formation	2,358	—	—	nd
SC-25	Nittany Formation	708	—	—	nd
297	Reedsville Formation	---	13	30	nd
399	Reedsville Formation	---	9	24	nd
SC-63	upper sandy member, Gatesburg Formation	1,822	—	—	0.00060
SC-64	upper sandy member, Gatesburg Formation	746	—	—	.00051
SC-65	upper sandy member, Gatesburg Formation	4,878	—	—	.00030
SC-19	lower sandy member, Gatesburg Formation	14,472	—	—	nd
SC-17	lower sandy member, Gatesburg Formation	34,974	—	—	nd
SC-78	Mines Member, Gatesburg Formation	4,109	—	—	nd
UN-2	upper sandy member, Gatesburg Formation	---	4,355	7,705	nd
413	upper sandy member, Gatesburg Formation	---	1,702	3,082	nd
UN-25	upper sandy member, Gatesburg Formation	---	224	462	nd
UN-3	upper sandy member, Gatesburg Formation	---	4,824	8,509	nd
UN-16	upper sandy member, Gatesburg Formation	---	851	1,568	nd
UN-17	upper sandy member, Gatesburg Formation	---	3,980	7,102	nd
UN-20	upper sandy member, Gatesburg Formation	---	42	99	nd
UN-24	upper sandy member, Gatesburg Formation	---	5,762	10,050	nd
SC-5	upper sandy member, Gatesburg Formation	---	14,606	24,924	nd
UN-14	upper sandy member, Gatesburg Formation	---	2,251	4,087	nd
SC-55	upper sandy member, Gatesburg Formation	1,876	—	—	.00049
SC-57	upper sandy member, Gatesburg Formation	1,876	—	—	.00049
SC-62	upper sandy member, Gatesburg Formation	32,294	—	—	.00072

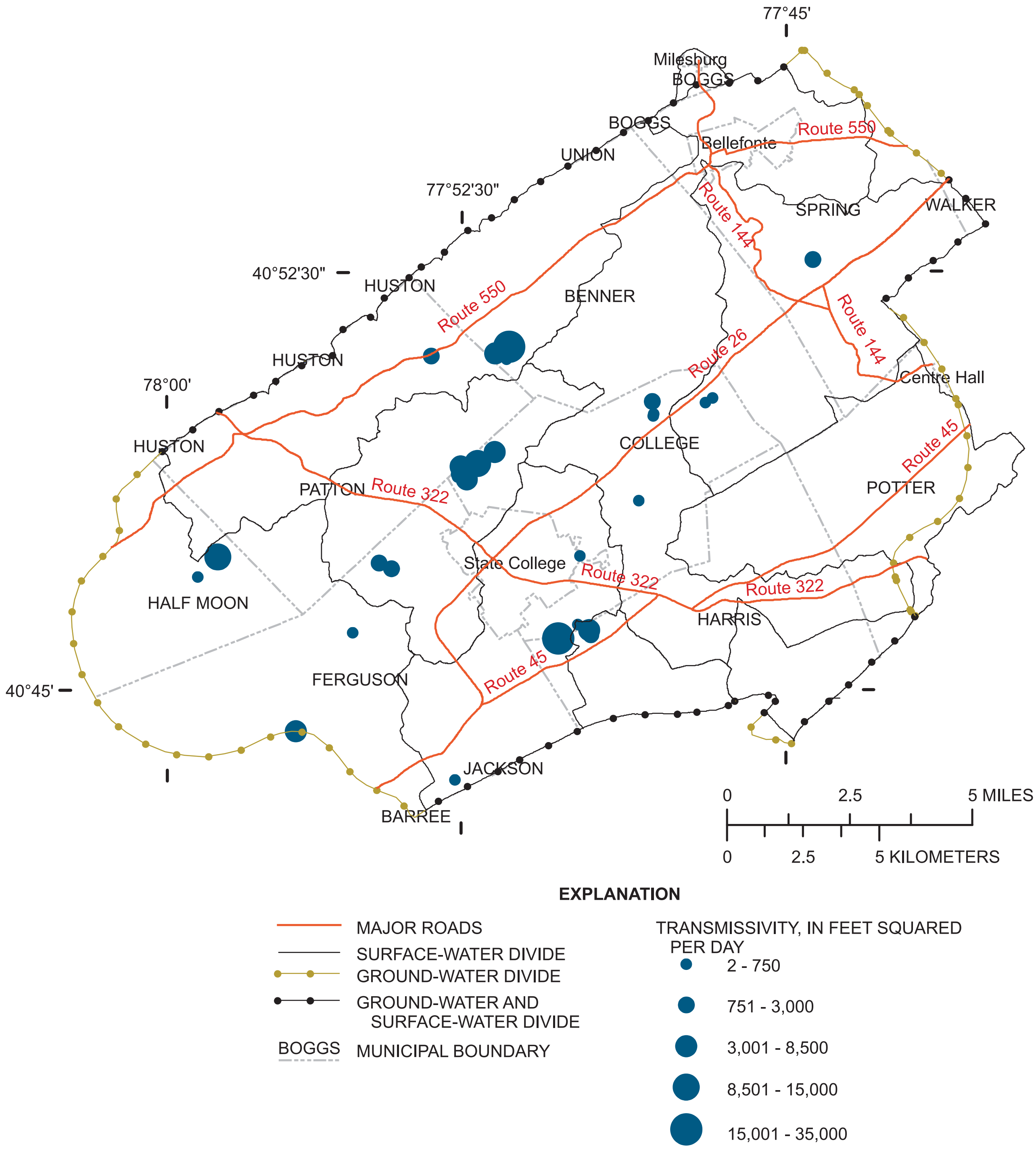


Figure 17. Transmissivity values determined from aquifer tests in the Spring Creek Basin, Centre County, Pennsylvania.

Water Levels

The maps of Giddings (1974), Wood (1980), and Taylor (1997) show the configuration of the water table in the Spring Creek Basin. Giddings (1974) showed that the extent of the ground-water basin was distinct from the extent of the surface-water drainage basin of Spring Creek (fig. 18) on the basis of water levels from a network of more than 125 observation wells during March 1969. Wood (1980) enhanced the Giddings' water-table map by adding water-level data from wells beyond the ground-water basin boundary to better define the ground-water basin boundary; however, the data from beyond the boundary were collected after March 1969. Taylor (1997) delineated the extent of the ground-water basin from water levels measured at 254 wells in October 1994, although some water-level data are from time periods prior to October 1994 (fig. 19). Taylor delineated a ground-water basin area smaller than Giddings (1974) by about 10 mi^2 (about 165.6 mi^2). The reason for the difference is probably that the ground-water divide is dynamic and influenced by precipitation. Two areas were identified where the ground-water basin is significantly different from the surface-water basin: the southwestern part of the area, which includes the barrens northeast of Half Moon Creek and the region north of Fairbrook, and a smaller area south of Centre Hall. The locations of these discrepancies correlate with the presence of plunging anticlines in the bedrock. The ground-water basin appears to be larger than the surface-water basin where the direction of anticlinal plunge is toward the Spring Creek Basin, and smaller where the opposite occurs. Other factors, such as bedrock permeability, also must have an influence on the boundary of the ground-water basin (Taylor, 1997).

Wells and Springs

In the Spring Creek Basin, ground water principally discharges to streams and springs. Many of the streams in the Spring Creek surface-water basin are intermittent or disappearing streams that reappear because of discharge from springs. The locations and yields of several large springs are shown in figure 20. Many of the spring locations are aligned with the strike of the rocks in the valley. A number of the larger yielding springs in the basin have been used as water sources by public water suppliers, and water withdrawals average about 6.9 Mgal/d. An inventory of spring-water withdrawals for public use is presented in table 16. Domestic and industrial users also withdraw spring water, but records of these withdrawals are not available.

Table 16. Inventory of water withdrawals for public use from springs in the Spring Creek Basin, Centre County, Pennsylvania.

Spring name	Local well number	Use	Establishment name	Reported average use (million gallons per day)	Year reported
Bathgate #1 Spring	CE SP2	Public supply	Lemont Water Company	0.089	1994
Bathgate #2 Spring	CE SP27	Public supply	Lemont Water Company	.089	1994
Big Spring	CE SP5	Public/commercial supply	Bellefonte Borough Water Authority	5.909	2000
Benner Spring	CE SP16	Public/institutional supply	Rockview State Correction Institute	.524	2000
Axemann Spring	CE SP17	Public supply	Spring Township Water Authority	.149	1994
Unnamed	CE SP15	Public supply	Ferguson Township Authority	.054	1994

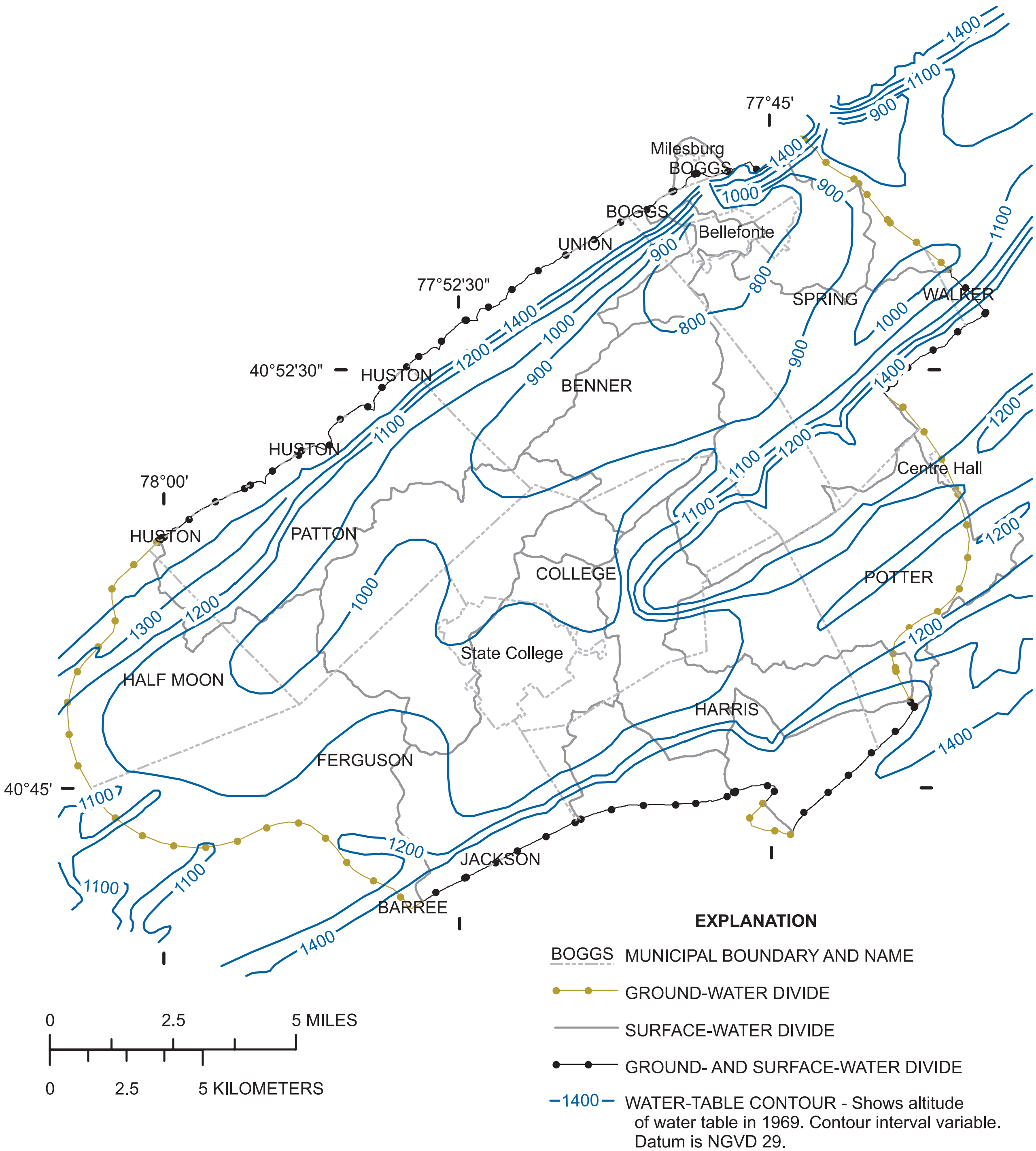


Figure 18. Water-table map of the Spring Creek Basin, Centre County, Pennsylvania, 1969 (from Wood, 1980). The ground-water divide (from Giddings, 1974) does not agree with water-table contours in some areas because additional water-level data were obtained by Wood (1980).

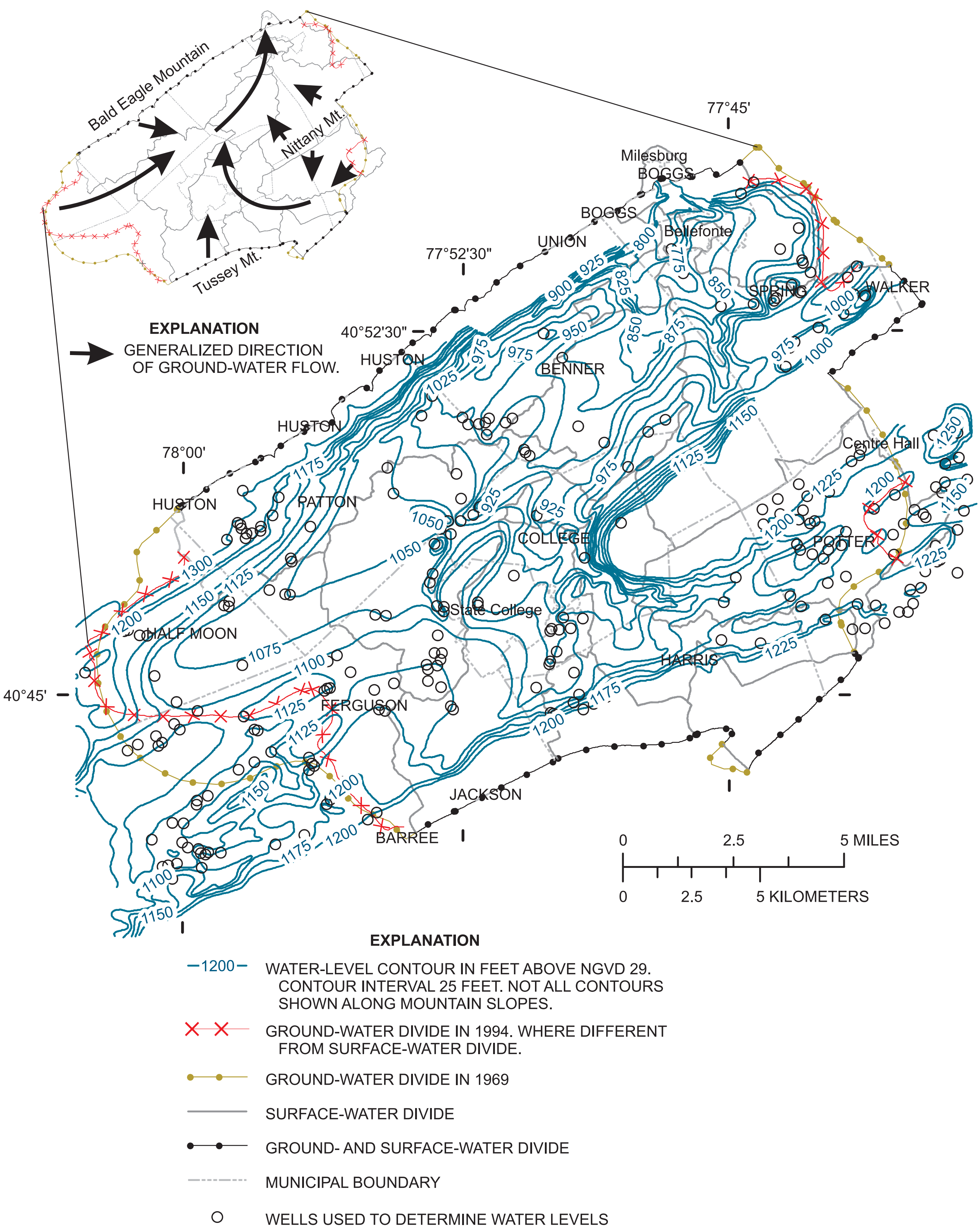


Figure 19. Water-table map of the Spring Creek Basin, Centre County, Pennsylvania, and generalized direction of ground-water flow, 1994 (from Taylor, 1997).

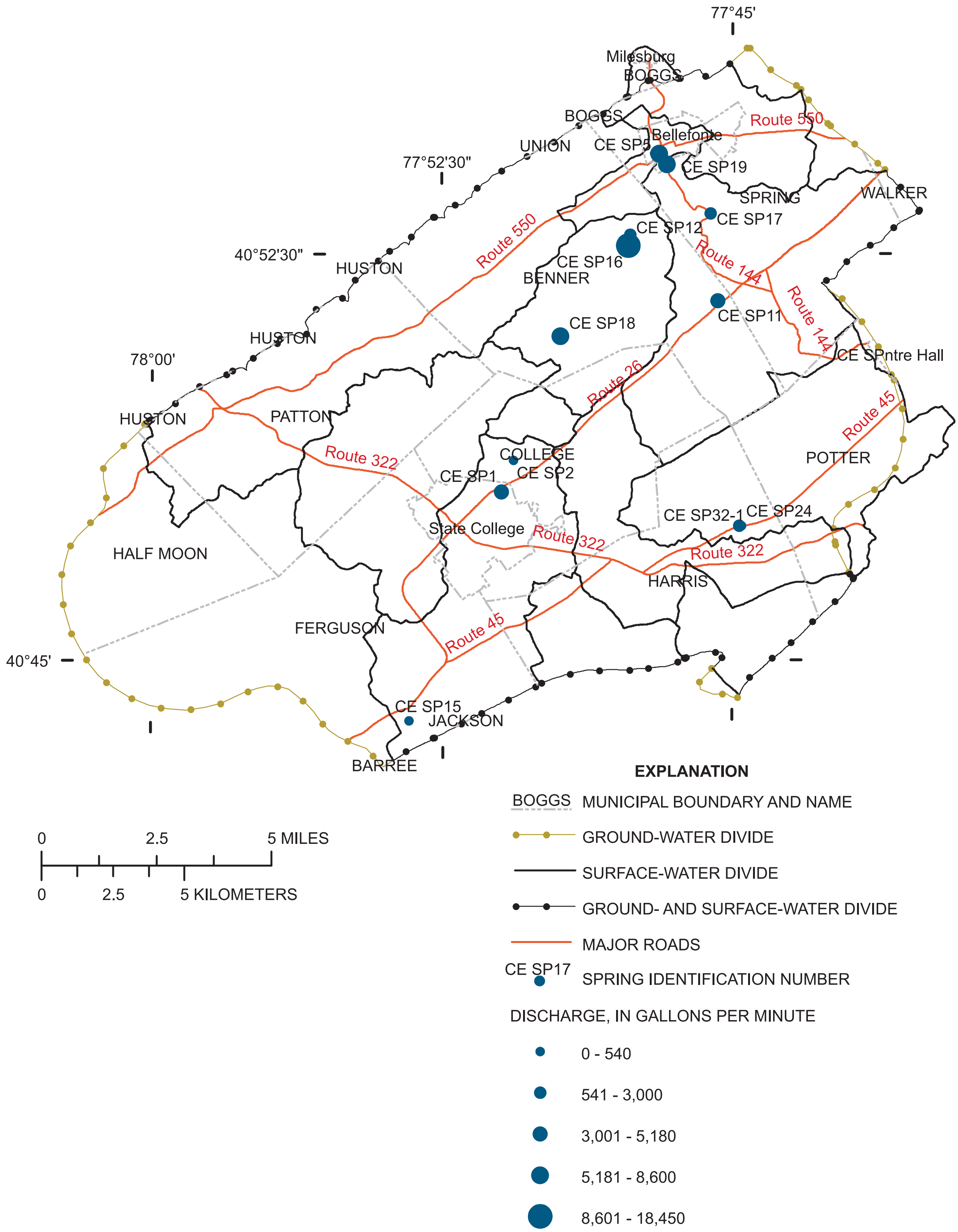


Figure 20. Location and average discharge of major springs in the Spring Creek Basin, Centre County, Pennsylvania (data from Saad and Hippe, 1990; Pennsylvania Department of Environmental Protection, written commun., 2004).

Big Spring, in Bellefonte, has the greatest average discharge rate in the ground-water basin at about 19 Mgal/d, and 5.9 Mgal/d of that is withdrawn for water supply. This spring is downslope in the valley from the Birmingham Thrust Fault. The discharge rate from 1986 to 2003 is plotted in figure 21. The weir used to determine the discharge rate was improved in 2002, which accounts for the increase in measured discharge.

Springs that discharge from limestone and dolomite have been classified into two types by Shuster and White (1971). In diffuse springs, water flows at low velocities along joints, fractures, and bedding planes, which are generally less than 1 in. wide. In conduit springs, the flow commonly is turbulent and is through solution openings ranging from 1 in. to 10 ft in diameter. The conduit-flow springs respond quickly to precipitation (a few days), and the diffuse-flow springs respond more slowly (days to months) to precipitation (Wood, 1980).

Ground-water withdrawals for public supply have been increasing in Spring Creek Basin over the past 22 years (fig. 22). The pumpage shown includes average annual ground-water withdrawal rates available from State College Borough Water Authority during 1980-2002, from the Pennsylvania State University during 1994-2002, and from College Township only during 2000-02 (Max Gill, State College Borough Water Authority, written commun., 2003; John Gaudlip, Pennsylvania State University, written commun., 2003; Gary Williams, College Township, written commun., 2003). These withdrawal data are for public supply only and are presented in table 17. Ground-water withdrawals for private supply have not been compiled. Ground-water withdrawals for industrial or manufacturing use may not all be included in the public-supply numbers.

Table 17. Average annual base flow of Spring Creek at Milesburg, Pennsylvania, 1968-2002, and average annual ground-water withdrawals from public supply wells in the Spring Creek Basin, 1980-2002 (from (Max Gill, State College Borough Water Authority, written commun., 2003; John Gaudlip, Pennsylvania State University, written commun., 2003; Gary Williams, College Township, written commun., 2003).

[Mgal/d, million gallons per day; na, data not available]

Year	Annual base flow (Mgal/d)	Average yearly pumpage rate (Mgal/d)
1968	88.0	na
1969	72.9	na
1970	116.6	na
1971	111.9	na
1972	136.1	na
1973	140.6	na
1974	126.2	na
1975	137.1	na
1976	139.3	na
1977	141.2	na
1978	158.0	na
1979	165.8	na
1980	131.0	3.1
1981	109.4	2.4
1982	134.0	2.4
1983	124.8	2.8
1984	159.7	2.8
1985	124.6	2.8
1986	114.4	3.0
1987	115.3	3.1
1988	98.4	4.6
1989	124.4	4.6
1990	137.2	4.4
1991	119.4	4.4
1992	97.4	4.4
1993	146.6	5.1
1994	154.7	5.6
1995	112.0	5.1
1996	168.5	5.2
1997	136.1	6.1
1998	155.8	5.1
1999	103.7	7.0
2000	103.8	8.3
2001	92.8	8.9
2002	105.0	9.1

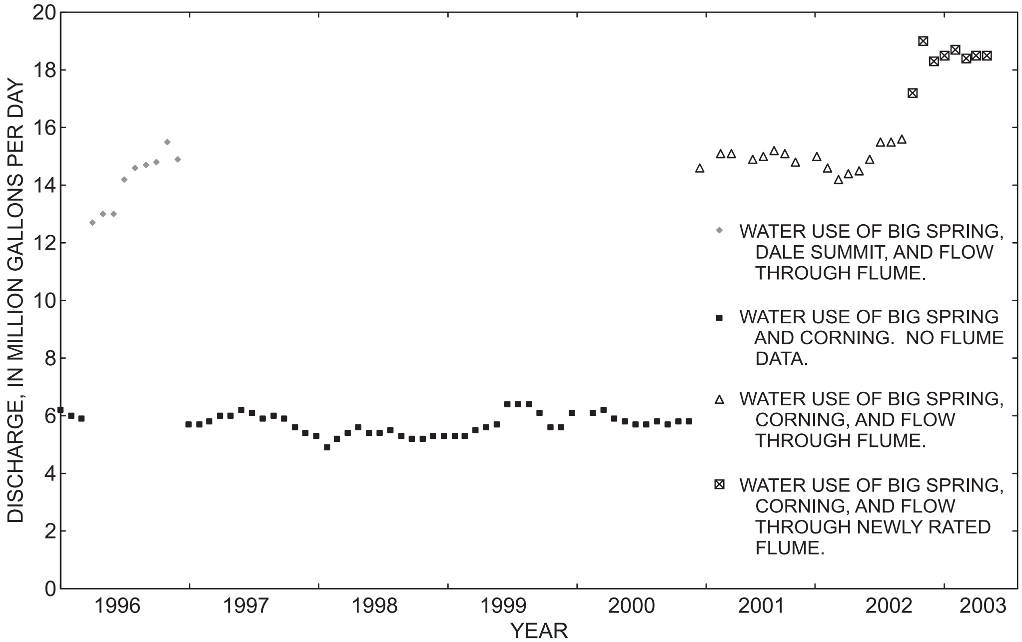


Figure 21. Discharge at Big Spring in Bellefonte, Pennsylvania (1996-2003) (from Ralph Stewart, Bellefonte Borough, written commun., 2003).

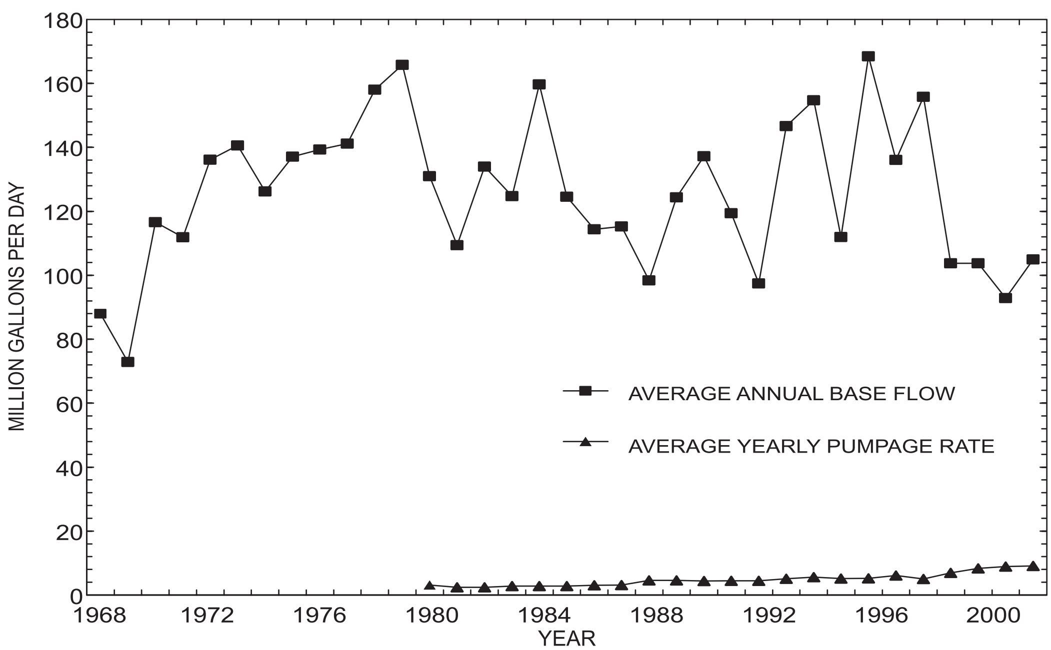


Figure 22. Average annual rate of ground-water withdrawals for public supply and average annual base-flow rate at Milesburg for Spring Creek Basin, Centre County, Pennsylvania. (The pumpage includes average annual ground-water withdrawal rates available from State College Borough Water Authority during 1980-2002, from the Pennsylvania State University during 1994-2002, and from College Township during 2000-2002.)

The ground-water withdrawals have increased from about 3 Mgal/d to over 9 Mgal/d in 2002. Because of the lack of withdrawal data prior to 1994, withdrawals shown for pre-1994 are incomplete estimates of total withdrawals. The withdrawals are only about 7 percent of average ground-water recharge rate estimated at 125 Mgal/d. Although the pumpage will result in lowered water levels locally, the total withdrawals are small compared to total recharge rates. The total allocations of the water-supply companies and authorities may result in a larger percentage of the recharge being used for supply. During years of low precipitation, such as 1969, 1968, and 2001, the ground-water recharge was much less (73, 87, and 92 Mgal/d, respectively). The rate of ground-water withdrawal for 2001 (about 8.9 Mgal/d) was 9.6 percent of the average base flow of 2001. As ground-water withdrawal rates increase, the percentage of recharge extracted for supply will increase, and in future drought years, the percentage of base flow used for water supply could be larger than at present. The effects of increased percentage of recharge used for supply during future drought years would result in lowering of water levels below present levels, and the recovery of water levels in deep ground-water-flow systems, such as in the Gatesburg Formation, may take much more time than current recovery of water levels in nondrought years.

The timing of the withdrawals can have a notable effect on water levels, and there is a seasonal pattern to the ground-water withdrawals, as shown in figure 23. The withdrawals are greatest in the summer and probably reflect greater usage of water for irrigation and recreation. During the summer, the water-level declines would be greater than in winter months because of increased pumpage and also because of greatly reduced recharge when evapotranspiration is high.

The pumpage in the Spring Creek Basin is distributed throughout much of the study area but is concentrated in the vicinity of State College and farther west in Nittany Valley where the productive Gatesburg Formation aquifer is present. The 2002 average annual pumpage rates for public supply are illustrated in figure 24.

Water Quality

Water-quality data for the Spring Creek Basin have been collected at various locations and for various constituents for more than 50 years. The PaDEP, the SCWC, and the USGS have accumulated the most comprehensive databases. Other water-quality data have been collected by various water users, dischargers, and students at the Pennsylvania State University. Water-quality data of interest include surface- and ground-water physical and chemical characteristics. Water-quality data from spring discharges are also of importance because of the large contribution to surface-water discharge from springs in the Spring Creek Basin. A summary of the water-quality data is presented in table 18 (at the back of the report).

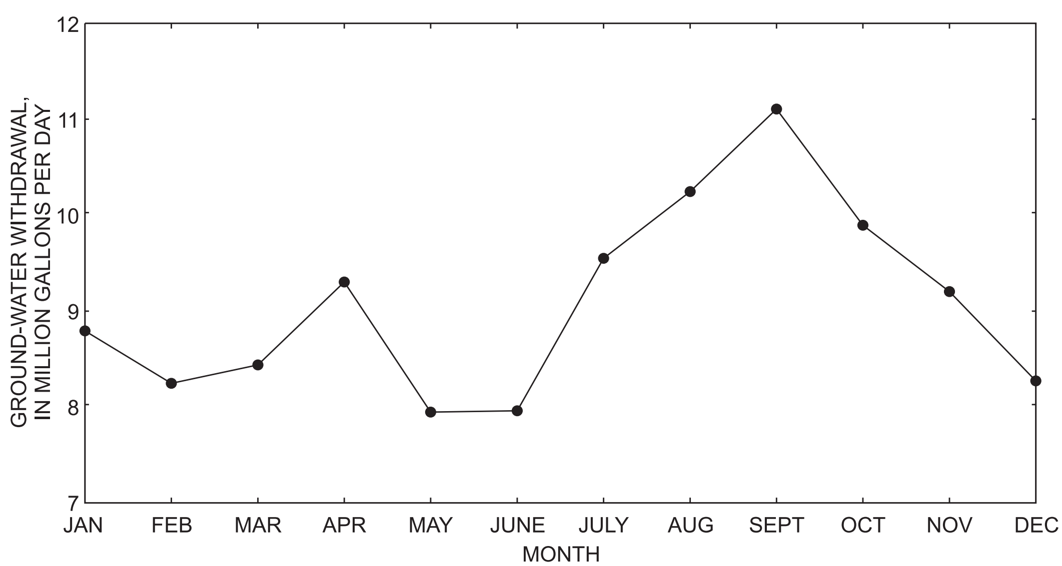


Figure 23. Average monthly ground-water withdrawals for public supply in Spring Creek Basin, Centre County, Pennsylvania, 1980-2002.

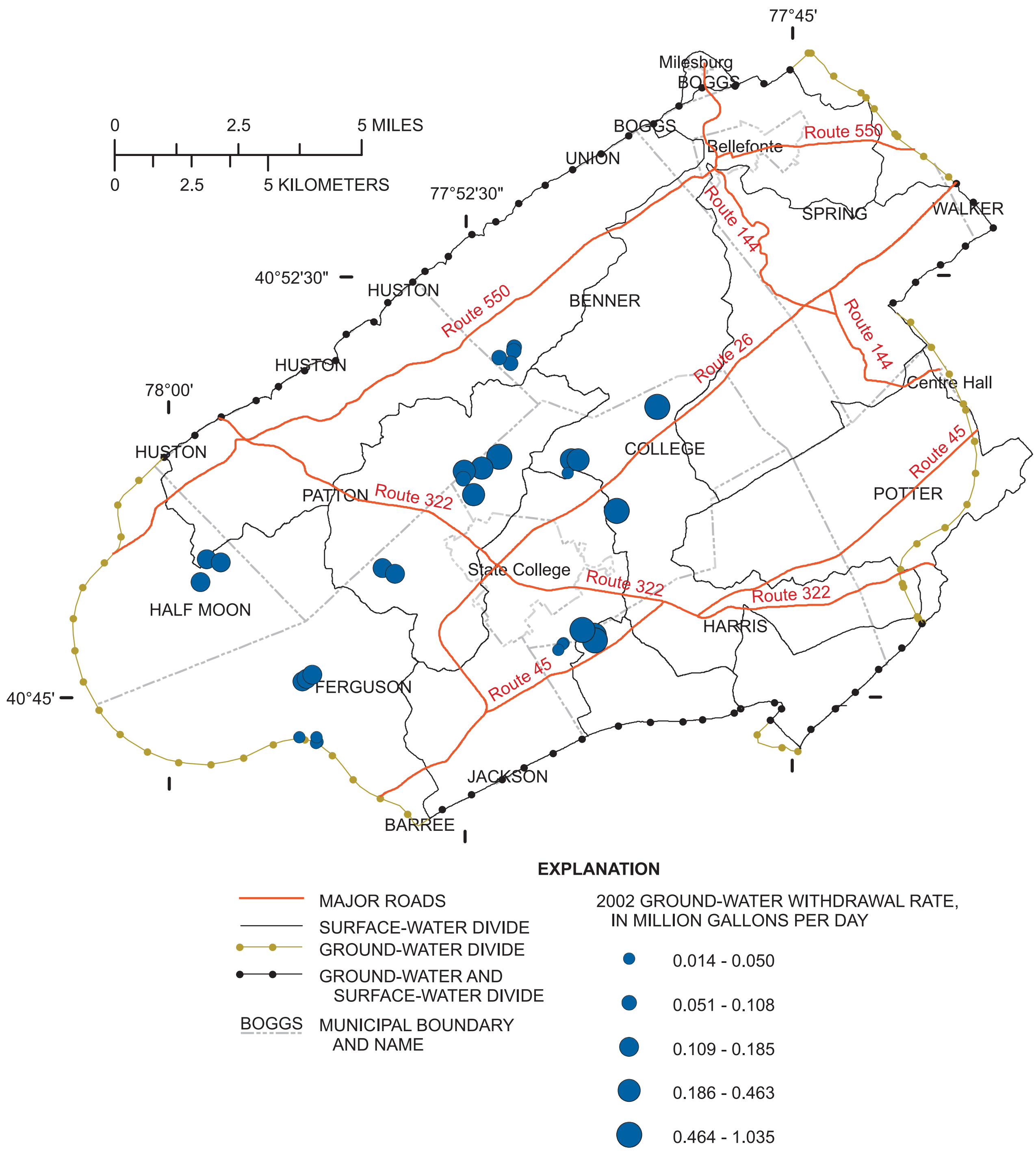


Figure 24. Ground-water withdrawal rates for public supply wells in Spring Creek Basin, Centre County, Pennsylvania, 2002.

Surface Water

Surface-water-quality data for Spring Creek Basin include synoptic (collected as simultaneously as possible) data and periodic sample data. These data include physical and chemical water-quality characteristics from 12 locations in the basin (table 18).

The longest period of record exists for the site on Spring Creek near Axemann, Pa. Since 1950, the PaDEP has sampled this site (WQN415) on a regular schedule as part of their Water Quality Network (WQN). WQN415 is collocated with USGS streamflow-gaging station 01546500 (fig. 14). Water quality at this site also has been sampled by the SCWC (site SPA) and the USGS. The suite of constituents sampled has changed over time. An inventory of current (2003) and historical water-quality data at this site is listed in table 19 (at the back of the report).

Beginning in 1999, the SCWC began collecting comprehensive water-quality data at 12 locations in Spring Creek Basin. Six of these sites are collocated with existing streamflow-gaging stations operated by the Pennsylvania Cooperative Fish and Wildlife Research Unit or by the USGS. An inventory of the constituents sampled is listed in table 19 and is the same for all 12 sites.

The USGS has collected a limited amount of surface-water-quality data in the basin. All but a few random samples have been collected from Spring Creek near Axemann, Pa. (USGS streamflow-gaging station 01546500) (table 19).

Ground Water

Water-quality data contained in the USGS database for wells in the Spring Creek Basin are listed in tables 20 through 24 (at the back of the report). Water-quality data for selected springs are shown in table 25 (at the back of the report). Thirty of the 41 wells are open to the carbonate-rock aquifers and 4 are screened in siliciclastic-rock aquifers. The water-quality data have not been correlated to the aquifer type.

As expected from ground-water samples from carbonate-rock aquifers, calcium, magnesium, and bicarbonate concentrations and pH values are high relative to concentrations in ground water from siliciclastic-rock aquifers. Nitrate concentrations range from 0.05 to 12.7 mg/L; the mean and median concentrations are 3.7 and 3.5 mg/L, respectively. Two of the wells sampled contained nitrate concentrations greater than 10 mg/L, the maximum contaminant level permitted by the U.S. Environmental Protection Agency drinking-water regulations (U.S. Environmental Protection Agency, 2002). Radon was reported in one well. Samples from three wells were analyzed for organic pesticides. Acifluorfen, alachlor, atrazine, deethyl atrazine, metalochlor, prometon, and simazine were detected in the water from at least one well and some of the organics were detected in all three wells. Samples from three wells were analyzed for *Escherichia coli*, enterrococci, and fecal streptococci bacteria, and water from two of the three wells contained bacteria colonies.

The PaDEP has investigated the presence of Perchloroethylene (PCE) in the State College area (Randy Farmerie, Pennsylvania Department of Environmental Protection, written commun., 2004). Since the mid-1980s, PCE has been found in several springs in the State College area at concentrations ranging from 5 to 50 ∝g/L. PCE also has been found in four water-supply wells in the State College area at concentrations ranging from 1 to 8 ∝g/L. In the summer of 2002, the PaDEP drilled six observation wells to monitor the PCE and try to determine the source of the contamination, but only one well showed a very low concentration of PCE and the other five wells showed no PCE.

Conceptual Hydrologic Model of Spring Creek Basin

A conceptual model is a simplified representation of the hydrologic system that is to be modeled (Anderson and Woessner, 1992). Karst conceptual models are physical in nature and describe the hydrologic connectivity between recharge areas, hydraulic properties, and geology that controls the way in which water is added, stored, conveyed, and discharged through the system (White, 2003). Because of the variability in land use and the hydrologic complexity of the Spring Creek Basin, the conceptual model must consider the integration of surface water and ground water to (1) account for the physical exchange of water, and (2) identify the processes that influence source (recharge) and sink (water use) terms within a basin. This simplification is necessary, because a complete accounting of water is not possible. Traditionally, most hydrologic systems are analyzed as parts, rather than a single entity.

The Spring Creek Basin consists of two principal settings—a forested, siliciclastic-bedrock upland and a carbonate-bedrock valley with agricultural and urban land use (fig. 25). Precipitation, runoff, and infiltration from the uplands provide streamflow and ground-water recharge to the valley. The conceptual model for the Spring Creek Basin can be described by the processes of precipitation, runoff, infiltration, and streamflow that are common to the hydrology of the siliciclastic-bedrock upland and of the carbonate-bedrock valley. These concepts are discussed below and illustrated in figure 26.

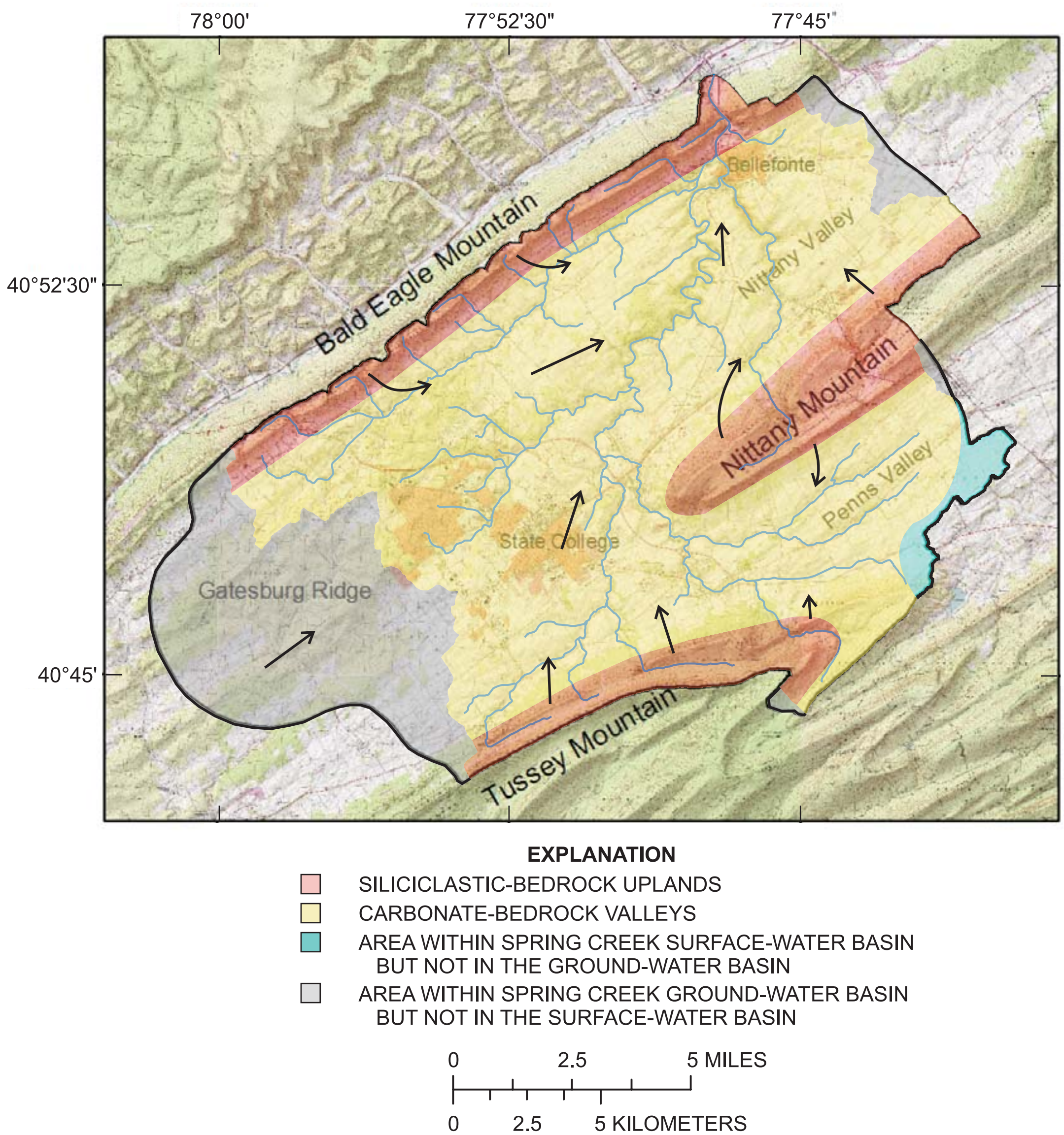
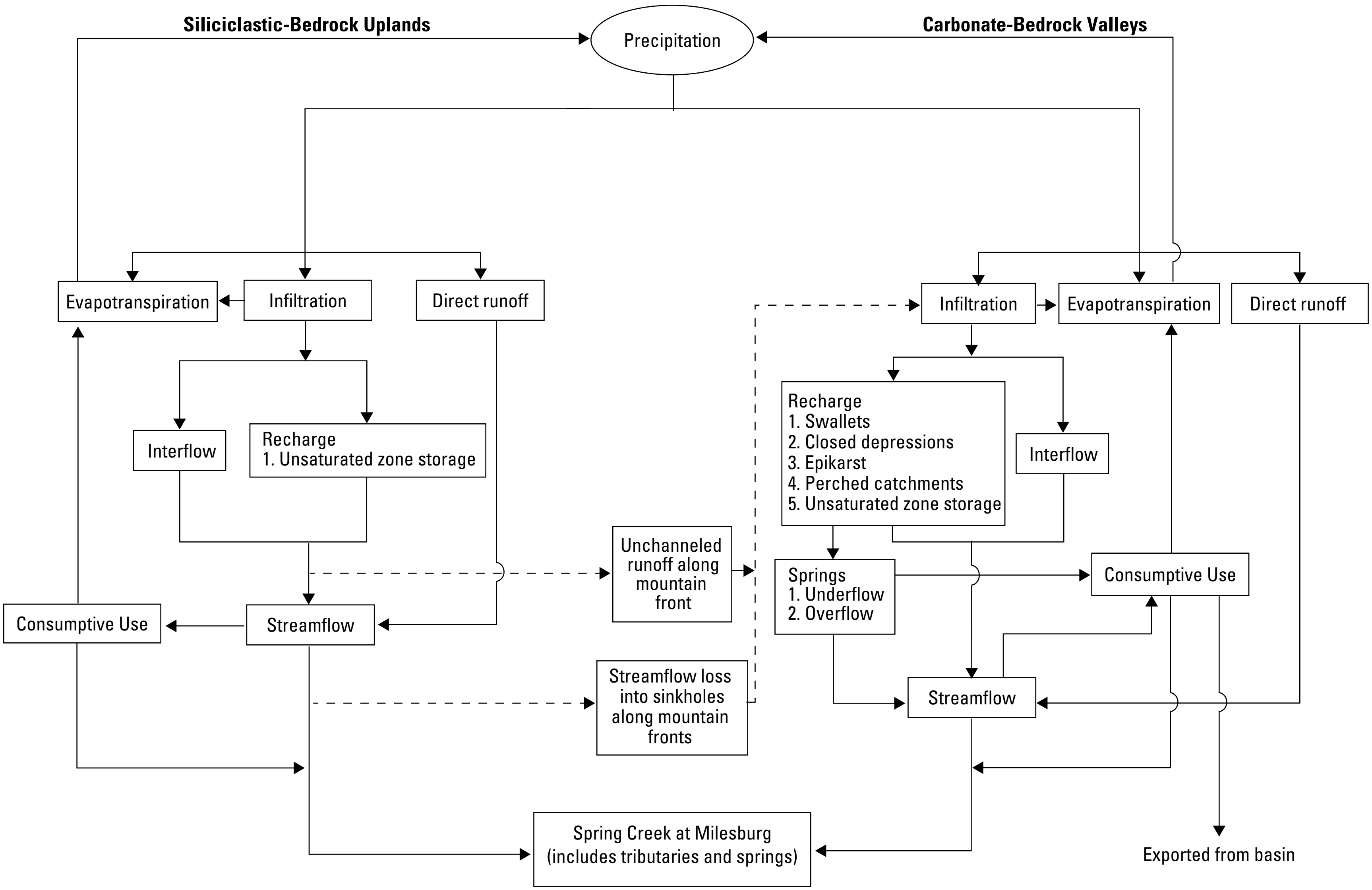


Figure 25. Major hydrologic settings, boundaries, and generalized direction of ground-water movement in Spring Creek Basin, Centre County, Pennsylvania.



EXPLANATION

- - - - - EXCHANGE BETWEEN UPLANDS AND VALLEYS

Figure 26. Water-budget components showing exchange of water from siliciclastic-bedrock uplands to carbonate-bedrock valley.

Precipitation, Runoff, Infiltration, and Streamflow

To conceptualize the hydrology of a basin, the relation between precipitation and runoff must be established. From a water-balance perspective, it is important to understand the mechanics of how a basin responds to a precipitation event and how streamflow is generated. This is particularly true in the case of the Spring Creek Basin, where the geology, topography, land use, soil cover, and vegetation are extremely variable from one subbasin to another.

The three components that contribute to streamflow include overland runoff, subsurface stormflow, and ground-water flow. For the purposes of this section, only overland runoff and subsurface stormflow are discussed below. Ground-water contributions in the form of recharge and discharge will be addressed in the siliclastic-bedrock upland and carbonate-bedrock valley sections that follow.

Overland runoff is the product of either (1) infiltration excess associated with a rainfall event where its intensity exceeds the infiltration capacity of the soil or (2) saturation excess where the soil above the water table or perched surface becomes completely saturated and any additional precipitation produces runoff. The former is known as partial source-area contributions (PSAc) and the latter as variable source-area contributions (VSAc) It is rare that overland runoff is created by infiltration excess from vegetated cover in humid regions such as the Spring Creek Basin, where vegetation protects the soil from compaction and dispersion from precipitation. As a result, the soil structure is maintained. In contrast, PSAc may develop in areas where impervious cover is prevalent such as Bellefonte, Centre Hall, Milesburg, and State College or in areas where thin soil layers and low infiltration capacities dominate such as the Hagerstown-Opequon-Hublersburg, Murrill, and Opequon-Hagerstown soil groups, common to Nittany and Penns Valleys. PSAc are fixed spatially and are reorganized as areas within the basin that regularly contribute overland runoff.

Saturation excess related to VSAc occurs when the unsaturated zone is not capable of transmitting subsurface stormflow (interflow), and the soil becomes saturated. If the rate of subsurface stormflow entering a saturated area from upslope exceeds its capacity to be transmitted, the excess stormflow returns to the surface as runoff. As precipitation continues, the saturated area grows in extent, increasing the area capable of generating runoff (Cornell University, Soil and Water Laboratory, 2005). VSAc tend to expand and contract depending on the intensity and duration of saturation. Runoff originates from small areas within a basin, which constitute no more than 10 percent and often as little as 1 to 3 percent of the total basin area (Freeze and Cherry, 1979).

VSAc saturation excess is common in regions such as the Spring Creek Basin that are humid and possess soils that are thin, are well vegetated with large infiltration capacities, and are underlain by low-permeability layers (bedrock and fragipan). Subsurface flow (lateral flow within the unsaturated zone) above the water-table surface also supplies water to streamflow. Typically, runoff forms adjacent to drainage ways (near converging topography), stream banks, shallow water tables, and at the bottom of hill slopes such as Galbraith Gap Run, Logan Bald Eagle, and Roaring Run. These saturated areas expand along hollows or where the water table is close to the ground surface (Larry Fennessey, Sweetland Engineering and Associates, written commun., 2005).

To quantify VSAc runoff, the following parameters are needed: rainfall intensity and duration, unsaturated zone thickness, available water-storage capacity, depth to bedrock, soil hydraulic properties, water table or perched water depth, hydrology of the upland-subbasin area, and local topography.

The eight subbasins within the Spring Creek surface-water basin differ relative to their underlying geology, soil, slope, vegetation cover, infiltration rate, and the distribution of rainfall (intensity, duration, and depth). As a result, processes associated with streamflow generation can be complex and different for each subbasin.

For example, subbasins such as Galbraith Gap Run, Logan Run, and Roaring Run are well vegetated, are located along steep slopes, and possess soil mantles that are thin with high infiltration capacities. Runoff from these subbasins is produced when subsurface flow saturates the soil above the water-table surface near the bottom of hill slopes and near streambanks as precipitation continues to fall on saturated soil.

Streamflow is produced by overland runoff and subsurface stormflow. The exchange of water within the channel and the underlying aquifer system must be established to provide a proper accounting of the water budget for the Spring Creek Basin. This is particularly true in subbasins that have permanent streams within gaps (Buffalo Run, Roaring Run, and Galbraith Gap Run) and receive mountain runoff. Water within the streams may be lost by infiltration through the streambed. Streamflow is discharged directly to sinkholes or flows into tributaries to Spring Creek. Depending on the hydraulic head differences between the underlying aquifer and the surface-water elevation, the exchange could be substantial.

Siliciclastic-Bedrock Uplands

The siliciclastic-bedrock uplands within the Spring Creek Basin include Bald Eagle (headwaters of Buffalo Run), Nittany Mountain (headwaters of Cedar Run and Logan Branch), and Tussey Mountain (headwaters of Slab Cabin Run, Roaring Run, and Galbraith Gap Run) (fig. 25). The uplands were formed from erosion-resistant sandstones of Ordovician and Silurian age. Owing to their rugged topography, the uplands are predominantly forested.

Hydrologic Boundaries

The siliciclastic-upland ridge lines form the physical and hydrologic boundaries of the Spring Creek Basin along its northwestern and southeastern margins. The configuration of the water-table surface beneath these ridges indicates they will act as ground-water divides (figs. 11 and 12). Because the ridges are at significant distances from ground-water withdrawals, the location and orientation of the ground-water divides will be fixed with time and can be conceptualized as no-flow boundaries.

Precipitation on the siliciclastic-bedrock uplands is first intercepted by the forest canopy. Any water not lost to evapotranspiration falls through to the forest floor and is either lost to evapotranspiration, moves overland as direct runoff, or infiltrates to become subsurface interflow or ground-water recharge (fig. 26). Direct runoff is produced by either (1) infiltration excess or (2) saturation excess. Infiltration excess is rare in the vegetated, humid uplands of the Spring Creek Basin except during periods of rain on snow or frozen ground. Saturation excess occurs when the unsaturated zone is not capable of transmitting subsurface stormflow (interflow), and the soil becomes saturated from below, thereby preventing additional infiltration. Direct runoff in upland settings of the Spring Creek Basin is probably generated from variable source areas caused by saturation excess, especially in areas possessing thin soils with large infiltration capacities, and that are underlain by low permeability layers (bedrock and fragipan). Typically, these areas are adjacent to streambanks, near converging topography, and at the bottom of hill slopes.

Water that infiltrates into the soil can move laterally within the unsaturated zone as interflow. It can reemerge on the surface as direct runoff or move in the subsurface until discharging to a nearby spring or stream. The portion of interflow (and direct runoff) not directed to upland streams can move as unchanneled runoff, becoming an important source of recharge to the ground-water system in the carbonate-bedrock valley. In similar upland settings within the glaciated parts of the northeastern United States, unchanneled runoff provides 13 to 57 percent of recharge to valley-fill aquifer systems (Kontis and others, 2004). In the Spring Creek Basin, Konikow (in Parizek and others, 1971, p. 83) identified about one-third of the siliciclastic-bedrock uplands as having slopes where drainage is poorly integrated and unchanneled runoff contributes to the ground-water system of the carbonate-bedrock valley (fig. 27, recharge pathway 4).

Surface Water

Streams in the siliciclastic-bedrock uplands lose part or all of their flow to sinkholes near the margin of the carbonate-bedrock valley. Streamflow lost into sinkholes at the base along the flanks of the mountain ridges provides recharge to the carbonate-rock aquifers (fig. 27, recharge pathway 3). Konikow (1969) showed that although the mountain ridges comprise 22 percent of the Spring Creek Basin, mountain runoff equaled about 33 percent of the total Spring Creek discharge. Thus, the mountain ridges yielded 50 percent more surface water per unit area than the carbonate valleys.

Ground Water

Subsurface water becomes ground-water recharge when it enters the saturated zone at the water table. The water-bearing rocks beneath the uplands are generalized as a fracture-dominated siliciclastic aquifer (Parizek, 1984), which includes all rocks in the Spring Creek Basin of Silurian and Devonian age along with the Juniata, Bald Eagle, and Reedsville Formations of Ordovician age (fig. 28). The water-bearing properties of these ridge-forming siliciclastic rocks were described by Konikow (1969), Wood (1980), and Giddings and Associates (1995); in general, these aquifers are the least productive in the Spring Creek Basin. Most ground-water recharge to the fracture-dominated siliciclastic aquifer probably occurs during periods when evapotranspiration from the forest cover is small (November through May) and the ground is not frozen. Groundwater in the siliciclastic uplands moves downslope through fractures in the bedrock, from areas of high hydraulic head (hilltops) to areas of low hydraulic head (valleys). Most flow is through the shallow highly fractured part of the bedrock aquifer within 200 ft of land surface, though some deep ground-water movement has been hypothesized to depths of up to 1,000 ft within permeable rock units such as the Dale Sandstone Member of the Bellefonte Dolomite (Parizek and others, 1971, p. 61). Ground water ultimately discharges to upland springs and streams or moves as ground-water flow into the carbonate-bedrock valley.

Carbonate-Bedrock Valleys

The carbonate-bedrock valleys within the Spring Creek Basin include Nittany and Penns Valleys (fig. 25), which include the main stem of Spring Creek and its major tributaries. The valleys are formed on carbonate rocks that are less resistant to weathering than the siliciclastic rocks of the uplands. Land use in the valley is predominantly agricultural but in some areas includes residential, commercial, and industrial activities, except for the Gatesburg Ridge, which is mostly forested (fig. 8). The valley is linked hydrologically to the adjacent siliciclastic uplands by runoff and ground-water discharge from the uplands. These provide a substantial amount of streamflow and recharge to the valley, shown schematically in figure 27.

Hydrologic Boundaries

Hydrologic boundaries of the Spring Creek Basin within the carbonate-bedrock valley are more difficult to delineate than in the siliciclastic uplands. It has been well established that the surface-water and ground-water divides are not coincident for the Spring Creek Basin (fig. 25), resulting in surface-water contributions from a basin of about 146 mi^2 and ground-water contributions from a basin of about 175 mi^2. The major differences between divides are in the carbonate-bedrock valley where the divides may differ because of geologic structure and ground-water withdrawals. The largest difference is in the

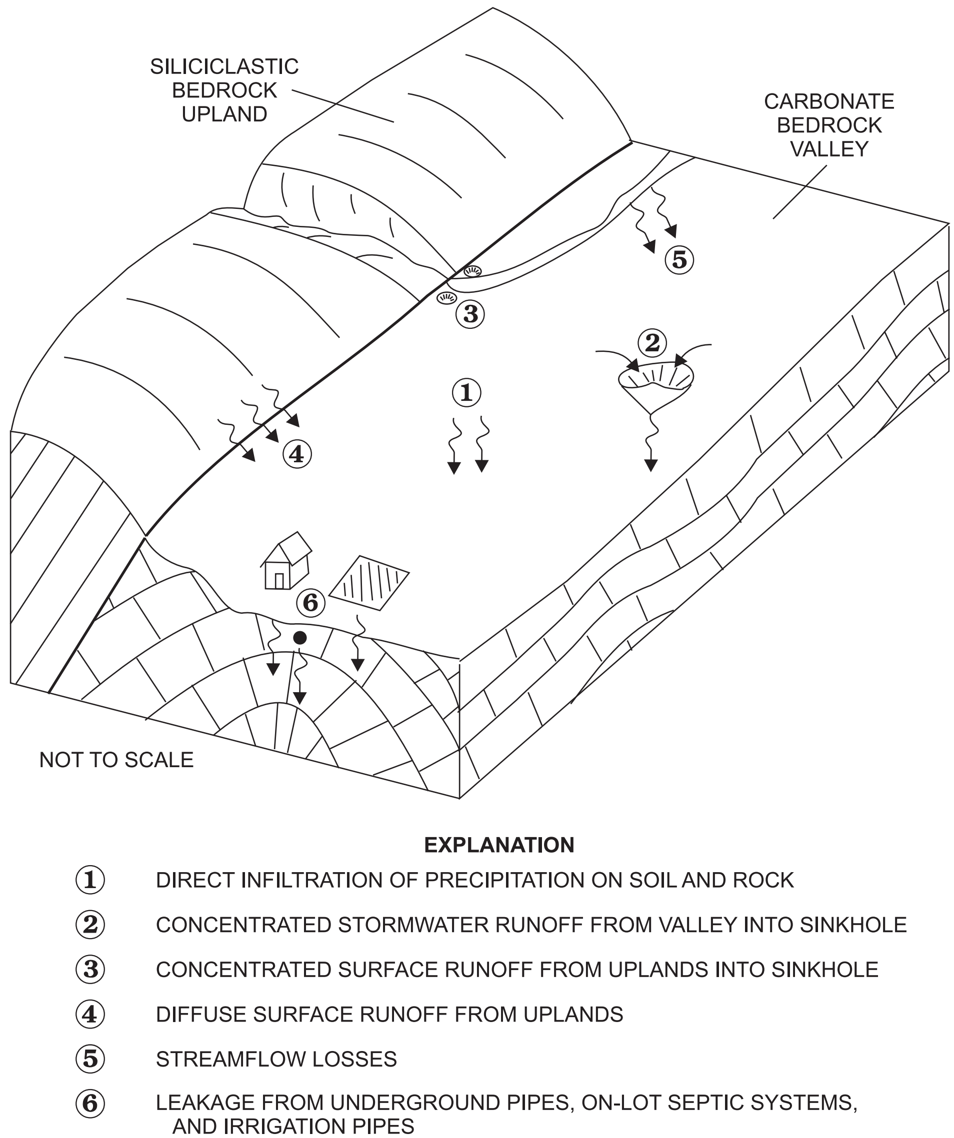


Figure 27. Conceptualized major sources of ground-water recharge to the carbonate-bedrock valley.

Gatesburg Ridge area, where the ground-water divide between the Spring Creek and Spruce Creek watersheds extends as much as 5 mi beyond the surface-water divide, but differences also exist in Penns Valley at the headwaters of Cedar Run and along the northeastern part of Nittany Valley (fig. 25). The area between the Spring Creek surface-water and ground-water divides in the Gatesburg Ridge area is termed the “extended ground-water basin” in this report.

Conceptually, within the extended ground-water basin, ground water will contribute to the water budget of Spring Creek Basin but streams will convey water to the Spruce Creek Basin. Surface water lost as infiltration through the streambed presumably becomes ground-water recharge to the Spring Creek Basin (fig. 29). The reverse is true for areas such as Penns Valley, where the surface-water divide extends beyond the ground-water divide. The budgeting of water in these areas is further complicated by the fact that the ground-water divides are not stationary, because they are influenced by pumping and natural climatic changes. The differences in the positions of ground-water divides mapped in 1969 and 1994 may be an example of the variability of the divide location (fig. 19) but also might be the result of the limited data available for contouring in 1969 compared to 1994. Regardless, hydrologic boundaries in the extended ground-water basin and in other parts of the valley need to be conceptualized as variable with respect to location and flux. Numerical models of the hydrologic system would need to include parts of Spruce Creek watershed to simulate the dynamic ground-water/surface-water relation in the carbonate-bedrock valley.

The base of the Spring Creek Basin within the carbonate-bedrock valley is conceptualized as a no-flow boundary at the depth of active ground-water flow, as indicated by the depth that permeability has been enhanced by weathering. The depth of the weathering zone in the bedrock may extend to more than

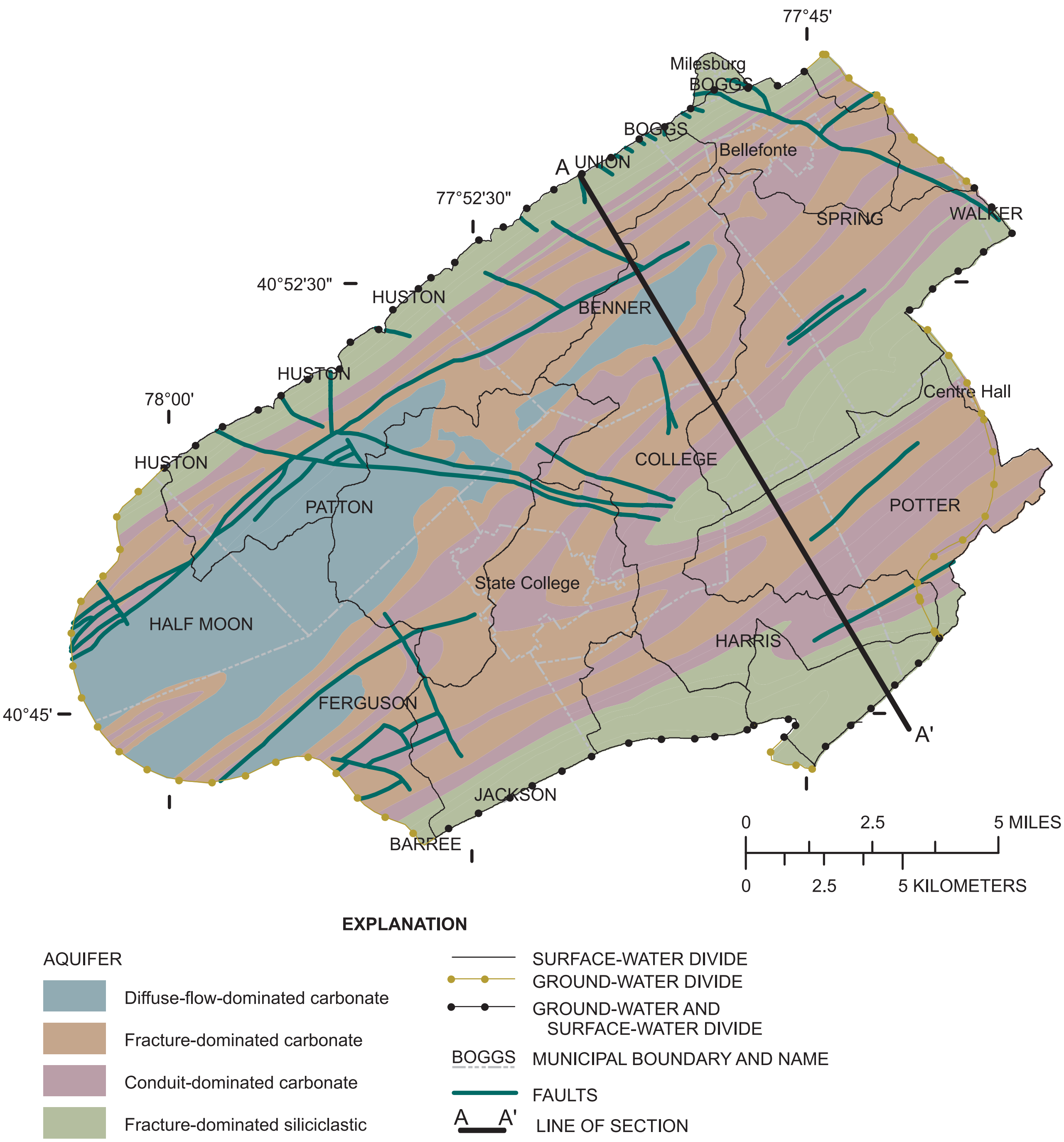


Figure 28. Generalized aquifer types in the Spring Creek Basin, Centre County, Pennsylvania (modified after Parizek and others, 1971; Parizek, 1984).

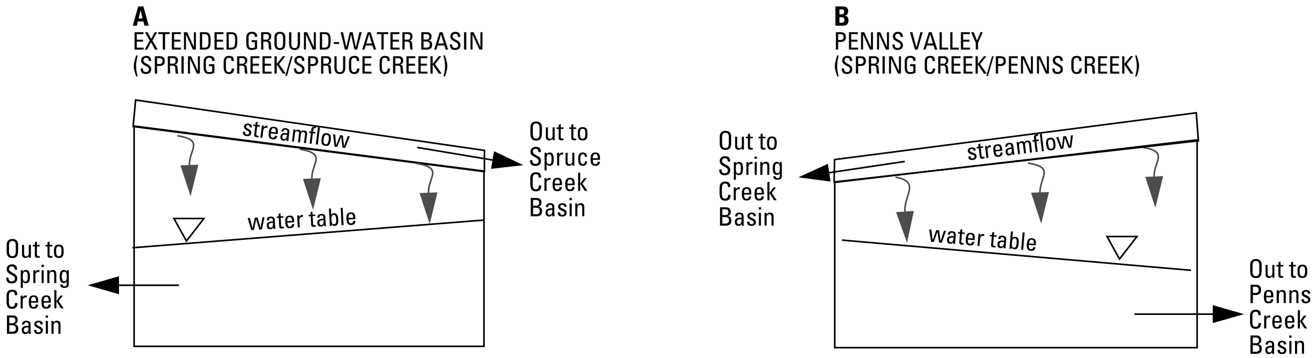


Figure 29. Ground-water/surface-water relations in two areas within the carbonate-bedrock valley where surface-water and ground-water divides do not coincide, Spring Creek Basin, Centre County, Pennsylvania.

500 ft in the carbonate-bedrock aquifers in the study area. Intergranular and vugular permeability within the Gatesburg Formation potentially extends thousands of feet below the valley (Parizek and others, 1971, p. 98). Conceptually, a lower boundary between 500 and 1,000 ft. would most likely include most of the active ground-water flow in the Spring Creek Basin.

Surface Water

Streamflow is sustained in Spring Creek and its major tributaries in the carbonate-bedrock valley mostly by ground-water discharge from the carbonate-bedrock aquifer. This is indicated by base flow in Spring Creek at Milesburg, which averages about 87 percent of streamflow. Ground-water discharge occurs at several large springs (fig. 20) and along stream channels as innumerable small springs and seeps. Because of the large ground-water contribution to streamflow, the discharge and quality of streamflow is controlled to a great extent by the ground-water-flow system of the carbonate-bedrock aquifer.

Direct runoff may contribute to the streamflow hydrograph during intense storms (or periods of rain on frozen ground or snow) when precipitation rates exceed the infiltration capacity on partial source areas. Direct runoff will develop mostly in developed areas where impervious cover is prevalent such as State College, Bellefonte, Centre Hall, and Milesburg or in areas where soils are thin or have low infiltration capacity—such as the Hagerstown-Opequon-Hublersburg, Murrill, and Opequon-Hagerstown soil groups, which are present in Nittany and Penns Valleys.

Ground Water

The carbonate-bedrock valley is underlain by approximately 6,000 to 8,000 ft of interbedded limestone and dolomite that has been altered to differing degrees by dissolution along bedding planes, high-angle fractures, and faults. The carbonate-bedrock aquifers have been conceptualized according to the nature of the openings creating permeability as described by Parizek and others (1971) and Parizek (1984). On this basis, three generalized aquifer types were delineated in the Spring Creek Basin—(1) diffuse-flow-dominated carbonate, (2) fracture-dominated carbonate, and (3) conduit-dominated carbonate (fig. 28). The intergranular and conduit permeabilities serve as end-members of the permeability conditions in the carbonate rocks, and the fracture-dominated rocks represent a degree of permeability between the two end-members. The three aquifer types are capable of providing large quantities of ground water to wells. The carbonate-rock aquifer types are composed mostly of limestones and dolomites overlain in some areas with colluvial and alluvial deposits.

The distribution of generalized aquifer types is shown in figures 28 and 30. The diffuse-flow-dominated carbonate aquifer type includes the upper sandy member, Ore Hill Member, and lower sandy member of the Gatesburg Formation. The upper sandy member of the Gatesburg Formation has sandy beds, vugs, and some fractures. The fracture-dominated carbonate aquifer type includes the dolomite-rich Bellefonte and Nittany Formations and the Mines Member of the Gatesburg Formation. Ground water moves predominately through fractures that may be more or less interconnected depending on location. These rocks are similar in terms of their geochemistry, groundwater yields, and conditions encountered during drilling. Fracture permeability is modified by solution so that fractures apertures range from tenths or hundredths of inches to 0.4 in. (White, 2003). The matrix porosity of many carbonates is very low and commonly can be ignored (White, 2003). The conduit-dominated carbonate aquifer type includes limestones of the Axeman, Stonehenge, and Coburn through Loysburg Formations, which contain sinkholes and major networks of caves and interconnected conduits that favor rapid recharge and movement of ground water. Because limestone and dolomite differ in solubility, voids in limestone generally are larger than in dolomite and may reach cave proportions in competent, thick-bedded, or shallow-dipping bedrock. Dolomite normally retains a thicker residual soil cover than limestone, which delays and dampens the water-table response to precipitation, particularly

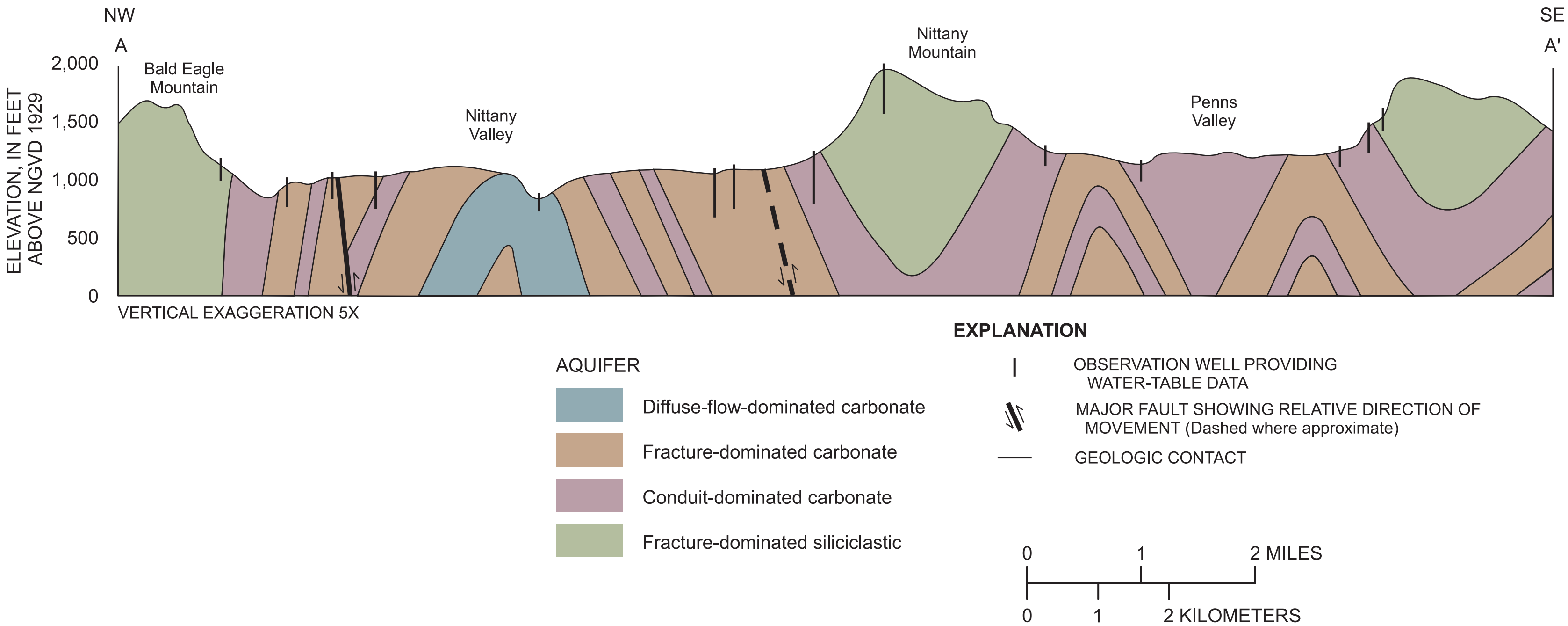


Figure 30. Geologic cross section A-A′ and generalized aquifer types, Spring Creek Basin, Centre County, Pennsylvania (modified from Giddings, 1974; geology by Butts and Moore, 1936). Approximate location of section A-A′ is shown on figure 10.

in areas underlain by the Gatesburg Formation. Conduits can range in size from about 0.25 in. to greater than tens of feet. Hydrologically, they act as storm drains (White, 2003).

The four major aquifer types shown in cross section in figure 30 are conceptualized in figure 31 as they might be simulated in a numerical model. This illustration shows the basin represented as a four-layer model, in which each aquifer type is represented as a model layer. Depending on the magnitude of the head differences reported within the flow domain, it may be necessary to subdivide the layers to more accurately simulate vertical flow gradients. Also, additional information regarding the hydrogeologic framework (including vertical orientation of fractures, conduits, and aquifer properties) would be useful for determining specifically how to best simulate geologic units and boundary conditions within the Spring Creek Basin.

Ground water in the carbonate-bedrock aquifer is recharged by differing mechanisms that affect its magnitude, timing, and chemical characteristics. Six conceptual pathways for ground-water recharge (after Parizek, 1984) are: (1) direct infiltration of precipitation into soils and exposed bedrock, (2) concentrated stormwater runoff from the valley into sinkholes, (3) concentrated surface runoff from uplands into sinkholes, (4) diffuse surface runoff from uplands, (5) streamflow losses from perched or intermittent streams on karst terrain, and (6) leakage from underground pipes, disposal of on-lot sewage effluent, and irrigation (fig. 27).

The magnitude of ground-water recharge from all sources has been estimated from hydrograph separation of the base flow in Spring Creek. This approach for estimating recharge assumes that base flow represents ground-water discharge and that ground-water discharge is a good approximation of recharge. Base flow for the entire 175 mi^2 Spring Creek Basin averaged 15.1 in. (125 Mgal/d) as computed from the local-minimum method of hydrograph separation (Pettyjohn and Henning, 1979) using data from 1968 to 2002 at the streamflow-gaging station Spring Creek at Milesburg, Pa. (01547100). This base flow is about 87 percent of total streamflow measured at Milesburg. Using base flow as a surrogate for recharge may underestimate recharge because neither ground-water withdrawals nor loss of ground water to evapotranspiration were included in the calculation; however, the ground-water usage was likely not highly consumptive because the wastewater-treatment plant serving much of the area discharges back into Spring Creek above the streamflow-gaging station near Axeman (01546500). Also, base flow includes contributions from some large conduit springs that are principally fed by streamflow lost into sinkholes. Thus, water reemerging as springflow may never have been part of the larger ground-water reservoir beneath the water table; therefore, base flow may overestimate ground-water recharge by an amount equal to the conduit springflow.

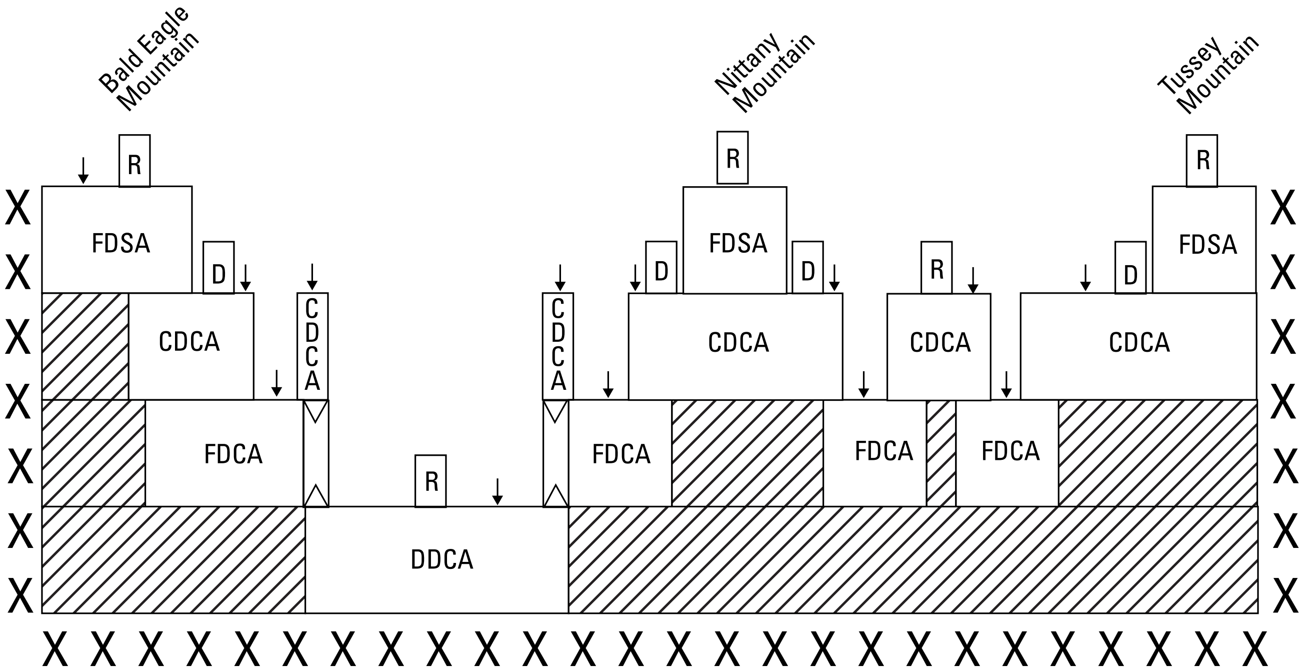
Runoff from the siliciclastic-bedrock uplands that partly bound the Spring Creek Basin is a major source of recharge to the carbonate-rock aquifers in the valley. Konikow (in Parizek and others, 1971, p. 83) showed that runoff lost to sinkholes from the uplands equaled about 33 percent of the flow of Spring Creek during his study. Parizek (1984, p. 13) estimated that 50 to 60 percent of recharge to carbonate aquifers is from mountain runoff. Conceptually, all of this apparent recharge may not truly serve as recharge to the aquifer, but much of it may travel rapidly through a conduit system above the water table—never becoming recharge to the main ground-water reservoir of the valley. Some recharge to the main ground-water reservoir of the carbonate-bedrock valley is contributed from mountain runoff, but the amount is unknown.

The general direction of ground-water movement can be inferred from maps of Giddings (1974), Wood (1980), and Taylor (1997) showing the configuration of the water table in the Spring Creek Basin (figs. 19 and 25). Ground water flows from the siliciclastic-bedrock uplands into the valley, generally towards Spring Creek, and to the surface-water drainage low point at the confluence of Spring Creek with Bald Eagle Creek at Milesburg, Pa. Ground water from the southwestern part of the valley in the ground-water extended basin (Gatesburg Ridge area) flows to the northeast toward Bellefonte and Milesburg.

Structural geologic features may complicate any conceptualization of ground-water movement by adding an unknown degree of anisotropy (preferential direction of flow) parallel to the strike of the carbonate-bedrock aquifers. Ground-water flow, especially within the fracture-dominated and conduit-dominated aquifers is altered by structural controls and secondary permeability features such as solution-enlarged fractures, joints, and sinkholes. These features, and regional structures such as the Birmingham Thrust Fault, enhance ground-water movement parallel to strike and valley alignment. Ground-water flow across the strike of beds is conceptualized as localized along cross-cutting fracture zones, joints, and high-angle faults.

The Birmingham Thrust Fault and solution channels aligned with the base of the mountain ridges have been conceptualized as structures that influence regional ground-water flow (Giddings, 1974). A regional ground-water trough has been documented along and in the vicinity of the Birmingham Thrust Fault (Parizek and others, 1971; Giddings, 1974). The Birmingham Thrust Fault, along with minor faults, controls the ground-water-flow rates and the location of large springs. The effects of the fault and other fracture traces add to the degree of anisotropy in the flow regime. The very deep water table in the Gatesburg Formation is the result of the development of solution conduits along the zone of the Birmingham Thrust Fault (fig. 10) and underdrainage in dissolution-enhanced sandy bedrock units.

Ground-water discharges from the carbonate-bedrock aquifer to streams, springs, wells, and as evapotranspiration to riparian vegetation. Little ground water is expected to leave the basin as underflow because of the constriction caused by the water gap at the outlet of the basin near Milesburg. Most ground water discharges to streams and springs. Although withdrawals from wells within the carbonate-bedrock valley are large and provide the principal source of water supply, total withdrawals in 2002 amounted to less than 9 percent of the base flow of Spring Creek at Milesburg.



EXPLANATION

FDSA — FRACTURE-DOMINATED SILICICLASTIC AQUIFER

CDCA — CONDUIT-DOMINATED CARBONATE AQUIFER

FDCA — FRACTURE-DOMINATED CARBONATE AQUIFER

DDCA — DIFFUSE-FLOW-DOMINATED CARBONATE AQUIFER

R — RIVER WITH STREAMBED LEAKAGE

D — DRAIN (SPRINGS)

AQUIFER NOT PRESENT OR NOT REPRESENTED

DIRECT HYDRAULIC CONNECTION, INTERVENING UNIT NOT REPRESENTED

X — NO FLOW

↓ — RECHARGE

Figure 31. Schematic diagram of cross-valley section in the Spring Creek Basin. (Units not to scale. All outcrop units not represented. Aquifers could be subdivided to represent vertical flow.)

Suggestions for Future Work

Based on the information collected to date, a number of data gaps exist and would need to be addressed prior to development of a numerical model. In this section, additional data-collection needs are identified, and tasks are listed to further define the interaction of surface water and ground water within the basin.

1. Acquire paper or electronic form of well ID, latitude, longitude, and water-level elevation for the SRBC Spring Creek data set.
2. Collect additional transmissivity and storage data, particularly for mountain ridges. Some data from Siddiqui (1969) cannot be located or are insufficient for use.
3. Develop anisotropy values for bedrock units and bedrock settings.
4. Investigate how transmissivity values have been determined and select optimal values.
5. Review specific capacity and well-productivity results, analysis of hydrogeologic boundaries, image-well analysis, and anisotropic effects.
6. Obtain additional pumping data from 1994 to present from all sources.
7. Determine values of hydraulic conductivity based on available transmissivity data.
8. Determine if other major springs exist in addition to those listed in Saad and Hippe (1990).
9. Confirm base-flow estimates from Spring Creek at Milesburg streamflow-gaging station from 1994 to 2003.
10. Collect synoptic water levels from wells within the basin representative of low- and high-base flow; reference water-level data to the formation where the screen/open hole is located.
11. Determine whether it is necessary to obtain the water-level data collected in 1969 and 1994 and plot using geostatistics (kriging); errors in converting the map image to an electronic form may contain spatial errors.
12. Collect synoptic spring-flow data during low and high base flow.
13. Prepare structural contour maps and hydrogeologic cross sections illustrating the surface and base elevations for each of the aquifer types reported for the basin. The information could be used to better define the geometry and spatial variability of the stratigraphic units within the basin.
14. The importance of accurate spatial representation of precipitation events cannot be overstated. Radar-derived estimates of precipitation offer the best available data for achieving the desired accuracy. However, available data are limited to the period April 1995 to the present. In addition, these data, which show about 35 percent missing values, appear to lack continuity. It is not known whether additional unprocessed data may be available to resolve the missing data problem.
15. Snowfall data is available for the meteorological data-collection stations listed in table 3, but radar-derived estimates of snowfall are considered unreliable. Snowpack depths and water equivalents are valuable for calibrating the snowmelt process in a hydrologic model. Snowpack depth data appear to be limited to reports from four of the stations listed in table 3 (Clarence, Millheim, Philipsburg 8 E, and State College). Water equivalents for the snowpack data are not supplied. The areal extent of a snowpack is also of value for model calibration. No data on the areal extent of snowcover has been located.
16. Solar-radiation data from the immediate basin area is not available for the period 1985 to 1998. The closest solar data-collection station for this time period is near Williamsport, Pa. The quality of the pre-1985 data currently is unknown and may impact its usefulness; however, values could be generated using a NOAA weather-generator model.
17. An annual average pan evaporation coefficient is available for the area (Farnsworth and others, 1982) but monthly coefficients that factor in seasonal variation would be preferred.

Summary and Conclusions

This study, which was conducted in cooperation with ClearWater Conservancy, was undertaken to (1) compile baseline data needed to assess the effects of rapid growth and development on the high-quality water resources of Spring Creek Basin, and (2) lay the groundwork needed to create a decision tool that could be transferred to other basins. The Spring Creek Basin lies entirely within Centre County and includes all or part of the Boroughs of Bellefonte, Centre Hall, Milesburg, and State College. The Spring Creek surface-water basin is approximately 146 mi^2 in size, but its ground-water basin extends beyond the surface-water basin and encompasses a larger area—about 175 mi^2. The ground-water-flow system is especially important in the Spring Creek Basin, because ground water is the source of most water supplies and it sustains the high-quality cold-water streamflow in Spring Creek.

This report describes the characteristics of the Spring Creek Basin and includes the following: a compilation of available climatological, physiographic, geologic, and hydrologic data; a summary of available water-quantity and quality data; development of a conceptual hydrologic model for the basin; and suggestions for additional data collection and other future work that would enhance the development of a numerical model for the basin. Available GIS and hydrologic data sets are summarized in the body of the report and are provided in electronic format as appendixes. The data presented could be used as baseline data for development of predictive hydrologic models of the basin that could serve as prototype models for other basins in similar hydrogeologic settings.

The Spring Creek Basin is conceptualized as consisting of two principal hydrologic settings—a forested, siliciclastic-bedrock upland and a carbonate-bedrock valley with agricultural and urban land use. The two settings differ in physiography, geology, and land use, but are linked hydrologically by runoff and ground-water discharge from the uplands, which provides streamflow and ground-water recharge to the valley. The siliciclastic-bedrock uplands of Ordovician and Silurian age form the physical and hydrologic boundaries of the Spring Creek Basin along its northwestern and southeastern margins. The carbonate-bedrock valley is underlain by limestones and dolomites of Ordovician age that have been variously folded, fractured, and dissolved to produce highly productive aquifers. Within the carbonate-bedrock valley, hydrologic boundaries of ground-water and surface-water systems are not coincident everywhere and ground-water divides may vary with changes in recharge and pumping. The base of active ground-water flow in the Spring Creek Basin is not well known, but based on depth of weathering, a lower boundary between 500 and 1,000 ft. would likely include most of the active ground-water flow in the Spring Creek Basin.

The bedrock aquifers have been conceptualized according to lithology and the nature of the openings creating permeability as: (1) diffuse-flow-dominated carbonate, (2) fracture-dominated carbonate, (3) conduit-dominated carbonate, and (4) fracture-dominated siliciclastic aquifers. Recharge to the carbonate-bedrock aquifer occurs along one of six conceptual pathways (after Parizek, 1984): (1) direct infiltration of precipitation into soils and exposed bedrock; (2) concentrated stormwater runoff from the valley into sinkholes; (3) concentrated surface runoff from uplands into sinkholes; (4) diffuse surface runoff from uplands; (5) streamflow losses from perched or intermittent streams on karst terrain; and (6) leakage from underground pipes, disposal of on-lot sewage effluent, and irrigation. Ground water discharges to streams, springs, wells, and as evapotranspiration to riparian vegetation. Discharge to springs and streams accounts for about 87 percent of the streamflow of Spring Creek at Milesburg.

Suggestions for additional data collection and other future work are provided that would enhance the development of hydrologic simulation models of the Spring Creek Basin. For example, collection of additional data would be needed to define aquifer properties, additional synoptic stream and spring-flow measurements would be needed for model calibration, and radar-derived precipitation estimates would be needed to provide the best possible spatial distribution of precipitation. These suggested efforts would help refine the conceptual understanding of the basin and would likely increase the accuracy of hydrologic simulation models.

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Table 18. Summary of surface-water quality data through May 2003 for the Spring Creek Basin, Centre County, Pennsylvania.

[n, number of samples; —, no data; <, less than; deg C, degrees Celsius; ft^3/s, cubic feet per second; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; NTU, Nephelometric turbidity units; Data sources: Spring Creek Watershed Community, period ending February 2002; Pennsylvania Department of Environmental Resources, period ending May 2003; U.S. Geological Survey, period ending November 2002]

Constituent or characteristic	Parameter code	Units	Data-collection site name							
			Lower Buffalo Run				Upper Buffalo Run			
			n	Minimum	Median	Maximum	n	Minimum	Median	Maximum
Water temperature	00010	deg C	34	0.3	10.4	20.5	27	0.1	9.4	17.8
Discharge	00060	ft^3/s	—	—	—	—	—	—	—	—
Discharge, instantaneous	00061	ft^3/s	—	—	—	—	—	—	—	—
Specific conductance	00095	∝S/cm	—	—	—	—	—	—	—	—
Dissolved oxygen	00300	mg/L	34	7.6	11.85	15	26	7	11.25	14.8
Biological oxygen demand 5-day	00310	mg/L	—	—	—	—	—	—	—	—
pH, field	00400	standard units	32	7.4	8.1	8.6	25	6.9	7.7	8.3
pH, laboratory	00403	standard units	—	—	—	—	—	—	—	—
Acid neutralizing capacity	00410	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Residue, filtered	00515	mg/L	—	—	—	—	—	—	—	—
Residue, total nonfilterable	00530	mg/L	38	<2	7	46	29	<2	6	84
Nitrogen, total	00600	mg/L as N	—	—	—	—	—	—	—	—
Ammonia, dissolved	00608	mg/L as N	—	—	—	—	—	—	—	—
Ammonia, total	00610	mg/L as N	—	—	—	—	—	—	—	—
Nitrite, total	00615	mg/L as N	—	—	—	—	—	—	—	—
Nitrite, dissolved	00618	mg/L as N	36	<.04	1.76	2.94	27	<.04	1.34	1.81
Nitrate, total	00620	mg/L as N	38	<.04	1.8	2.43	29	<.04	1.39	1.85
Ammonia + organic nitrogen	00625	mg/L as N	—	—	—	—	—	—	—	—
Phosphate, total	00650	mg/L as PO_4	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00660	mg/L as PO_4	—	—	—	—	—	—	—	—
Phosphorous, total	00665	mg/L as P	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00671	mg/L as P	37	<.01	<.01	.028	28	<.01	.012	.031
Organic carbon, total	00680	mg/L as C	38	<1.0	1.3	3.3	29	<1.0	1.4	2.9
Organic carbon, dissolved	00681	mg/L as C	38	<1.0	1.5	5.1	28	<1.0	1.45	2.7
Hardness, total	00900	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Calcium, dissolved	00915	mg/L	—	—	—	—	—	—	—	—
Calcium, total	00916	mg/L	—	—	—	—	—	—	—	—
Magnesium, dissolved	00925	mg/L	—	—	—	—	—	—	—	—
Magnesium, total	00927	mg/L	—	—	—	—	—	—	—	—
Chloride, dissolved	00940	mg/L	38	<1.0	14	22	29	<1.0	20	40
Sulfate, dissolved	00945	mg/L as SO_4	—	—	—	—	—	—	—	—
Copper, dissolved	01040	∝g/L	38	<4.0	<4.0	10	29	<4.0	<4.0	13
Copper, total	01042	∝g/L	38	<4.0	<4.0	10	29	<4.0	<4.0	25
Iron, total	01045	∝g/L	—	—	—	—	—	—	—	—
Iron, dissolved	01046	∝g/L	—	—	—	—	—	—	—	—
Lead, dissolved	01049	∝g/L	37	<1.0	<1.0	1	28	<1.0	<1.0	1
Lead, total	01051	∝g/L	37	<1.0	<1.0	5.6	28	<1.0	<1.0	5.9
Manganese, total	01055	∝g/L	—	—	—	—	—	—	—	—
Manganese, dissolved	01056	∝g/L	—	—	—	—	—	—	—	—
Nickel, total	01067	∝g/L	—	—	—	—	—	—	—	—
Zinc, dissolved	01090	∝g/L	38	<10.	<10.	108	29	<10	<10	17
Zinc, total	01092	∝g/L	38	<10.	<10.	20	29	<10	<10	37
Aluminum, total	01105	∝g/L	—	—	—	—	—	—	—	—
Petroleum hydrocarbons, total	45501	∝g/L	36	<5.0	<5.0	7	27	<5.0	<5.0	8.2
Orthophosphate, total	70507	mg/L as P	37	<.01	.014	.047	28	<.01	.02	.081
Nitrate, dissolved	71851	mg/L as NO_3	—	—	—	—	—	—	—	—
Suspended sediment	80154	mg/L	—	—	—	—	—	—	—	—
Turbidity, total, laboratory	82079	NTU	37	<1.0	2.55	11	29	<1.0	2.47	17

Table 18. Summary of surface-water quality data through May 2003 for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[n, number of samples; —, no data; <, less than; deg C, degrees Celsius; ft^3/s, cubic feet per second; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; NTU, Nephelometric turbidity units; Data sources: Spring Creek Watershed Community, period ending February 2002; Pennsylvania Department of Environmental Resources, period ending May 2003; U.S. Geological Survey, period ending November 2002]

Constituent or characteristic	Parameter code	Units	Data-collection site name							
			Lower Cedar Run				Lower Logan Branch			
			n	Minimum	Median	Maximum	n	Minimum	Median	Maximum
Water temperature	00010	deg C	35	0.4	10.8	20.4	35	7.6	10.9	13.6
Discharge	00060	ft^3/s	—	—	—	—	—	—	—	—
Discharge, instantaneous	00061	ft^3/s	—	—	—	—	—	—	—	—
Specific conductance	00095	∝S/cm	—	—	—	—	—	—	—	—
Dissolved oxygen	00300	mg/L	35	10.1	11.8	15.4	35	10.1	11.1	13.3
Biological oxygen demand 5-day	00310	mg/L	—	—	—	—	—	—	—	—
pH, field	00400	standard units	34	7.1	8.1	8.4	33	7.1	7.7	8.3
pH, laboratory	00403	standard units	—	—	—	—	—	—	—	—
Acid neutralizing capacity	00410	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Residue, filtered	00515	mg/L	—	—	—	—	—	—	—	—
Residue, total nonfilterable	00530	mg/L	38	<2	6	70	36	<2	<2	94
Nitrogen, total	00600	mg/L as N	1	4.97	4.97	4.97	—	—	—	—
Ammonia, dissolved	00608	mg/L as N	1	<.02	<.02	<.02	—	—	—	—
Ammonia, total	00610	mg/L as N	2	<.02	<.02	.02	—	—	—	—
Nitrite, total	00615	mg/L as N	2	<.01	<.01	<.01	—	—	—	—
Nitrite, dissolved	00618	mg/L as N	35	<.04	4.26	5.15	34	<.04	2.74	3.26
Nitrate, total	00620	mg/L as N	39	<.04	4.3	5.41	36	<.04	2.77	3.58
Ammonia + organic nitrogen	00625	mg/L as N	—	—	—	—	—	—	—	—
Phosphate, total	00650	mg/L as PO_4	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00660	mg/L as PO_4	—	—	—	—	—	—	—	—
Phosphorous, total	00665	mg/L as P	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00671	mg/L as P	38	<.01	<.01	.018	35	<.01	.013	.043
Organic carbon, total	00680	mg/L as C	38	<1.0	1.1	1.8	36	<1.0	<1.0	1.8
Organic carbon, dissolved	00681	mg/L as C	37	<1.0	1.3	1.9	36	<1.0	<1.0	2.2
Hardness, total	00900	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Calcium, dissolved	00915	mg/L	—	—	—	—	—	—	—	—
Calcium, total	00916	mg/L	—	—	—	—	—	—	—	—
Magnesium, dissolved	00925	mg/L	—	—	—	—	—	—	—	—
Magnesium, total	00927	mg/L	—	—	—	—	—	—	—	—
Chloride, dissolved	00940	mg/L	38	<1.0	14	20	36	<1.0	19.5	26
Sulfate, dissolved	00945	mg/L as SO_4	—	—	—	—	—	—	—	—
Copper, dissolved	01040	∝g/L	38	<4.0	<4.0	16	36	<4.0	<4.0	10
Copper, total	01042	∝g/L	38	<4.0	<4.0	14.5	36	4	4.45	28
Iron, total	01045	∝g/L	—	—	—	—	—	—	—	—
Iron, dissolved	01046	∝g/L	—	—	—	—	—	—	—	—
Lead, dissolved	01049	∝g/L	38	<1.0	<1.0	1	35	<1.0	<1.0	1
Lead, total	01051	∝g/L	38	<1.0	<1.0	1	35	<1.0	1.1	2.6
Manganese, total	01055	∝g/L	—	—	—	—	—	—	—	—
Manganese, dissolved	01056	∝g/L	—	—	—	—	—	—	—	—
Nickel, total	01067	∝g/L	—	—	—	—	—	—	—	—
Zinc, dissolved	01090	∝g/L	38	<10.	<10.	12	36	<10	17	70
Zinc, total	01092	∝g/L	39	<10.	<10.	19	36	<10	20	81
Aluminum, total	01105	∝g/L	—	—	—	—	—	—	—	—
Petroleum hydrocarbons, total	45501	∝g/L	37	<5.0	<5.0	12.2	34	<5.0	<5.0	10.3
Orthophosphate, total	70507	mg/L as P	38	<.01	.014	.034	35	<.01	.015	.052
Nitrate, dissolved	71851	mg/L as NO_3	—	—	—	—	—	—	—	—
Suspended sediment	80154	mg/L	—	—	—	—	—	—	—	—
Turbidity, total, laboratory	82079	NTU	37	<1.0	2.25	13.8	35	<1.0	1.43	5.23

Table 18. Summary of surface-water quality data through May 2003 for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[n, number of samples; —, no data; <, less than; deg C, degrees Celsius; ft^3/s, cubic feet per second; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; NTU, Nephelometric turbidity units; Data sources: Spring Creek Watershed Community, period ending February 2002; Pennsylvania Department of Environmental Resources, period ending May 2003; U.S. Geological Survey, period ending November 2002]

Constituent or characteristic	Parameter code	Units	Data-collection site name							
			Upper Logan Branch				Lower Slab Cabin Run			
			n	Minimum	Median	Maximum	n	Minimum	Median	Maximum
Water temperature	00010	deg C	34	5.9	13.1	20.1	36	1.5	12.1	24.9
Discharge	00060	ft^3/s	—	—	—	—	—	—	—	—
Discharge, instantaneous	00061	ft^3/s	—	—	—	—	—	—	—	—
Specific conductance	00095	∝S/cm	—	—	—	—	—	—	—	—
Dissolved oxygen	00300	mg/L	34	8.2	10.25	13.6	36	6.8	11.75	16.5
Biological oxygen demand 5-day	00310	mg/L	—	—	—	—	—	—	—	—
pH, field	00400	standard units	32	7.1	7.8	8.2	34	7.1	7.8	8.3
pH, laboratory	00403	standard units	—	—	—	—	—	—	—	—
Acid neutralizing capacity	00410	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Residue, filtered	00515	mg/L	—	—	—	—	—	—	—	—
Residue, total nonfilterable	00530	mg/L	38	<2	4	66	40	<2	3	72
Nitrogen, total	00600	mg/L as N	—	—	—	—	—	—	—	—
Ammonia, dissolved	00608	mg/L as N	—	—	—	—	—	—	—	—
Ammonia, total	00610	mg/L as N	—	—	—	—	—	—	—	—
Nitrite, total	00615	mg/L as N	—	—	—	—	—	—	—	—
Nitrite, dissolved	00618	mg/L as N	36	<.04	2.65	3.85	37	<.04	1.73	4.01
Nitrate, total	00620	mg/L as N	38	<.04	2.69	5.82	40	<.04	1.83	4.56
Ammonia + organic nitrogen	00625	mg/L as N	—	—	—	—	—	—	—	—
Phosphate, total	00650	mg/L as PO_4	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00660	mg/L as PO_4	—	—	—	—	—	—	—	—
Phosphorous, total	00665	mg/L as P	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00671	mg/L as P	37	<.01	.045	.137	40	<.01	.014	.168
Organic carbon, total	00680	mg/L as C	38	<1.0	2	3.1	40	<1.0	1.7	4.5
Organic carbon, dissolved	00681	mg/L as C	38	<1.0	2	3	40	<1.0	1.9	4.4
Hardness, total	00900	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Calcium, dissolved	00915	mg/L	—	—	—	—	—	—	—	—
Calcium, total	00916	mg/L	—	—	—	—	—	—	—	—
Magnesium, dissolved	00925	mg/L	—	—	—	—	—	—	—	—
Magnesium, total	00927	mg/L	—	—	—	—	—	—	—	—
Chloride, dissolved	00940	mg/L	38	<1.0	31	61	40	<1.0	54.5	114
Sulfate, dissolved	00945	mg/L as SO_4	—	—	—	—	—	—	—	—
Copper, dissolved	01040	∝g/L	38	<4.0	<4.0	10	40	<4.0	<4.0	10
Copper, total	01042	∝g/L	38	<4.0	<4.0	21.3	40	<4.0	<4.0	10
Iron, total	01045	∝g/L	—	—	—	—	—	—	—	—
Iron, dissolved	01046	∝g/L	—	—	—	—	—	—	—	—
Lead, dissolved	01049	∝g/L	37	<1.0	<1.0	4.2	40	<1.0	<1.0	5.9
Lead, total	01051	∝g/L	37	<1.0	3.1	5.3	40	<1.0	<1.0	1.4
Manganese, total	01055	∝g/L	—	—	—	—	—	—	—	—
Manganese, dissolved	01056	∝g/L	—	—	—	—	—	—	—	—
Nickel, total	01067	∝g/L	—	—	—	—	—	—	—	—
Zinc, dissolved	01090	∝g/L	38	<10.	<10.	14	40	<10.	<10.	14
Zinc, total	01092	∝g/L	38	<10.	<10.	3,180	40	<10.	<10.	12
Aluminum, total	01105	∝g/L	—	—	—	—	—	—	—	—
Petroleum hydrocarbons, total	45501	∝g/L	37	<5.0	<5.0	8.2	38	<5.0	<5.0	12.9
Orthophosphate, total	70507	mg/L as P	37	<.01	.051	.133	40	<.01	.018	.21
Nitrate, dissolved	71851	mg/L as NO_3	—	—	—	—	—	—	—	—
Suspended sediment	80154	mg/L	—	—	—	—	—	—	—	—
Turbidity, total, laboratory	82079	NTU	38	<1.0	3.06	8.6	40	<1.0	1.51	7.25

Table 18. Summary of surface-water quality data through May 2003 for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[n, number of samples; —, no data; <, less than; deg C, degrees Celsius; ft^3/s, cubic feet per second; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; NTU, Nephelometric turbidity units; Data sources: Spring Creek Watershed Community, period ending February 2002; Pennsylvania Department of Environmental Resources, period ending May 2003; U.S. Geological Survey, period ending November 2002]

Constituent or characteristic	Para-meter code	Units	Data-collection site name							
			Upper Slab Cabin Run				Spring Creek near Axemann			
			n	Mini-mum	Median	Maxi-mum	n	Mini-mum	Median	Maxi-mum
Water temperature	00010	deg C	20	1	11.35	22.6	418	0	10.9	31
Discharge	00060	ft^3/s	—	—	—	—	404	2	73	600
Discharge, instantaneous	00061	ft^3/s	—	—	—	—	233	2.04	76	613
Specific conductance	00095	∝S/cm	—	—	—	—	343	225	488	665
Dissolved oxygen	00300	mg/L	20	3.4	10.6	13.7	382	2.8	10.8	16.6
Biological oxygen demand 5-day	00310	mg/L	—	—	—	—	5	2.1	3	4.5
pH, field	00400	standard units	20	7.1	7.5	8.22	380	6.4	7.9	9.5
pH, laboratory	00403	standard units	—	—	—	—	403	6.2	8.1	8.9
Acid neutralizing capacity	00410	mg/L as $CaCO_3$	—	—	—	—	399	23	180	2,010
Residue, filtered	00515	mg/L	—	—	—	—	256	34	325	3,240
Residue, total nonfilterable	00530	mg/L	22	<2	13	192	283	<2	10	370
Nitrogen, total	00600	mg/L as N	—	—	—	—	11	3.77	4.2	6.01
Ammonia, dissolved	00608	mg/L as N	1	<.02	<.02	<.02	3	.05	.22	.25
Ammonia, total	00610	mg/L as N	1	.02	.02	.02	335	<.02	.08	10.1
Nitrite, total	00615	mg/L as N	1	.01	.01	.01	335	<.01	.038	2.394
Nitrite, dissolved	00618	mg/L as N	20	<.04	2.345	4.48	38	<.04	4.39	6.92
Nitrate, total	00620	mg/L as N	22	<.04	2.355	4.83	372	<.04	4.09	8.3
Ammonia + organic nitrogen	00625	mg/L as N	—	—	—	—	2	.62	.675	.73
Phosphate, total	00650	mg/L as PO_4	—	—	—	—	11	.064	1.1	2.8
Orthophosphate, dissolved	00660	mg/L as PO_4	—	—	—	—	8	.03	1.15	2
Phosphorous, total	00665	mg/L as P	—	—	—	—	334	.02	.12	4.4
Orthophosphate, dissolved	00671	mg/L as P	22	<.01	.0375	.325	39	<.01	.022	.048
Organic carbon, total	00680	mg/L as C	22	<1.0	2.1	10.2	234	<1.0	1.9	31
Organic carbon, dissolved	00681	mg/L as C	21	<1.0	2.1	8.4	38	<1.0	1.85	3.5
Hardness, total	00900	mg/L as $CaCO_3$	—	—	—	—	360	41	203	384
Calcium, dissolved	00915	mg/L	—	—	—	—	16	18	51.6	67
Calcium, total	00916	mg/L	—	—	—	—	152	5.34	54.5	634
Magnesium, dissolved	00925	mg/L	—	—	—	—	16	.5	14.5	62.5
Magnesium, total	00927	mg/L	—	—	—	—	152	4.95	20.16	241
Chloride, dissolved	00940	mg/L	22	<1.0	25	57	243	<1.0	22	56
Sulfate, dissolved	00945	mg/L as SO_4	—	—	—	—	243	<10	25.3	235
Copper, dissolved	01040	∝g/L	22	<4.0	<4.0	10	41	<4.0	<4.0	10
Copper, total	01042	∝g/L	22	<4.0	<4.0	11	43	<4.0	<4.0	10
Iron, total	01045	∝g/L	—	—	—	—	13	80	180	450
Iron, dissolved	01046	∝g/L	—	—	—	—	6	10	40	270
Lead, dissolved	01049	∝g/L	22	<1.0	<1.0	1	39	<1.0	<1.0	1.1
Lead, total	01051	∝g/L	22	<1.0	<1.0	3.6	43	<1.0	<1.0	8.1
Manganese, total	01055	∝g/L	—	—	—	—	4	<10	<10	<10
Manganese, dissolved	01056	∝g/L	—	—	—	—	5	30	30	40
Nickel, total	01067	∝g/L	—	—	—	—	4	<50	<50	<50
Zinc, dissolved	01090	∝g/L	22	<10	<10	11	41	<10	<10	47
Zinc, total	01092	∝g/L	22	<10	<10	15	43	<10	<10	58
Aluminum, total	01105	∝g/L	—	—	—	—	4	<200	<200	300
Petroleum hydrocarbons, total	45501	∝g/L	22	<5.0	<5.0	9.2	38	<5.0	<5.0	10.2
Orthophosphate, total	70507	mg/L as P	22	.01	.0495	.4	42	<.01	.028	.057
Nitrate, dissolved	71851	mg/L as NO_3	—	—	—	—	10	1.5	13	27
Suspended sediment	80154	mg/L	—	—	—	—	75	3	17	584
Turbidity, total, laboratory	82079	NTU	22	<1.0	3.14	53.8	39	<1.0	2.88	9.03

Table 18. Summary of surface-water quality data through May 2003 for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[n, number of samples; —, no data; <, less than; deg C, degrees Celsius; ft^3/s, cubic feet per second; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; NTU, Nephelometric turbidity units; Data sources: Spring Creek Watershed Community, period ending February 2002; Pennsylvania Department of Environmental Resources, period ending May 2003; U.S. Geological Survey, period ending November 2002]

Constituent or characteristic	Parameter code	Units	Data-collection site name							
			Spring Creek at Houserville				Spring Creek at Milesburg			
			n	Minimum	Median	Maximum	n	Minimum	Median	Maximum
Water temperature	00010	deg C	34	2.6	11.4	21.3	29	5.7	11.7	20
Discharge	00060	ft^3/s	—	—	—	—	1	204	204	204
Discharge, instantaneous	00061	ft^3/s	—	—	—	—	—	—	—	—
Specific conductance	00095	∝S/cm	—	—	—	—	1	410	410	410
Dissolved oxygen	00300	mg/L	34	10.5	12.65	14.9	35	8.2	11.4	12.9
Biological oxygen demand 5-day	00310	mg/L	—	—	—	—	1	1.4	1.4	1.4
pH, field	00400	standard units	33	7.1	8	9	33	7.5	8.1	8.6
pH, laboratory	00403	standard units	—	—	—	—	—	—	—	—
Acid neutralizing capacity	00410	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Residue, filtered	00515	mg/L	—	—	—	—	—	—	—	—
Residue, total nonfilterable	00530	mg/L	38	<2	5	74	36	<2	<2	70
Nitrogen, total	00600	mg/L as N	—	—	—	—	—	—	—	—
Ammonia, dissolved	00608	mg/L as N	—	—	—	—	1	.08	.08	.08
Ammonia, total	00610	mg/L as N	—	—	—	—	—	—	—	—
Nitrite, total	00615	mg/L as N	—	—	—	—	—	—	—	—
Nitrite, dissolved	00618	mg/L as N	36	<.04	3.06	3.63	34	<.04	3.31	6.54
Nitrate, total	00620	mg/L as N	38	<.04	3.01	3.78	36	<.04	3.32	6.8
Ammonia + organic nitrogen	00625	mg/L as N	—	—	—	—	1	.41	.41	.41
Phosphate, total	00650	mg/L as PO_4	—	—	—	—	1	.71	.71	.71
Orthophosphate, dissolved	00660	mg/L as PO_4	—	—	—	—	1	.48	.48	.48
Phosphorous, total	00665	mg/L as P	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00671	mg/L as P	38	<.01	.011	.031	35	<.01	.023	.051
Organic carbon, total	00680	mg/L as C	38	<1.0	1.1	1.8	36	<1.0	1.3	2.4
Organic carbon, dissolved	00681	mg/L as C	38	<1.0	1.3	2	36	<1.0	1.4	2
Hardness, total	00900	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Calcium, dissolved	00915	mg/L	—	—	—	—	—	—	—	—
Calcium, total	00916	mg/L	—	—	—	—	—	—	—	—
Magnesium, dissolved	00925	mg/L	—	—	—	—	—	—	—	—
Magnesium, total	00927	mg/L	—	—	—	—	—	—	—	—
Chloride, dissolved	00940	mg/L	38	<1.0	33	42	36	<1.0	32.5	38
Sulfate, dissolved	00945	mg/L as SO_4	—	—	—	—	—	—	—	—
Copper, dissolved	01040	∝g/L	38	<4.0	<4.0	10	37	<4.0	<4.0	58
Copper, total	01042	∝g/L	38	<4.0	<4.0	10	36	<4.0	<4.0	18.2
Iron, total	01045	∝g/L	—	—	—	—	—	—	—	—
Iron, dissolved	01046	∝g/L	—	—	—	—	—	—	—	—
Lead, dissolved	01049	∝g/L	38	<1.0	<1.0	1	35	<1.0	<1.0	2.6
Lead, total	01051	∝g/L	38	<1.0	<1.0	1.6	35	<1.0	<1.0	1.6
Manganese, total	01055	∝g/L	—	—	—	—	—	—	—	—
Manganese, dissolved	01056	∝g/L	—	—	—	—	1	20	20	20
Nickel, total	01067	∝g/L	—	—	—	—	—	—	—	—
Zinc, dissolved	01090	∝g/L	38	<10.	<10	15	37	<10.	<10.	498
Zinc, total	01092	∝g/L	38	<10.	<10	11	36	<10.	10	499
Aluminum, total	01105	∝g/L	—	—	—	—	—	—	—	—
Petroleum hydrocarbons, total	45501	∝g/L	37	<5.0	<5.0	9.6	35	<5.0	<5.0	9.3
Orthophosphate, total	70507	mg/L as P	37	<.01	.015	.042	35	<.01	.031	.053
Nitrate, dissolved	71851	mg/L as NO_3	—	—	—	—	1	12	12	12
Suspended sediment	80154	mg/L	—	—	—	—	—	—	—	—
Turbidity, total, laboratory	82079	NTU	38	<1.0	1.915	8.14	36	<1.0	2.16	6.34

Table 18. Summary of surface-water quality data through May 2003 for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[n, number of samples; —, no data; <, less than; deg C, degrees Celsius; ft^3/s, cubic feet per second; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; NTU, Nephelometric turbidity units; Data sources: Spring Creek Watershed Community, period ending February 2002; Pennsylvania Department of Environmental Resources, period ending May 2003; U.S. Geological Survey, period ending November 2002]

Constituent or characteristic	Parameter code	Units	Data-collection site name							
			Upper Spring Creek				Lower Thompson Run			
			n	Minimum	Median	Maximum	n	Minimum	Median	Maximum
Water temperature	00010	deg C	35	5.3	10.4	13.6	34	7.4	12.2	16.2
Discharge	00060	ft^3/s	—	—	—	—	—	—	—	—
Discharge, instantaneous	00061	ft^3/s	—	—	—	—	—	—	—	—
Specific conductance	00095	∝S/cm	—	—	—	—	—	—	—	—
Dissolved oxygen	00300	mg/L	35	8.5	10.6	13.8	34	10	11.8	16.1
Biological oxygen demand 5-day	00310	mg/L	—	—	—	—	—	—	—	—
pH, field	00400	standard units	33	6.7	7.3	7.8	33	6.9	7.9	8.4
pH, laboratory	00403	standard units	—	—	—	—	—	—	—	—
Acid neutralizing capacity	00410	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Residue, filtered	00515	mg/L	—	—	—	—	—	—	—	—
Residue, total nonfilterable	00530	mg/L	41	<2	8	86	38	<2	8	64
Nitrogen, total	00600	mg/L as N	—	—	—	—	—	—	—	—
Ammonia, dissolved	00608	mg/L as N	1	<.02	<.02	<.02	—	—	—	—
Ammonia, total	00610	mg/L as N	1	<.02	<.02	<.02	—	—	—	—
Nitrite, total	00615	mg/L as N	1	<.01	<.01	<.01	—	—	—	—
Nitrite, dissolved	00618	mg/L as N	38	<.04	2.46	3.68	36	<.04	3.99	7.74
Nitrate, total	00620	mg/L as N	41	<.04	2.43	4.25	38	<.04	4.04	7.48
Ammonia + organic nitrogen	00625	mg/L as N	—	—	—	—	—	—	—	—
Phosphate, total	00650	mg/L as PO_4	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00660	mg/L as PO_4	—	—	—	—	—	—	—	—
Phosphorous, total	00665	mg/L as P	—	—	—	—	—	—	—	—
Orthophosphate, dissolved	00671	mg/L as P	41	<.01	<.01	.037	38	<.01	.019	.041
Organic carbon, total	00680	mg/L as C	41	<1.0	<1.0	3.4	38	<1.0	<1.0	2
Organic carbon, dissolved	00681	mg/L as C	40	<1.0	1	1.7	38	<1.0	1.1	2.9
Hardness, total	00900	mg/L as $CaCO_3$	—	—	—	—	—	—	—	—
Calcium, dissolved	00915	mg/L	—	—	—	—	—	—	—	—
Calcium, total	00916	mg/L	—	—	—	—	—	—	—	—
Magnesium, dissolved	00925	mg/L	—	—	—	—	—	—	—	—
Magnesium, total	00927	mg/L	—	—	—	—	—	—	—	—
Chloride, dissolved	00940	mg/L	41	<1.0	15	19	38	<1.0	53	68
Sulfate, dissolved	00945	mg/L as SO_4	—	—	—	—	—	—	—	—
Copper, dissolved	01040	∝g/L	41	<4.0	<4.0	10	38	<4.0	<4.0	10
Copper, total	01042	∝g/L	41	<4.0	<4.0	11.6	38	<4.0	<4.0	31
Iron, total	01045	∝g/L	—	—	—	—	—	—	—	—
Iron, dissolved	01046	∝g/L	—	—	—	—	—	—	—	—
Lead, dissolved	01049	∝g/L	41	<1.0	<1.0	1	38	<1.0	<1.0	1
Lead, total	01051	∝g/L	41	<1.0	<1.0	1	38	<1.0	<1.0	1.4
Manganese, total	01055	∝g/L	—	—	—	—	—	—	—	—
Manganese, dissolved	01056	∝g/L	—	—	—	—	—	—	—	—
Nickel, total	01067	∝g/L	—	—	—	—	—	—	—	—
Zinc, dissolved	01090	∝g/L	41	<10.	<10.	10	38	<10.	<10.	13
Zinc, total	01092	∝g/L	41	<10.	<10.	53	38	<10.	<10.	16
Aluminum, total	01105	∝g/L	—	—	—	—	—	—	—	—
Petroleum hydrocarbons, total	45501	∝g/L	38	<5.0	<5.0	9	37	<5.0	<5.0	16.8
Orthophosphate, total	70507	mg/L as P	41	<.01	.01	.31	38	<.01	.023	.054
Nitrate, dissolved	71851	mg/L as NO_3	—	—	—	—	—	—	—	—
Suspended sediment	80154	mg/L	—	—	—	—	—	—	—	—
Turbidity, total, laboratory	82079	NTU	41	<1.0	<1.0	4.9	38	<1.0	1.64	4.49

Table 19. Inventory of surface-water-quality data for the Spring Creek Basin, Centre County, Pennsylvania.

[PaDEP, Pennsylvania Department of Environmental Protection; USGS, U.S. Geological Survey; --, not applicable; BOD, biochemical oxygen demand; ft^3/s, cubic feet per second; JTU, Jackson turbidity unit; ∝g/L, micrograms per liter; mg/L, milligrams per liter; NTU, nephelometric turbidity units]

Sampling locations	Site identifier (Spring Creek Watershed Community, PaDEP, USGS)	Constituent	Parameter code	Units of measure	Period of data	Comments
Spring Creek near Axemann, Pa.	SPA, WQN415, 01546500	Water temperature	00010	degrees Celsius	5/22/1962 to present	
		Streamflow, daily mean	00060	ft^3/s	3/22/1950 to 9/26/1994	
		Streamflow, instantaneous	00061	ft^3/s	8/7/1975 to 11/9/1999	
		Turbidity	00070	JTU	10/29/1975 to 7/27/1976	
		Specific conductance	00095	∝S/cm	1/6/1970 to present	
		Dissolved oxygen	00300	mg/L	5/22/1962 to present	Sporadic: 10/3/1965 to 1/22/1978
		BOD, 5-day	00310	mg/L	1/27/1970 to 6/19/1970	
		pH, field	00400	standard units	5/22/1962 to present	Sporadic: 10/3/1965 to 6/19/1968
		pH, laboratory	00403	standard units	3/22/1950 to present	Sporadic: 10/3/1965 to 9/24/1970
		Alkalinity	00410	mg/L as $CaCO_3$	3/22/1950 to present	Sporadic: 10/3/1965 to 9/24/1971
		Residue, total filterable	00515	mg/L	11/16/1976 to present	No data: 12/9/1987 to 9/19/1990
		Residue, total nonfilterable	00530	mg/L	5/22/1962 to present	Sporadic: 10/3/1965 to 6/3/1992
		Nitrogen, total	00600	mg/L as N	4/17/2002 to present	
		Ammonia, total	00610	mg/L as N	10/2/1972 to present	
		Nitrite, total	00615	mg/L as N	10/2/1972 to present	
		Nitrate, total	00620	mg/L as N	10/2/1972 to present	
		Nitrate, dissolved	71851	mg/L as NO_3	3/23/1968 to 11/10/1971	Sporadic, 10 samples
		Phosphate, total	00650	mg/L as PO_4	1970, 2002	1970: 8 samples, 2002 4 samples
		Orthophosphate, dissolved	00660	mg/L as PO_4	1970	1970: 8 samples
		Phosphorus, total	00665	mg/L as P	10/2/1972 to present	
		Orthophosphate, dissolved	00671	mg/L as P	4/6/1999 to present	
		Orthophosphate, total	70507	mg/L as P	4/6/1999 to present	

Table 19. Inventory of surface-water-quality data for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[PaDEP, Pennsylvania Department of Environmental Protection; USGS, U.S. Geological Survey; --, not applicable; BOD, biochemical oxygen demand; ft^3/s, cubic feet per second; JTU, Jackson turbidity unit; ∝g/L, micrograms per liter; mg/L, milligrams per liter; NTU, nephelometric turbidity units]

Sampling locations	Site identifier (Spring Creek Watershed Community, PaDEP, USGS)	Constituent	Parameter code	Units of measure	Period of data	Comments
		Organic carbon, total	00680	mg/L as C	11/10/1971 to Present	Sporadic: 11/10/1971 to 1/12/1988
		Hardness	00900	mg/L as $CaCO_3$	5/22/1962 to Present	
		Calcium, dissolved	00915	mg/L	3/23/1968 to 7/27/1976	Sporadic
		Calcium, total	00916	mg/L	11/29/1977 to Present	No data: 11/4/1987 to 10/5/1998
		Magnesium, dissolved	00925	mg/L	3/27/1968 to 7/27/1976	Sporadic
		Magnesium, total	00927	mg/L	11/29/1977 to Present	No data: 11/4/1987 to 10/5/1998
		Chloride, dissolved	00940	mg/L	5/22/1962 to 12/8/1997	Sporadic: 5/22/1962 to 7/27/1976
		Sulfate, dissolved	00945	mg/L as SO_4	3/22/1950 to Present	Sporadic: 7/23/1965 to 9/24/1970
		Copper, dissolved	01040	∝g/L	4/6/1999 to Present	
		Copper, total	01042	∝g/L	4/6/1999 to Present	
		Iron, total	01045	∝g/L	10/29/1975 to 7/27/1976	
		Lead, dissolved	01049	∝g/L	4/6/1999 to Present	
		Lead, total	01051	∝g/L	4/6/1999 to Present	
		Zinc, dissolved	01090	∝g/L	4/6/1999 to Present	
		Zinc, total	01092	∝g/L	4/6/1999 to Present	
		Petroleum hydrocarbons	45501	∝g/L	4/6/1999 to Present	
		Sediment, suspended	80154	∝g/L	10/3/1965 to 5/3/1968	
		Turbidity	82079	NTU	4/6/1999 to Present	
Lower Cedar Run	CEL, --, --	Water temperature	00010	degrees Celsius	4/6/1999 to Present	
Upper Slab Cabin Run	SLU, --, --	Dissolved oxygen	00300	mg/L	4/6/1999 to Present	
Upper Spring Creek	SPU, --, --	pH, field	00400	standard units	4/6/1999 to Present	
		Alkalinity	00410	mg/L as $CaCO_3$	4/6/1999 to Present	

Table 19. Inventory of surface-water-quality data for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[PaDEP, Pennsylvania Department of Environmental Protection; USGS, U.S. Geological Survey; --, not applicable; BOD, biochemical oxygen demand; ft^3/s, cubic feet per second; JTU, Jackson turbidity unit; ∝g/L, micrograms per liter; mg/L, milligrams per liter; NTU, nephelometric turbidity units]

Sampling locations	Site identifier (Spring Creek Watershed Community, PaDEP, USGS)	Constituent	Parameter code	Units of measure	Period of data	Comments
		Residue, total nonfilterable	00530	mg/L	4/6/1999 to Present	
		Nitrate, total	00620	mg/L as N	4/6/1999 to Present	
		Orthophosphate, dissolved	00671	mg/L as P	4/6/1999 to Present	
		Orthophosphate, total	70507	mg/L as P	4/6/1999 to Present	
		Organic carbon, total	00680	mg/L as C	4/6/1999 to Present	
		Calcium, dissolved	00915	mg/L	4/6/1999 to Present	
		Chloride, dissolved	00940	mg/L	4/6/1999 to Present	
		Copper, dissolved	01040	∝g/L	4/6/1999 to Present	
		Copper, total	01042	∝g/L	4/6/1999 to Present	
		Lead, dissolved	01049	∝g/L	4/6/1999 to Present	
		Lead, total	01051	∝g/L	4/6/1999 to Present	
		Zinc, dissolved	01090	∝g/L	4/6/1999 to Present	
		Zinc, total	01092	∝g/L	4/6/1999 to Present	
		Petroleum hydrocarbons	45501	mg/L	4/6/1999 to Present	
		Turbidity	82079	NTU	4/6/1999 to Present	
Lower Buffalo Run	BUL, --, --	Water temperature	00010	degrees Celsius	5/13/1999 to Present	
Upper Buffalo Run	BUU, --, --	Dissolved oxygen	00300	mg/L	5/13/1999 to Present	
Lower Logan Branch	LOL, --, --	pH, field	00400	standard units	5/13/1999 to Present	
Upper Logan Branch	LOU, --, --	Alkalinity	00410	mg/L as $CaCO_3$	5/13/1999 to Present	
Lower Slab Cabin Run	SLL, --, --	Residue, total nonfilterable	00530	mg/L	5/13/1999 to Present	
Spring Creek at Houserville, Pa.	SPH, --, 01546400	Nitrate, total	00620	mg/L as N	5/13/1999 to Present	
Spring Creek at Milesburg, Pa.	SPM, --, 01547100	Orthophosphate, dissolved	00671	mg/L as P	5/13/1999 to Present	

Table 19. Inventory of surface-water-quality data for the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[PaDEP, Pennsylvania Department of Environmental Protection; USGS, U.S. Geological Survey; --, not applicable; BOD, biochemical oxygen demand; ft^3/s, cubic feet per second; JTU, Jackson turbidity unit; ∝g/L, micrograms per liter; mg/L, milligrams per liter; NTU, nephelometric turbidity units]

Sampling locations	Site identifier (Spring Creek Watershed Community, PaDEP, USGS)	Constituent	Parameter code	Units of measure	Period of data	Comments
Lower Thompson Run	THL, --, --	Orthophosphate, total	70507	mg/L as P	5/13/1999 to Present	
		Organic carbon, total	00680	mg/L as C	5/13/1999 to Present	
		Calcium, dissolved	00915	mg/L	5/13/1999 to Present	
		Chloride, dissolved	00940	mg/L	5/13/1999 to Present	
		Copper, dissolved	01040	∝g/L	5/13/1999 to Present	
		Copper, total	01042	∝g/L	5/13/1999 to Present	
		Lead, dissolved	01049	∝g/L	5/13/1999 to Present	
		Lead, total	01051	∝g/L	5/13/1999 to Present	
		Zinc, dissolved	01090	∝g/L	5/13/1999 to Present	
		Zinc, total	01092	∝g/L	5/13/1999 to Present	
		Petroleum hydrocarbons	45501	mg/L	5/13/1999 to Present	
		Turbidity	82079	NTU	5/13/1999 to Present	

Table 20. Summary of inorganic ground-water-quality data for the Spring Creek Basin.

[mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; Ca, calcium; Mg, magnesium; K, potassium; Na, sodium; Br, bromine; Cl, chlorine; F, fluorine; SO_4, sulfate; N, nitrogen; P, phosphorus; CO_2, carbon dioxide; DOC, dissolved organic carbon; C, carbon; TOC, total organic carbon; —, no data; <, less than]

Well number	Date sampled	Well depth (feet)	Noncarbonate hardness (mg/L as $CaCO_3$)	Total hardness (mg/L as $CaCO_3$)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Br (mg/L)	Cl (mg/L)	F mg/L)	SO_4 (mg/L)	Dissolved solids (mg/L)	Nitrogen (mg/L as N)	Nitrate (mg/L as N)	Phosphate (mg/L as P)	CO_2 (mg/L as CO_2)	DOC (mg/L as C)	TOC (mg/L as C)
CE 12	07/16/34	110	18	150	32	17	—	—	—	0.8	0.1	20	—	—	0	—	—	—	—
CE 25	06/14/34	301	5	51	14	3.8	0.7	1.3	—	.6	0	6.3	60	—	.05	—	—	—	—
	06/10/85	210	—	230	60.5	18.7	.9	15.1	—	66	<.1	< 10	—	—	10.3	0.003	15	—	—
CE 46	06/14/34	365	37	230	49	27	1.2	5.4	—	10	0	12	249	—	4.5	—	—	—	—
CE 47	06/14/34	609	28	190	43	21	1.1	3.5	—	4.8	0	9.4	208	—	4.1	—	—	—	—
CE 99	06/20/68	310	10	110	—	—	—	—	—	2.5	—	6.5	—	—	.8	—	6.2	—	—
CE 133	06/12/68	219	20	290	—	—	—	—	—	10	—	9.5	—	—	1.3	—	33	—	—
CE 214	09/09/69	29	20	33	—	—	—	—	—	8	0	2	—	—	4.5	.03	32	—	—
CE 216	07/12/67	75	0	20	—	—	—	—	—	2	0	1.5	—	—	0	0	61	—	—
	06/17/85	65	—	290	66.7	29	8.7	2.6	—	18	<.1	26	396	—	12.7	.003	38	—	—
CE 258	10/08/80	326	—	260	52	32	.9	1.1	—	4	<.1	10	258	—	1.9	—	19	—	—
CE 291	10/22/80	326	—	180	33	23	1	2.5	—	10	.2	10	191	—	2	—	13	—	8
CE 296	10/21/80	210	—	240	64	39	1.3	5.1	—	16	.3	15	323	—	5.9	—	10	—	3
CE 299	06/18/85	180	—	290	66.8	29	1.5	4.5	—	21	.2	32	334	—	6.6	.003	15	—	—
CE 324	10/22/80	135	—	200	58	35	2	10	—	29	<0.1	20	316	—	4	—	1.8	—	1
CE 326	10/22/80	83	—	220	—	17	2	2.1	—	11	.2	95	—	—	1.5	—	3.9	—	—
	03/23/71	278	21	190	—	—	—	—	—	8	0	6	—	—	2.4	—	6.6	—	—
CE 334	10/23/80	205	—	110	22	12	2	2.3	—	2	.1	15	116	—	.1	—	4.9	—	1
CE 396	11/30/00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 410	06/12/85	218	—	270	68.8	23.7	.9	12.8	—	4	.1	< 10	—	—	1.4	.002	3.5	—	—
CE 411	06/12/85	145	—	130	32.2	11.5	.9	7.4	—	27	<.1	17	256	—	5.5	.002	14	—	—
CE 414	06/20/85	125	—	260	66.7	23.1	.3	5.9	—	17	.1	31	304	—	3.5	.002	15	—	—
CE 418	06/20/85	300	—	270	60.2	29	<.1	1.7	—	5	.2	27	—	—	1.3	.002	20	—	—
CE 421	06/19/85	173	—	220	66.7	13.2	.3	1.5	—	6	<.1	28	252	—	3.5	<.002	12	—	—
CE 426	06/19/85	166	—	280	65.2	29	.2	7	—	66	.1	59	329	—	1.5	<.002	6.2	—	—
CE 438	06/12/85	150	—	300	64.5	34.7	1.17	13.3	—	42	.1	37	363	—	5.06	.003	15	—	—
CE 447	06/20/85	150	—	140	45.5	5.3	<0.1	1.6	—	2	0.1	22	—	—	1.1	0.002	5.1	—	—

Table 20. Summary of inorganic ground-water-quality data for the Spring Creek Basin. —Continued

[mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; Ca, calcium; Mg, magnesium; K, potassium; Na, sodium; Br, bromine; Cl, chlorine; F, fluorine; SO_4, sulfate; N, nitrogen; P, phosphorus; CO_2, carbon dioxide; DOC, dissolved organic carbon; C, carbon; TOC, total organic carbon; —, no data; <, less than]

Well number	Date sampled	Well depth (feet)	Noncarbonate hardness (mg/L as $CaCO_3$)	Total hardness (mg/L as $CaCO_3$)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Br (mg/L)	Cl (mg/L)	F mg/L)	SO_4 (mg/L)	Dissolved solids (mg/L)	Nitrogen (mg/L as N)	Nitrate (mg/L as N)	Phosphate (mg/L as P)	CO_2 (mg/L as CO_2)	DOC (mg/L as C)	TOC (mg/L as C)
	06/10/85	223	—	140	39.4	9.1	.7	.3	—	5	.1	< 10	—	—	8.4	.003	.8	—	—
CE 494	06/27/85	201	—	330	70.4	36.4	.6	12.3	—	30	.1	38	377	—	3.7	.005	28	—	—
CE 531	05/02/67	322	48	72	—	—	—	—	—	5	0	42	—	—	.3	0	1.8	—	—
	07/16/80	210	—	200	52	20	—	1	—	8	<.1	20	—	—	5.1	—	6.1	—	26
	08/09/94	210	—	260	62	25	1.4	3.5	0.01	11	.2	18	290	—	—	<.01	11	0.3	—
	11/16/71	130	5	100	22	11	1.1	2.5	—	1.9	.1	1.9	104	—	.11	.04	1.9	—	—
CE 640	06/18/85	206	—	290	66.7	29	.7	1.4	—	10	.2	50	366	—	7.9	<.002	18	—	—
CE 655	09/12/90	206	—	310	72	32	1.2	13	—	44	.2	23	356	4.8	—	—	16	—	.3
CE 657	09/12/90	115	—	310	72	31	1.9	13	—	35	.2	24	347	5.5	—	—	18	—	.4
CE 659	09/12/90	67	—	380	82	42	2.8	24	—	71	.2	57	473	9.4	—	—	25	—	.7
CE 661	09/12/90	45	—	270	72	21	1.1	7.9	—	18	.3	23	295	3.9	—	—	12	—	.7
CE 681	08/03/98	290	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 683	08/04/98	299	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 685	09/20/00	273	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 21. Summary of metals and radon concentrations in ground water for the Spring Creek Basin.

[∝g/L, micrograms per liter; Al, aluminum; As, arsenic; Ba, barium; Cd, cadmium; Cr, chromium; Cu, copper; Fe, iron; Pb, lead; Mn, manganese; Ni, nickel; Sr, strontium; Zn, zinc; pCi/L, picocuries per liter; —, no data; <, less than]

Well number	Date sampled	Well depth (feet)	Al (∝g/L)	As (∝g/L)	Ba (∝g/L)	Cd (∝g/L)	Cr (∝g/L)	Cu (∝g/L)	Fe (∝g/L)	Pb (∝g/L)	Mn (∝g/L)	Ni (∝g/L)	Sr (∝g/L)	Zn (∝g/L)	Radon (pCi/L)
CE 12	07/16/34	110	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 25	06/14/34	301	—	—	—	—	—	—	10	—	—	—	—	—	—
	06/10/85	210	< 35	< 500	22	< 10	< 50	—	90	< 45	< 10	< 25	< 10	< 10	—
CE 46	06/14/34	365	—	—	—	—	—	—	30	—	—	—	—	—	—
CE 47	06/14/34	609	—	—	—	—	—	—	30	—	—	—	—	—	—
CE 99	06/20/68	310	—	—	—	—	—	—	40	—	—	—	—	—	—
CE 133	06/12/68	219	—	—	—	—	—	—	400	—	—	—	—	—	—
CE 214	09/09/69	29	—	—	—	0	0	—	40	—	10	—	—	20	—
CE 216	07/12/67	75	—	—	—	—	—	—	0	—	—	—	—	—	—
	06/17/85	65	< 35	< 500	49	< 10	< 50	—	< 10	< 45	< 10	< 25	< 10	< 10	—
CE 258	10/08/80	326	60	< 5	—	< 1	< 10	10	30	< 5	10	< 10	—	< 10	—
CE 291	10/22/80	326	80	< 5	—	< 1	< 10	—	10	< 5	< 10	—	—	10	—
CE 296	10/21/80	210	20	< 5	—	< 1	< 10	80	60	< 5	10	—	—	140	—
CE 299	06/18/85	180	< 35	< 500	53	< 10	< 50	—	50	< 45	< 10	25	< 10	< 10	—
CE 324	10/22/80	135	30	< 5	—	< 1	< 10	10	50	< 5	—	< 10	—	10	—
CE 326	10/22/80	83	60	< 5	—	< 1	< 10	—	30	< 5	—	—	—	160	—
	03/23/71	278	—	—	—	—	—	—	300	—	10	—	—	—	—
CE 334	10/23/80	205	50	—	—	< 1	—	—	60	—	10	—	—	20	—
CE 396	11/30/00	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 410	06/12/85	218	< 35	< 500	65	10	< 50	—	30	< 45	< 10	< 25	< 10	< 10	—
CE 411	06/12/85	145	< 35	8.8	63	—	< 50	—	30	—	< 10	—	< 10	20	—
CE 414	06/20/85	125	< 35	< 500	47	< 10	< 50	—	< 10	< 45	< 10	< 25	< 10	< 10	—
CE 418	06/20/85	300	< 35	< 500	53	< 10	< 50	—	50	< 45	< 10	< 25	< 10	< 10	—
CE 421	06/19/85	173	< 35	< 500	12	< 10	< 50	—	150	< 45	< 10	< 25	< 10	< 10	—
CE 426	06/19/85	166	< 35	< 500	67	< 10	< 50	—	140	< 45	< 10	< 25	< 10	< 10	—
CE 438	06/12/85	150	< 35	< 500	30	< 10	< 50	—	< 10	< 45	< 10	< 25	< 10	< 10	—
CE 447	06/20/85	150	< 35	< 500	26	< 10	< 50	—	1070	< 45	< 10	< 25	< 10	< 10	—
	06/10/85	223	< 35	< 500	16	< 10	< 50	—	240	< 45	< 10	< 25	< 10	< 10	—
CE 494	06/27/85	201	< 35	< 500	83	< 10	< 50	—	< 10	< 45	< 10	< 25	440	< 10	—
CE 531	05/02/67	322	—	—	—	—	—	—	0	—	—	—	—	—	—

Table 21. Summary of metals and radon concentrations in ground water for the Spring Creek Basin.—Continued

[∝g/L, micrograms per liter; Al, aluminum; As, arsenic; Ba, barium; Cd, cadmium; Cr, chromium; Cu, copper; Fe, iron; Pb, lead; Mn, manganese; Ni, nickel; Sr, strontium; Zn, zinc; pCi/L, picocuries per liter; —, no data; <, less than]

Well number	Date sampled	Well depth (feet)	Al (∝g/L)	As (∝g/L)	Ba (∝g/L)	Cd (∝g/L)	Cr (∝g/L)	Cu (∝g/L)	Fe (∝g/L)	Pb (∝g/L)	Mn (∝g/L)	Ni (∝g/L)	Sr (∝g/L)	Zn (∝g/L)	Radon (pCi/L)
	07/16/80	210	10	< 10	—	< 3	< 10	—	220	< 50	—	—	—	30	—
	08/09/94	210	—	—	—	—	—	—	< 3	—	< 1	—	40	—	430
	11/16/71	130	—	—	—	—	—	—	20	—	0	—	—	—	—
CE 640	06/18/85	206	< 35	< 500	33	< 10	< 50	—	370	< 45	< 10	< 25	< 10	30	—
CE 655	09/12/90	206	—	—	—	—	—	—	—	—	—	—	110	—	—
CE 657	09/12/90	115	—	—	—	—	—	—	—	—	—	—	240	—	—
CE 659	09/12/90	67	—	—	—	—	—	—	—	—	—	—	110	—	—
CE 661	09/12/90	45	—	—	—	—	—	—	—	—	—	—	570	—	—
CE 681	08/03/98	290	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 683	08/04/98	299	—	—	—	—	—	—	—	—	—	—	—	—	—
CE 685	09/20/00	273	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 22. Summary of organic pesticides measured in ground water for the Spring Creek Basin.

[ft, feet; ∝g/L, micrograms per liter; <, less than; E, estimated; —, no data]

Well number	Date sampled	Well depth (ft)	Acifluorfen (∝g/L)	Alachlor (∝g/L)	Atrazine (∝g/L)	Metolachlor (∝g/L)	Prometon (∝g/L)	Simazine (∝g/L)
CE 531	08/09/94	210	0.04	0.023	0.122	< 0.002	E 0.01	0.006
CE 681	08/03/98	290	—	.002	.052	<.002	.04	.013
CE 683	08/04/98	299	—	.002	.117	.008	<.02	.021

Table 23. Summary of general ground-water-quality data for the Spring Creek Basin.
[ft, feet; mg/L, milligrams per liter; °C, degrees Celsius; —, no data; <, less than]

Well number	Date sampled	Well depth (ft)	Dissolved oxygen (mg/L)	pH, field (standard units)	Specific conductance at 25°C	Temperature (°C)
CE 12	07/16/34	110	—	—	—	—
CE 25	06/14/34	301	—	—	—	—
	06/10/85	210	—	7.4	640	10.5
CE 46	06/14/34	365	—	—	—	11.7
CE 47	06/14/34	609	—	—	—	—
CE 99	06/20/68	310	—	7.5	—	10
CE 133	06/12/68	219	—	7.2	—	12
CE 214	09/09/69	29	9	5.9	60	9.5
CE 216	07/12/67	75	—	6	—	—
	06/17/85	65	—	7.2	750	11
CE 258	10/08/80	326	—	7.4	310	9.5
CE 291	10/22/80	326	—	7.4	430	—
CE 296	10/21/80	210	—	7.7	650	10
CE 299	06/18/85	180	—	7.5	610	11
CE 324	10/22/80	135	—	8.4	430	14
CE 326	10/22/80	83	—	7.9	430	14
	03/23/71	278	—	7.7	—	—
CE 334	10/23/80	205	—	7.6	230	12
CE 396	11/30/00	—	11.7	7.5	298	11.8
CE 410	06/12/85	218	—	7.9	308	10
CE 411	06/12/85	145	—	7.5	565	10
CE 414	06/20/85	125	—	7.5	575	11
CE 418	06/20/85	300	—	7.4	515	11
CE 421	06/19/85	173	—	7.5	455	11
CE 426	06/19/85	166	—	7.7	620	11
CE 438	06/12/85	150	—	7.5	670	11
CE 447	06/20/85	150	—	7.7	285	11
	06/10/85	223	—	8.5	320	10
CE 494	06/27/85	201	—	7.3	690	10.5
CE 531	05/02/67	322	—	7.4	—	—
	07/16/80	210	—	7.8	420	10.5
	08/09/94	210	7.5	7.6	520	12.5
	11/16/71	130	—	8	186	—
CE 640	06/18/85	206	—	7.5	660	11
CE 655	09/12/90	206	—	7.5	676	10.1
CE 657	09/12/90	115	—	7.4	660	10.2
CE 659	09/12/90	67	—	7.3	872	10.1
CE 661	09/12/90	45	—	7.5	546	9.5
CE 681	08/03/98	290	5.3	7.1	714	11.7
CE 683	08/04/98	299	10.5	7.4	630	11.5
CE 685	09/20/00	273	6.6	7.1	1360	12.9

Table 24. Summary of fecal-indicator bacteria measured in ground water for the Spring Creek Basin.

[ft, feet; MPN/100 mL; most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; —, no data; E, estimated; <, less than]

Well number	Date sampled	Well depth (ft)	*Escherichia coli* (MPN/ 100 mL)	Entero-cocci (MPN/ 100 mL)	Fecal strepto-cocci (col/100 mL)
CE 396	11/30/00	—	—	22	—
CE 531	08/09/94	210	—	—	E 6
CE 685	09/20/00	273	< 1	< 1	—

Table 25. Summary of water-quality data for selected springs in the Spring Creek Basin, Centre County, Pennsylvania.

[ft, feet; gal/min, gallons per minute; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; >, greater than; —, no data; <, less than]

Local identification number	Name	Date	Time	Aquifer	Depth below land surface (ft) (P72019)	Elevation of land surface (ft) (P72000)	Flow rate (gal/min) (P00059)	Field pH (standard units) (P00400)	Lab pH (standard units) (P00403)
CE SP1	Thompson Spring	11/9/1971	1230	Axemann Formation	0	1,010	5,060	7.8	—
CE SP11	Blue Shutgart Spring	8/13/1985	1820	Loysburg Formation	—	900	—	7.5	6.9
CE SP12	Blue Shutgart Spring	11/9/1971	1530	Loysburg Formation	0	900	—	7.7	—
CE SP16	Forked Spring or Paradise Spring	11/10/1971	1230	Gatesburg Formation	0	830	—	7.7	—
CE SP16	Forked Spring or Paradise Spring	8/12/1944	1200	Gatesburg Formation	0	830	2,580	7.6	—
CE SP17	Axemann Spring	11/10/1971	1415	Nittany Formation	0	840	2,030	7.8	—
CE SP17	Axemann Spring	8/8/1985	1200	Nittany Formation	—	840	—	7.4	7.6
CE SP18	Benner (Rock) Spring	8/12/1944	1200	Miners Member of Gatesburg Formation	0	910	7,300	7.8	—
CE SP18	Benner (Rock) Spring	11/10/1971	1000	Miners Member of Gatesburg Formation	0	910	—	7.7	—
CE SP18	Benner (Rock) Spring	8/15/1985	1200	Miners Member of Gatesburg Formation	—	910	—	7.5	7
CE SP19	Kelly Spring	8/12/1944	1200	Nittany Formation	0	765	3,000	7.7	—
CE SP19	Kelly Spring	11/10/1971	1545	Nittany Formation	0	765	—	7.9	—
CE SP19	Kelly Spring	8/8/1985	1015	Nittany Formation	—	765	—	8	7.8
CE SP2		5/10/1963	1200	Nittany Formation	0	1,000	520	7.6	—
CE SP2		11/9/1971	1100	Nittany Formation	0	1,000		7.9	—
CE SP27	Bathgate #2 Spring	5/21/1969	1200	Nittany Formation	0	970	500	7.2	—
CE SP32		8/7/1985	1445	Nealmont Formation Undifferentiated	—	1,125	—	7.6	7.2
CE SP5	Big Spring	11/11/1971	0800	Axemann Formation	0	740	—	7.8	—
CE SP5	Big Spring	7/10/1934	1200	Axemann Formation	0	740	18	—	—
CE SP5	Big Spring	2/7/1968	1220	Axemann Formation	0	740	12,000	7.5	—

Table 25. Summary of water-quality data for selected springs in the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[ft, feet; gal/min, gallons per minute; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; >, greater than; —, no data; <, less than]

Local identification number	Specific conductance (∝S/cm) (P00095)	Water temperature (°C) (00010)	Noncarbonate (mg/L as $CaCO_3$) (P00902)	Potassium, dissolved (mg/L as K) (P00900)	Magnesium, dissolved (mg/L as Mg) (P00915)	Calcium, dissolved (mg/L as Ca) (P00925)	Hardness, total (mg/L as $CaCO_3$) (P00935)	Sodium + potassium (mg/L as Na) (P00933)	Sodium, dissolved (mg/L as Na) (P00930)	Alkalinity (P90410)	Alkalinity (P00410)
CE SP1	475	12	—	220	57	18.6	0.33	—	1.55	198	—
CE SP11	446	10	25	210	51	21	—	5.5	—	—	189
CE SP12	—	—	30	260	—	—	—	—	—	—	225
CE SP16	572	11	39	260	60	26	—	8.7	—	—	218
CE SP16	—	12	47	260	—	—	—	2.3	—	—	213
CE SP17	287	10	10	150	37	14	—	2.9	—	—	140
CE SP17	345	10	66	160	46	12	—	2.1	—	—	98
CE SP18	395	12	—	170	40.2	16.9	.63	—	3.8	156	—
CE SP18	450	11	—	210	64.9	11.7	.72	—	4.36	172	—
CE SP18	468	10	0	140	39	11	—	40	—	—	163
CE SP19	468	10	28	210	51	20	—	8.5	—	—	182
CE SP19	367	11.5	13	190	46	19	—	4.1	—	—	180
CE SP19	535	10	52	280	67	27	—	1.4	—	—	226
CE SP2	600	12	—	290	67.4	30.6	.63	—	4.3	242	—
CE SP2	272	—	5	140	32	14	—	4.8	—	—	132
CE SP27	299	—	0	110	27	11	—	23	—	—	130
CE SP32	310	12	—	130	29.2	13.9	.4	—	3.31	132	—
CE SP5	262	10	6	120	27	13	—	8.7	—	—	115
CE SP5	—	—	10	120	27	13	1	5.7	4.7	—	111
CE SP5	—	11.7	0	120	—	—	—	19	—	—	144

Table 25. Summary of water-quality data for selected springs in the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[ft, feet; gal/min, gallons per minute; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; >, greater than; —, no data; <, less than]

Local identification number	Alkalinity (P00440)	Alkalinity (P00445)	Chloride, dissolved (mg/L as Cl) (P00940)	Fluoride, dissolved (mg/L as F) (P00950)	Silica, dissolved (mg/L as SiO_2) (P00955)	Sulfate, dissolved (mg/L as SO_4) (P00945)	Residue, dissolved (mg/L) (P00515)	Residue, dissolved at 180°C (mg/L) (P70300)	Nitrogen, nitrate (mg/L as N) (P00618)	Nitrate + nitrite, dissolved (mg/L as N) (P00631)	Nitrogen, nitrite (mg/L as N) (P00613)	Phosphate, ortho (mg/L as PO_4) (P00660)
CE SP1	—	—	8	<0.1	—	—	366	—	5.06	5.06	<0.001	0.006
CE SP11	230	0	7.3	—	—	14	—	—	3.4	—	—	.03
CE SP12	274	0	9	—	—	—	—	300	—	—	—	—
CE SP16	266	0	7.9	—	—	28	—	—	5.2	—	—	.03
CE SP16	260	—	16	.1	—	20	—	295	2.8	—	—	—
CE SP17	171	0	1.9	0	5.4	5.8	—	162	2.1	—	—	—
CE SP17	120	0	33		—	11	—	—	3.4	—	—	0
CE SP18	—	—	14	<.1	—	<10	218	—	4.2	4.2	<.001	.012
CE SP18	—	—	13	<.1	—	26	274	—	5.46	5.46	<.001	.006
CE SP18	199	0	1.8		—	51	—	—	3.2	—	—	.28
CE SP19	222	0	5.3		—	20	—	—	5.1	—	—	1
CE SP19	220	0	2.5	.1	6.4	11	—	207	1.7	—	—	
CE SP19	276	0	3	—	—	28	—	—	6.2	—	—	.03
CE SP2	—	—	16	<.1	—	28	252	—	7.92	7.92	<.001	.006
CE SP2	161	0	4.5	1	6	5.8	—	150	.93	—	—	
CE SP27	158	0	13	—	—	7.2	—	—	1.7	—	—	0
CE SP32	—	—	10	<.1	—	<10	452	—	1.88	1.88	<.001	.006
CE SP5	140	0	11	—	—	6.3	—	—	.9	—	—	0
CE SP5	135	0	6.2	.2	11	7.7	—	—	.54	—	—	—
CE SP5	176	—	6.2	0	—	9	—	200	—	—	—	—

Table 25. Summary of water-quality data for selected springs in the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[ft, feet; gal/min, gallons per minute; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; >, greater than; —, no data; <, less than]

Local identification number	Orthophosphate (mg/L as P) (P00671)	Carbon dioxide (mg/L as CO_2) (P00405)	Carbon, total organic (mg/L as C) (P00680)	Aluminum, dissolved (∝g/L as Al) (P01106)	Arsenic, dissolved (∝g/L as As) (P01000)	Barium, dissolved (∝g/L as Ba) (P01005)	Cadmium, dissolved (∝g/L as Cd) (P01025)	Chromium, dissolved (∝g/L as Cr) (P01030)	Copper, dissolved (∝g/L as Cu) (P01040)	Iron, dissolved (∝g/L as Fe) (P01046)	Lead, dissolved (∝g/L as Pb) (P01049)	Manganese, dissolved (∝g/L as Mn) (P01056)
CE SP1	0.002	9.6	—	<35	<1,000	39	<10	<50	—	<10	<45	<10
CE SP11	.01	5.8	1.5	—	—	—	—	—	—	—	—	—
CE SP12	—	11	—	—	—	—	—	—	—	0	—	—
CE SP16	.01	5.4	6.5	—	—	—	—	—	—	—	—	—
CE SP16	—	26	—	—	—	—	—	—	—	0	—	—
CE SP17	—	4.3	—	—	—	—	—	—	—	20	—	—
CE SP17	0	3.8	2	—	—	—	—	—	—	—	—	—
CE SP18	.004	9.5	—	<35	<1,000	22	<10	<50	—	<10	<45	<10
CE SP18	.002	11	—	<35	<1,000	48	<10	<50	—	30	<45	<10
CE SP18	.09	6.4	—	—	—	—	—	—	—	—	—	—
CE SP19	.33	7.1	2.5	—	—	—	—	—	—	—	—	—
CE SP19	—	8.8	—	—	—	—	—	—	—	20	—	—
CE SP19	.01	7	2	—	—	—	—	—	—	—	—	—
CE SP2	.002	19	—	<35	<1,000	32	<10	<50	—	<10	<45	<10
CE SP2	—	5.1	—	—	—	—	—	—	—	80	—	—
CE SP27	0	3.2	2	—	—	—	—	—	—	—	—	—
CE SP32	.002	2.5	—	<35	<1,000	23	<10	<50	—	<10	<45	<10
CE SP5	0	3.6	1.5	—	—	—	—	—	—	—	—	—
CE SP5	—	—	—	—	—	—	—	—	—	—	—	—
CE SP5	—	8.9	—	—	—	—	—	10	0	20	—	—

Table 25. Summary of water-quality data for selected springs in the Spring Creek Basin, Centre County, Pennsylvania.—Continued

[ft, feet; gal/min, gallons per minute; ∝S/cm, microsiemens per centimeter; mg/L, milligrams per liter; ∝g/L, micrograms per liter; >, greater than; —, no data; <, less than]

Local identification number	Nickel, dissolved (∝g/L as Ni) (P01065)	Strontium, dissolved (∝g/L as Sr) (P01080)	Zinc, dissolved (∝g/L as Zn) (P01090)	Alachlor, total (∝g/L) (P77825)	Atrazine, total (∝g/L) (P39630)	Cyanazine (∝g/L) (P81757)	Metolachlor (∝g/L) (P39356)	Propazine (∝g/L) (P39024)	Simazine, total (∝g/L) (P39055)	Toxaphene, total (∝g/L) (P39400)
CE SP1	<25	90	<10	<0.1	0.1	<0.2	<0.1	<0.2	<0.2	<1
CE SP11	—	—	—	—	—	—	—	—	—	—
CE SP12	—	—	—	—	—	—	—	—	—	—
CE SP16	—	—	—	—	—	—	—	—	—	—
CE SP16	—	—	—	—	—	—	—	—	—	—
CE SP17	—	—	—	—	—	—	—	—	—	—
CE SP17	—	—	—	—	—	—	—	—	—	—
CE SP18	<25	<10	<10	—	—	—	—	—	—	—
CE SP18	<25	210	<10	—	—	—	—	—	—	—
CE SP18	—	—	—	—	—	—	—	—	—	—
CE SP19	—	—	—	—	—	—	—	—	—	—
CE SP19	—	—	—	—	—	—	—	—	—	—
CE SP19	—	—	—	—	—	—	—	—	—	—
CE SP2	<25	30	<10	M	.3	<.2	<.1	<.2	<.2	<1
CE SP2	—	—	—	—	—	—	—	—	—	—
CE SP27	—	—	—	—	—	—	—	—	—	—
CE SP32	<25	<10	<10	—	—	—	—	—	—	—
CE SP5	—	—	—	—	—	—	—	—	—	—
CE SP5	—	—	—	—	—	—	—	—	—	—
CE SP5	0	—	0	—	—	—	—	—	—	—