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Prepared in cooperation with the
County Commission of Jefferson County, West Virginia, and the
West Virginia Division of Water and Waste Management

Hydrogeologic Factors Affecting Base-Flow Yields in the Jefferson County Area, West Virginia, October–November 2007

Scientific Investigations Report 2009–5145

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Conversion Factors and Datums

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	0.4047	square hectometer (hm^2)
square mile (mi^2)	259.0	square hectometer (hm^2)
	Flow rate	
inch per year (in/yr)	2.54	centimeter per year (cm/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per acre (gal/d/acre)	0.000935	cubic meter per day per square hectometer ($m^3/d/hm^2$)

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 theNorth American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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

Hydrogeologic Factors Affecting Base-Flow Yields in the Jefferson County Area, West Virginia, October–November 2007

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Abstract

Base-flow yields at approximately the annual 75-percent-duration flow were determined for watersheds in the Jefferson County area, WV, from stream-discharge measurements made during October 31 to November 2, 2007. Five discharge measurements of Opequon Creek defined increased flow from 29,000,000 gallons per day (gal/d) at Carters Ford to 51,400,000 gal/d near Vanville. No flow was observed at 45 of 110 additional stream sites inspected, and discharge at the 65 flowing stream sites ranged from 1,940 to 17,100,000 gallons per day (gal/d). Discharge at 28 springs ranged from no flow to 2,430,000 gal/d. Base-flow yields were computed as the change in stream-channel discharge between measurement sites divided by the change in drainage area between the sites. Yields were negative for losing (influent) channel reaches and positive for gaining (effluent) reaches. Channels in 14 watersheds were determined to have lost flow ranging from -9.6 to -1,770 gallons per day per acre (gal/d/acre). Channels in 51 watersheds were determined to have gained flow ranging from 3.4 to 235,000 gal/d/acre.

Water temperature at the stream sites ranged from 5.0 to 16.3 °C (quarry pumpage), and specific conductance ranged from 51 to 881 microsiemens per centimeter (µS/cm). Water temperature at the springs ranged from 11.5 to 15.0 °C, and specific conductance ranged from 22 to 958 µS/cm.

Large springs in some watersheds in western Jefferson County are adjacent to other watersheds with little or no surface-water discharge; this is probably the result of interbasin transfer of groundwater along faults that dissect the area. Most watersheds located adjacent to the Potomac River in northeastern Jefferson County were not flowing during this study; this is most likely because the Potomac River is deeply incised, and groundwater flows directly to it rather than to the local stream systems in these areas. Except for one watershed with a yield of 651 gal/d/acre, no watersheds in northeastern Jefferson County yielded more than 305 gal/d/acre. Base-flow yields of several watersheds in south-central Jefferson County exceeded 400 gal/d/acre, and the effect of the Shenadoah River on base flows in the watershed appears to be less than that of the Potomac River in the northeastern part of the county. In the southeastern part of the county, because of steep relief and low-permeability bedrock, several streams were not flowing at the time of the study, and yields from all flowing streams were all less than 100 gal/d/acre.

On the basis of historical data from 1961 through 2008, the mean and median depths to groundwater in 213 wells in western Jefferson County were 33.4 and 29.3 ft, respectively. Mean and median depths to groundwater in 69 wells in the northeastern county area were 56.0 and 55.0 ft below land surface, respectively. However, mean and median depths to groundwater in 28 wells within 1.5 miles of the Potomac River were 70.0 and 71.3 ft below land surface, respectively. Mean and median depths to groundwater in 108 wells in the south-central county area were 53.9 and 52.8 ft below land surface, respectively. Mean and median depths to groundwater of 26 wells in the southeastern county area were 86.6 and 59.5 ft below land surface, respectively.

Introduction

Jefferson County, WV, an area of approximately 212 square miles (mi^2) is the easternmost county of the Eastern Panhandle of the State. The population of Jefferson County in 2006 was 50,443, an increase of about 19.6 percent since 2000 (U.S. Census Bureau, 2008). Increases in population place ever greater demands on the water resources of the county. Estimates of 2004 water use in Jefferson County were 11,000,000 gallons per day (gal/d) from surface-water sources and 4,000,000 gal/d from groundwater sources (Atkins, 2007). Information is needed for management of water resources in Jefferson County in anticipation of continued population growth.

During base-flow conditions from October 31 to November 2, 2007, the U.S. Geological Survey (USGS), in cooperation with the County Commission of Jefferson County, inspected 115 stream sites and 29 springs throughout the

county. Measurements of discharge, temperature, and specific conductance were made at sites having flowing water (unless otherwise noted). The base flow of streams is derived from groundwater discharge and stream-discharge measurements made under base-flow conditions usually are used to describe surface-water resources during low-flow conditions (Stedinger and Thomas, 1985). In this report, base-flow yields from 110 watersheds were determined and used also to infer the probable pathways of groundwater discharge to streams.

Description of the Study Area

Jefferson County, WV, is bounded on the northwest by Berkeley County, on the northeast by the Potomac River and Maryland, on the southeast and the southwest by Virginia (plate 1). Most of the county is in the Shenandoah Valley, which has a gently rolling topography, ranging in altitude from 400 to 600 ft (NAVD 88). The southeastern edge of the county is in the Blue Ridge Mountains and altitudes range from 1,100 to 1,700 ft (Beiber, 1961).

Average annual precipitation in the county is 39.39 inches per year (in/yr), based on measurements made from 1971 to 2000 at the Eastern West Virginia Regional Airport in southern Berkeley County (National Climatic data Center, 2002). Recharge to groundwater is approximately 10 in/yr based on analysis of streamflow records for USGS streamgaging station 01616500 Opequon Creek near Martinsburg, WV (Kozar and Mathes, 2001).

According to Kozar and others (1991), most of the geologic units in the county are faulted and folded, and the axes of the folds trend northeast-southwest. This has produced outcrop bands with the same northeast-southwest trend. In general, the rocks strike northeast, dip southeast and northwest, and decrease in age from east to west. The main natural factors affecting groundwater recharge and the groundwater-flow system in Jefferson County are geology and precipitation. Because average rainfall is nearly constant over the county (Hobba and others, 1972), geology has the dominant effect on the hydrology. Most of the county is underlain by carbonate rocks (limestones and dolomites) that form a karst terrain. However, the Blue Ridge Mountain area east of the Shenandoah River in southeast Jefferson County is underlain by metamorphosed shales and sandstones, and the area near Opequon Creek in western Jefferson County is underlain by shale. Each of these areas has different hydrogeologic properties.

The Potomac River drains all of Jefferson County. The principal tributaries that drain watersheds in Jefferson County to the Potomac River are Opequon Creek, Rockymarsh Run, Rattlesnake Run, Elks Run, and the Shenandoah River (plate 1). Three of the larger tributaries to the Shenandoah River in Jefferson County are Evitts Run, Bullskin Run, and Flowing Springs Run (plate 1). Base-flow discharges were measured in all streams, except for the Potomac and Shenandoah Rivers.

Hydrologic Conditions Prior to and During the Study

USGS streamgaging stations available for assessment of hydrologic conditions immediately prior to and during this study include Opequon Creek near Martinsburg, WV (01616500); Tuscarora Creek above Martinsburg, WV (01617000), which is tributary to Opequon Creek; and Shenandoah River at Millville, WV (01636500) (plate 1). The drainage areas at these stations are 273 mi^2, 11.3 mi^2, and 3,041 mi^2, respectively.

During October 23 to 27, 2007, a total of 2.54 in. of rain was recorded at the Eastern West Virginia Regional Airport (National Climatic Data Center, 2008). The Opequon Creek near Martinsburg streamgage recorded a rise to 304,400,000 gal/d on October 27; the stream had not completely returned to base-flow conditions by October 31. Streamflow at this station averaged 60,400,000 gal/d during the time that most measurements were made for the study (October 31, 2007, at 0730 hrs. to November 1, 2007, at 1730 hrs.). The smaller tributary streams, however, were at base-flow conditions, based on streamflow at the station on Tuscarora Creek above Martinsburg which had returned to stable low-flow conditions by October 31. No rainfall was reported at Martinsburg from October 28 through November 2 (National Climatic Data Center, 2008). Streamflow measured at the station on the Shenandoah River at Millville averaged 788,500,000 gal/d during the study period but was affected by regulation and was not used in this assessment of hydrologic conditions.

The flow of streams and springs in the Jefferson County area during October 31 to November 2, 2007, was at approximately the 75-percent duration (flow equaled or exceeded 75 percent of the time) of annual flows reported by Wiley (2006). This determination of hydrologic conditions is based on extension of the receding hydrograph for the streamgage on Opequon Creek near Martinsburg back to the time of the measurement survey and estimation of the base-flow component of stream discharge as 54,300,000 gal/d.

A study of base-flow yield was conducted July 25 to 28, 2005, in adjacent Berkeley County by Evaldi and Paybins (2006). Streamflow in Opequon Creek near Martinsburg at the time of that study was at approximately the 65-percent-duration of annual flows, based on a discharge of 63,700,000 gal/d.

Stream and Spring Measurements

During base-flow conditions from October 31 through November 2, 2007, 115 stream sites and 29 springs were inspected. Discharge, water temperature, and specific conductance measurements were made at sites having flowing water (table 1, at end of report, and plate 1). All discharge measurements were made by wading with current meters. Observations

of width, depth, and velocity were made at intervals for a cross section of the stream or outflow. Measured discharge is the summation of the products of the subsection areas of the cross sections and their respective average velocities (Rantz and others, 1982). Equipment used for measuring flow was checked for accuracy before and after data collection, and accuracy was found to be within acceptable operational limits. The accuracy of individual discharge measurements was dependent on channel or outflow conditions; error generally was estimated to be less than 10 percent. No flow was observed at 45 of the stream sites. Five discharge measurements of Opequon Creek defined increased flow from 29,000,000 gal/d at Carters Ford to 51,400,000 gal/d near Vanville (table 1). Discharge at the other 65 sites on flowing streams ranged from 1,940 to 17,100,000 gal/d. The flow from Byrd Spring near Charles Town could not be measured. Discharge at 28 other springs ranged from no flow observed at two sites to 2,430,000 gal/d.

Locations of the stream and spring sites were determined with global positioning system (GPS) equipment with horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83). Some adjustments to the reported latitude and longitude of sites were made to compensate for differences between measured GPS coordinates and geographic information system (GIS) coverage of lesser accuracy.

Water temperature was obtained with field thermometers, and a sample of water was collected for laboratory analysis of specific conductance. The unnamed tributary to Shenandoah River at Millville (site 106) was affected by return flow from quarry pumpage and had the highest water temperature of all the sites measured at 16.3 °C. Water temperature at the remaining stream sites ranged from 5.0 to 15.0 °C, and specific conductance ranged from 51 to 881 microsiemens per centimeter (μS/cm). Water temperature at the springs ranged from 11.5 to 15.0 °C, and specific conductance ranged from 22 to 958 μS/cm.

Base-Flow Yields

Base-flow yields at approximately the 75-percent-duration of annual flows were observed in streams in watersheds in Jefferson County from October 31 to November 2, 2007 (table 1; plate 1). For headwater-channel sites, the base-flow yields were computed as the measured flow divided by the upstream drainage area. Base-flow yields for other stream-channel sections were computed as the change in discharge between measurement sites divided by the change in drainage area between measurement sites. The base-flow yields are expressed in gal/d/acre of intervening drainage area. For computation of change in discharge between measurement sites along a channel, all tributary inflows to the channel reach were subtracted. Yields are negative for losing (influent) channel reaches and positive for gaining (effluent) reaches.

Stream channels in 51 watersheds were determined to have gained flow which, expressed as positive base-flow watershed yields, ranged from 3.4 to 235,000 gal/d/acre. Channels in 14 watersheds were determined to have lost flow. The losses in flow, expressed as negative base-flow watershed yields, ranged from -9.6 to -1,770 gal/d/acre. These negative base-flow yields might indicate losses of flow to the groundwater system, channel underflow, or possible lack of discharge-measurement accuracy. Groundwater flow in this karst terrain does not necessarily mimic topographically controlled overland flow paths. Areas of surplus or deficient yield to the stream systems, as presented in plate 1, can be useful in inferring groundwater-flow paths.

Hydrogeologic Factors Affecting Base-Flow Yields

Depth to Groundwater

Measurements of depth to groundwater were not obtained during this study but such data were available from the USGS National Water Information System (Campbell, 2008). These data, which are presented in figure 1, were obtained from 1961 through 2008, and do not necessarily depict depth to groundwater during the base-flow conditions of October-November 2007. Instead, the ranges of values in figure 1 are intended to represent the general relative differences of depth to groundwater in the four hydrogeologic areas of the county.

Western Jefferson County (fig. 1) is characterized by a relatively shallow water table, as indicated by the measurements of 213 wells in the area with mean and median depths to groundwater of 33.4 and 29.3 ft below land surface, respectively. The bedrock lithologies are predominantly carbonate with some shale of the Martinsburg Formation, and is extensively faulted. Mean and median depths to groundwater at 69 wells completed in predominantly carbonate bedrock in northeastern Jefferson County (fig. 1) were 56.0 and 55.0 ft below land surface, respectively. However, mean and median depths to groundwater at 28 wells within 1.5 miles of the Potomac River were 70.0 and 71.3 ft below land surface, respectively. Depths to groundwater in areas within 1.5 miles of the Potomac River were greater than those in other areas of the county with similar carbonate bedrock. Depth to groundwater at 108 wells completed in similar carbonate rocks in south-central Jefferson County (fig. 1) had mean and median values of 53.9 and 52.8 ft below land surface, respectively. This is about the same depth to groundwater in the carbonate-dominated bedrock of the northeastern part of the county. Southeastern Jefferson County (fig. 1) is dominated by non-carbonate bedrock in the Blue Ridge Physiographic Province, and depth to groundwater is greater than in other areas of the county. Mean and median depths to groundwater at 26 wells

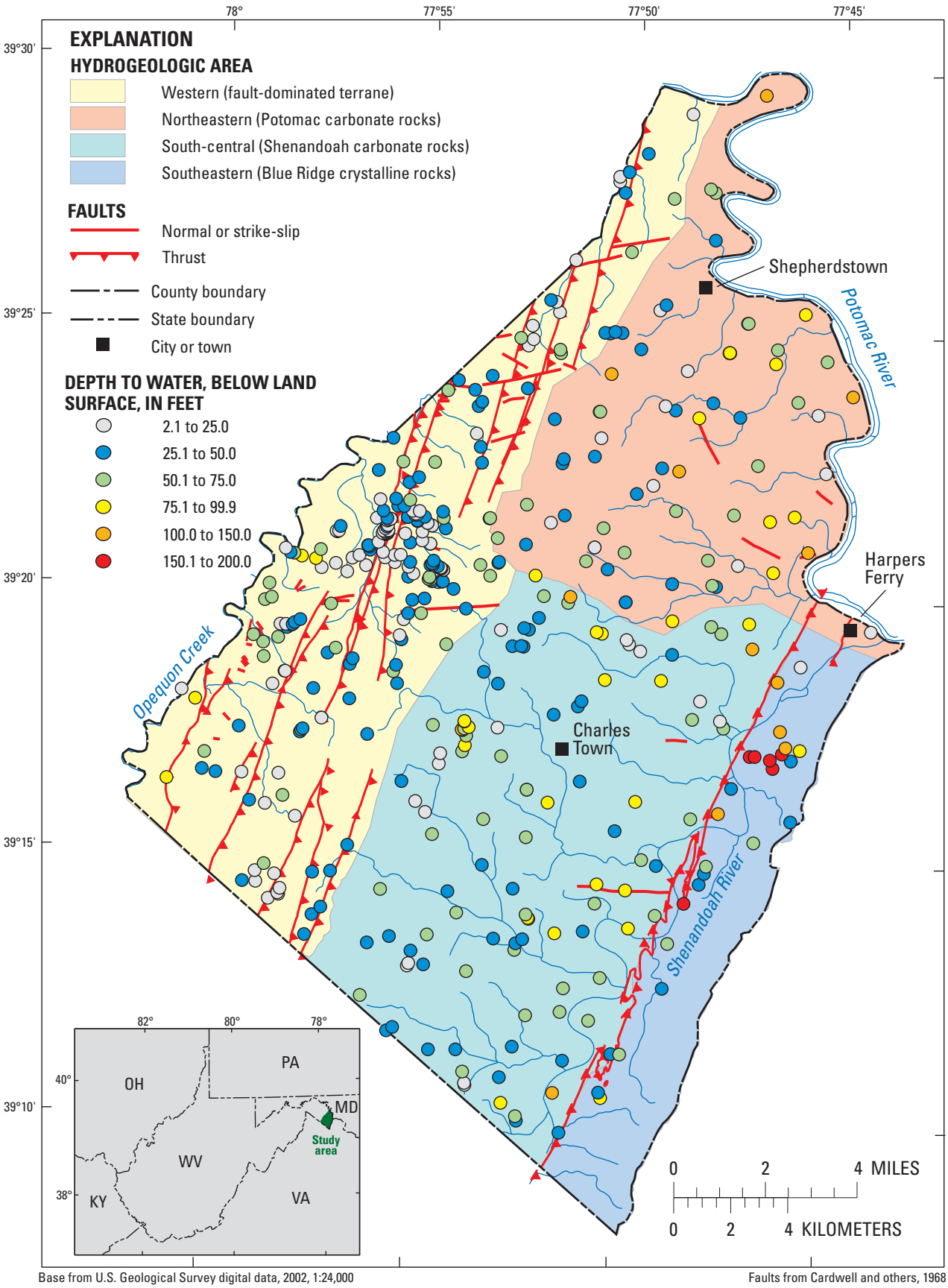

Figure 1. Depth to groundwater and hydrogeologic areas in Jefferson County, West Virginia, based on data collected from 1961 through 2008.

measured in this region of the county were 86.6 and 59.5 ft below land surface, respectively. The low permeability of the metamorphosed shale and sandstone and steep relief in this area are assumed to be the causes for the greater depths to groundwater.

Structural Geologic Features, Lithologies, and Hydraulic Gradients

The depth and flow paths of groundwater in Jefferson County are controlled by topography and geologic structure (Kozar and others, 1991). Structural geologic features, such as thrust faults, cross-strike faults, normal faults, and low-permeability bedrock, are well-documented (Kozar and others, 2008). In southeastern Jefferson County, the bedrock is mostly low-permeability metamorphic and sedimentary rocks, and groundwater can be deep below land surface as a result of the low-permeability bedrock and steep topography. These structurally, topographically, and lithologically controlled hydrogeologic areas are shown in figure 1.

Western Jefferson County

Movement of groundwater in the western Jefferson County area is largely influenced by structural controls, especially by thrust faults, and cross-strike faults, and by low permeability lithologic units such as the Conococheague Limestone and the Martinsburg Formation. Many of the streams in the area were not flowing, but a few watersheds had substantial outflow from springs. Interbasin transfer of groundwater between the watersheds is thought to occur along fault zones, and three examples of this process were evident in this study at three sites. The first site is at Priest Field Spring near Middleway (site P, table 1; plate 1), which had measured flow of 2,410,000 gal/d on October 31, 2007. This spring is adjacent to a watershed with no surface-water flow that is dissected by thrust faults and strike-slip faults (fig. 1). It is likely that groundwater flow is captured along these faults and discharges at the spring. The second example is the small watershed area measured for Hopewell Run at Leetown (site 17 on plate 1) which had a large base-flow yield of 7,990 gal/d/acre on November 2, 2007. Three major thrust faults traverse this area (fig. 1), and an adjacent watershed, which had no surface-water flow, contains a strike-slip fault that is mapped in connection with one of the thrust faults. The third example of fault-conveyance of groundwater in western Jefferson County is in the Rockymarsh Run Watershed. Rock Spring near Shepherdstown (site C, table 1; plate 1) discharges into Rockymarsh Run along a thrust fault (fig. 1). The flow from Rock Spring was measured at 2,430,000 gal/d on October 31, 2007. The channel flow not far downstream from Rock Spring at site 27 measured only 2,110,000 gal/d, and flow losses along the channel also were noted further downstream at sites 32 (2,020,000 gal/d) and 33 (1,770,000 gal/d). These losses are probably the result of the capture of flow along a thrust fault and then the discharge of flow at Spring Hill Spring northwest of Shepherdstown (site B); this may indicate that diversions from Rock Spring might reduce the flow from Spring Hill Spring.

Northeastern Jefferson County

The greatest base-flow yield measured in watersheds in northeastern Jefferson County was 651 gal/d/acre, but no other watershed in the area yielded more than 305 gal/d/acre. Most watersheds adjacent to the Potomac River had no flow during this study. In addition, the watershed area immediately upstream from Elks Run at Harpers Ferry (site 67, table 1; plate 1) lost 19.2 gal/d/acre on October 31, 2007.

In northeastern Jefferson County, groundwater flow paths and depth to groundwater are dominated more by lithologic controls than by structural controls. In areas immediately adjacent to the Potomac River, topographic controls on depth to groundwater are important. Base-flow discharge to the local stream system follows a typical path of groundwater discharge from a watershed by gravity drainage when the stream channel is below the water-table elevation. This often is not the case, however, in areas near a receiving stream where the largest elevation gradient is not to the local stream channel but to the receiving stream channel. The Potomac River is deeply incised, and probably groundwater flows directly to it rather than to the local stream system in these areas.

South-Central Jefferson County

Groundwater flow paths and depth to groundwater in south-central Jefferson County are similar to those in the northeastern area of the county in that they are dominated more by lithologic controls than by structural controls. The south-central Jefferson County watersheds, however, seem water-rich in comparison to the northeastern area watersheds. Base-flow yields of several watersheds exceeded 400 gal/d/acre. No flow was noted in several streams near their confluence with the Shenandoah River but the areal extent of no-flow streams was smaller than that observed along the Potomac River. It is likely that the hydraulic gradient to the Shenadoah River in south-central Jefferson County is not as great as that to the Potomac River in the northeastern area of the county and that the Shenandoah River has a lesser effect on the local stream systems than the Potomac River does.

Flow from the watershed measured at the unnamed tributary to Shenandoah River at Millville (site 106, table 1; plate 1) was 17,100,000 gal/d on November 1, 2007, and base-flow yield was determined to be 10,200 gal/d/acre. However, this was not an accurate base-flow yield because much of this flow was probably return flow from quarry pumpage, which may be drawing groundwater from adjacent watersheds to the north and south, and possibly from the Shenandoah River.

Table 1. Characteristics of streams and springs in the Jefferson County area of West Virginia, October–November 2007.

[SOWV number is the Jefferson County spring identification number assigned in the report "Springs of West Virginia" by McColloch (1986); ft^3/s, cubic feet per second; gal/d, gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; °, degrees; ′ , minutes; ″, seconds; ---, unknown]

Map identifier (plate 1)	Site name (SOWV number)	Date	Time	Latitude[1]	Longitude[1]	Discharge		Water temperature, in °C	Specific conductance, in µS/cm	Drainage area, in acres	Base-flow[2] yield, in (gal/d)/acre
						ft^3/s	gal/d				
	Streams										
1	Opequon Creek at Carters Ford	10/31/07	0850	39°15′52″	78°01′58″	44.8	29,000,000	8.0	779	---	---
2	Opequon Creek near Ridgeway	10/31/07	0925	39°17′17″	78°01′16″	51.1	33,000,000	8.0	750	---	---
3	Unnamed Tributary to Opequon Creek near Ridgeway	10/31/07	1200	39°17′27″	78°01′09″	0	0	---	---	133	0
4	Opequon Creek at Ford near Middleway	10/31/07	1055	39°17′59″	78°00′40″	52.7	34,100,000	8.0	746	---	---
5	Turkey Run above Middleway	10/31/07	0800	39°17′38″	77°57′21″	0	0	---	---	1,880	0
6	Turkey Run at Middleway	10/31/07	0925	39°18′07″	77°59′22″	0.920	597,000	6.0	569	2,010	459
7	East Unnamed Tributary to Turkey Run at Middleway	10/31/07	1015	39°18′04″	77°59′34″	0	0	---	---	1,950	0
8	Turkey Run near mouth near Middleway	10/31/07	1210	39°18′05″	77°59′52″	0.837	541,000	9.0	567	8,270	-362
9	West Unnamed Tributary to Turkey Run at Middleway	10/31/07	1030	39°17′54″	77°59′52″	0	0	---	---	3,990	0
10	Opequon Creek near Middleway	10/31/07	1315	39°18′37″	77°59′50″	58.8	38,000,000	9.0	735	---	---
11	Unnamed Tributary to Opequon Creek near Middleway	10/31/07	1200	39°19′28″	77°59′06″	0	0	---	---	1,290	0
12	Unnamed Tributary to Opequon Creek near Leetown	10/31/07	1200	39°20′40″	77°58′12″	0	0	---	---	763	0
13	Unnamed Tributary to Opequon Creek at Eqypt	10/31/07	1200	39°21′13″	77°57′46″	0	0	---	---	238	0
14	South Branch Hopewell Run at County Route 1 at Leetown	10/31/07	1230	39°21′05″	77°56′06″	1.15	745,000	10.0	637	4,400	169
15	Link Spring Run near Leetown	11/02/07	0835	39°21′03″	77°54′26″	0	0	---	---	467	0
16	Hopewell Run at County Route 1 at Leetown	10/31/07	1325	39°21′07″	77°55′49″	0	0	---	---	1,660	0
17	Hopewell Run at Leetown	11/02/07	0805	39°21′16″	77°56′00″	3.64	2,350,000	9.0	619	6,260	7,990
18	Dry Run at Leetown	10/31/07	1105	39°20′45″	77°56′37″	0	0	---	---	301	0
19	Hopewell Run near mouth near Leetown	10/31/07	1400	39°22′16″	77°56′26″	2.87	1,860,000	12.0	593	7,620	-471
20	Opequon Creek near Vanville	10/31/07	1545	39°22′49″	77°56′22″	79.5	51,400,000	10.0	678	---	---
21	Shaw Run near Kearneysville	10/31/07	1445	39°23′44″	77°55′17″	0.873	564,000	11.0	744	4,750	119
22	Rockymarsh Run near Kearneysville	10/31/07	1020	39°24′51″	77°51′14″	0	0	---	---	2,290	0
23	Unnamed Tributary to Rockymarsh Run near Kearneysville	10/31/07	1030	39°25′02″	77°51′04″	0	0	---	---	288	0
24	Unnamed Tributary to Rockymarsh Run near Shepherdstown	10/31/07	1240	39°25′43″	77°50′09″	0	0	---	---	282	0
25	Rockymarsh Run above Rock Spring near Shepherdstown	10/31/07	1110	39°26′07″	77°50′47″	0.059	38,100	9.5	632	3,670	47.1

Table 1. Characteristics of streams and springs in the Jefferson County area of West Virginia, October–November 2007.—Continued

[SOWV number is the Jefferson County spring identification number assigned in the report "Springs of West Virginia" by McColloch (1986); ft^3/s, cubic feet per second; gal/d, gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; °, degrees; ′, minutes; ″, seconds; ---, unknown]

Map identifier (plate 1)	Site name (SOWV number)	Date	Time	Latitude[1]	Longitude[1]	Discharge		Water temperature, in °C	Specific conductance, in µS/cm	Drainage area, in acres	Base-flow[2] yield, in (gal/d)/acre
						ft^3/s	gal/d				
26	Rockymarsh Run below Rock Spring near Shepherdstown	10/31/07	1140	39°26′09″	77°50′50″	3.81	2,460,000	12.0	---	3,680	235,000
27	Rockymarsh Run at State Route 45 near Shepherdstown	10/31/07	0740	39°26′24″	77°50′54″	3.27	2,110,000	10.0	607	3,880	-1,770
28	West Fork Rockymarsh Run above Wynkoop Spring	10/31/07	0945	39°25′32″	77°51′51″	0.419	271,000	6.0	607	2,180	124
29	West Fork Rockymarsh Run at Wynkoop Spring	10/31/07	0900	39°26′09″	77°51′34″	0.687	444,000	5.5	582	2,720	323
30	West Fork Rockymarsh Run near Shepherdstown	10/31/07	1315	39°26′31″	77°51′18″	0.847	547,000	15.0	582	2,890	585
31	Unnamed Tributary to Rockymarsh Run near Wynkoop Spring	10/31/07	1600	39°26′49″	77°50′42″	0	0	---	---	105	0
32	Rockymarsh Run at County Route 12 near Shepherdstown	10/31/07	1520	39°27′06″	77°50′46″	3.13	2,020,000	12.5	600	3,960	-660
33	Rockymarsh Run near Fairview School	10/31/07	1530	39°27′36″	77°50′27″	2.74	1,770,000	10.5	560	4,250	-860
34	Unnamed Tributary to Rockymarsh Run near Fairview School	10/31/07	1530	39°27′37″	77°50′24″	0	0	---	---	222	0
35	Rockymarsh Run above Scrabble	10/31/07	1235	39°28′09″	77°50′19″	2.97	1,920,000	10.0	548	4,650	844
36	Unnamed Tributary to Rockymarsh Run above Scrabble	10/31/07	1205	39°28′07″	77°50′13″	2.05	1,320,000	12.0	592	716	1,850
37	Unnamed Tributary to Rockymarsh Run at Scrabble	10/31/07	1350	39°28′30″	77°50′02″	0	0	---	---	245	0
38	Rockymarsh Run at Scrabble	10/31/07	1030	39°28′59″	77°49′54″	4.97	3,210,000	7.5	542	6,350	-48.4
39	Rockymarsh Run near Scrabble	10/31/07	0935	39°29′17″	77°49′40″	4.65	3,010,000	6.0	562	6,570	-891
40	Rockymarsh Run at mouth near Scrabble	10/31/07	0830	39°29′33″	77°49′31″	4.45	2,870,000	7.0	549	6,720	-935
41	Unnamed Tributary to Potomac River near Dam No. 4	10/31/07	1000	39°29′28″	77°48′45″	0.015	9,690	7.5	881	43.2	225
42	Unnamed Tributary to Potomac River near Shepherds Island	10/31/07	0930	39°29′26″	77°48′37″	0.088	56,900	7.0	571	433	131
43	Unnamed Tributary to Potomac River at Horseshoe Bend	10/31/07	1120	39°28′39″	77°47′55″	0	0	---	---	108	0
44	Unnamed Tributary to Potomac River below Horseshoe Bend	10/31/07	1200	39°28′15″	77°47′44″	0	0	---	---	375	0
45	Unnamed Tributary to Potomac River above Shepherdstown	10/31/07	1320	39°26′32″	77°47′53″	0.453	293,000	11.0	611	961	305
46	Unnamed Tributary to Potomac River at Shepherdstown	10/31/07	1350	39°26′25″	77°48′20″	0	0	---	---	624	0
47	Town Run at Shepherdstown	10/31/07	1510	39°25′42″	77°48′22″	1.62	1,050,000	10.0	623	1,610	651
48	Unnamed Tributary No. 1 to Potomac River at Shepherdstown	11/01/07	1540	39°25′48″	77°47′32″	0	0	---	---	1,110	0

Table 1. Characteristics of streams and springs in the Jefferson County area of West Virginia, October–November 2007.—Continued

[SOWV number is the Jefferson County spring identification number assigned in the report "Springs of West Virginia" by McColloch (1986); ft^3/s, cubic feet per second; gal/d, gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; °, degrees; ′, minutes; ″, seconds; ---, unknown]

Map identifier (plate 1)	Site name (SOWV number)	Date	Time	Latitude[1]	Longitude[1]	Discharge		Water temperature, in °C	Specific conductance, in µS/cm	Drainage area, in acres	Base-flow[2] yield, in (gal/d)/acre
						ft^3/s	gal/d				
49	Unnamed Tributary No. 2 to Potomac River at Shepherdstown	11/02/07	1555	39°25′44″	77°47′15″	0	0	---	---	149	0
50	Unnamed Tributary No. 3 to Potomac River at Shepherdstown	10/31/07	1605	39°25′40″	77°46′42″	0	0	---	---	413	0
51	Rattlesnake Run near Skeetersville	10/31/07	0833	39°23′51″	77°48′31″	0.104	67,200	7.0	634	2,080	32.3
52	Rattlesnake Run near Shepherdstown	10/31/07	0925	39°24′01″	77°46′27″	0.236	153,000	5.8	607	5,210	27.3
53	Rattlesnake Run at mouth near Moler Crossroads	10/31/07	1200	39°25′08″	77°45′07″	0.417	270,000	9.0	625	6,490	91.2
54	Unnamed Tributary to Potomac River below Knott Island	10/31/07	1200	39°24′14″	77°44′35″	0	0	---	---	373	0
55	Unnamed Tributary to Potomac River near Moler Crossroads	10/31/07	1000	39°23′34″	77°44′51″	0	0	---	---	597	0
56	Unnamed Tributary No. 1 to Potomac River near Bakerton	10/31/07	1013	39°22′54″	77°45′14″	0	0	---	---	320	0
57	Unnamed Tributary No. 2 to Potomac River near Bakerton	10/31/07	1024	39°22′28″	77°45′12″	0	0	---	---	1,760	0
58	Unnamed Tributary No. 3 to Potomac River near Bakerton	10/31/07	1024	39°21′59″	77°44′42″	0	0	---	---	147	0
59	Unnamed Tributary No. 4 to Potomac River near Bakerton	10/31/07	1040	39°21′02″	77°45′06″	0	0	---	---	404	0
60	Elks Run near Shenandoah Junction	10/31/07	0750	39°20′25″	77°49′37″	0.030	19,400	6.0	822	1,130	17.1
61	Unnamed Tributary to Elks Run near Halltown	10/31/05	1200	39°20′07″	77°48′06″	0	0	---	---	1,910	0
62	Elks Run near Halltown	10/31/07	0835	39°20′06″	77°47′56″	0.053	34,300	6.0	715	3,900	17.4
63	Elk Branch at Skeetersville	10/31/07	1053	39°21′51″	77°49′06″	0.505	326,000	8.5	625	3,050	107
64	Elk Branch at Reedson	10/31/07	1006	39°21′10″	77°48′04″	0.494	319,000	5.0	625	3,790	-9.60
65	Elk Branch at Engle	10/31/07	1140	39°20′37″	77°46′45″	0.710	459,000	8.7	650	5,470	83.1
66	Unnamed Tributary to Elks Run at Harpers Ferry	10/31/07	1250	39°20′01″	77°45′42″	0.031	20,000	9.6	711	432	46.3
67	Elks Run at Harpers Ferry	10/31/07	1335	39°20′06″	77°45′30″	0.731	472,000	10.0	628	11,500	-19.2
68	Unnamed Tributary to Potomac River at Harpers Ferry	10/31/07	1435	39°19′54″	77°44′57″	0.128	82,700	9.2	595	204	406
69	Rocky Branch near Riverside	10/31/07	0800	39°09′06″	77°50′47″	0.047	30,400	8.7	68	446	68.0
70	Unnamed Tributary to Shenandoah River near Riverside	10/31/07	0900	39°09′36″	77°51′10″	0.003	1,940	8.5	58	578	3.40
71	Hog Run at Riverside	10/31/07	0850	39°09′54″	77°51′11″	0	0	---	---	1,320	0
72	Long Marsh Run at State Line	10/31/07	1800	39°10′37″	77°53′28″	3.51	2,270,000	13.3	528	3,880	585

Table 1. Characteristics of streams and springs in the Jefferson County area of West Virginia, October–November 2007.—Continued

[SOWV number is the Jefferson County spring identification number assigned in the report "Springs of West Virginia" by McColloch (1986); ft^3/s, cubic feet per second; gal/d, gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; °, degrees; ′, minutes; ″, seconds; ---, unknown]

Map identifier (plate 1)	Site name (SOWV number)	Date	Time	Latitude[1]	Longitude[1]	Discharge		Water temperature, in °C	Specific conductance, in µS/cm	Drainage area, in acres	Base-flow[2] yield, in (gal/d)/acre
						ft^3/s	gal/d				
73	Unnamed Tributary to Long Marsh Run near Rippon	10/31/07	1830	39°11′47″	77°53′45″	1.70	1,100,000	13.4	583	4,120	267
74	Long Marsh Run near Riverside	10/31/07	1640	39°11′02″	77°52′29″	4.46	2,880,000	12.1	548	9,810	-272
75	Long Marsh Run at Riverside	10/31/07	1515	39°11′04″	77°51′14″	5.11	3,300,000	10.4	560	11,500	255
76	Unnamed Tributary No.1 to Shenandoah River at Meyerstown	11/01/07	1200	39°11′47″	77°50′59″	0	0	---	---	148	0
77	Unnamed Tributary No.2 to Shenandoah River at Meyerstown	10/31/07	0943	39°12′20″	77°50′11″	0	0	---	---	245	0
78	Bullskin Run near Summit Point	11/01/07	0930	39°14′13″	77°57′18″	0.243	157,000	10.0	530	981	160
79	Bullskin Run near Mount Pleasant	11/01/07	0835	39°14′34″	77°55′30″	0.986	637,000	9.0	581	3,490	192
80	Bullskin Run at Wheatland	11/01/07	0745	39°14′16″	77°54′16″	1.03	664,000	9.0	546	5,480	13.6
81	North Fork Bullskin Run near Mount Pleasant	11/01/07	0900	39°15′56″	77°54′26″	0	0	---	---	1,830	0
82	North Fork Bullskin Creek near Wheatland	11/01/07	0815	39°14′44″	77°53′12″	0.956	618,000	11.0	641	3,320	414
83	Bullskin Run above Kabletown	11/01/07	1320	39°13′10″	77°51′57″	5.07	3,280,000	11.0	593	12,400	558
84	Bullskin Run below Kabletown	11/01/07	1415	39°12′41″	77°50′05″	6.76	4,370,000	11.0	600	14,000	663
85	Unnamed Tributary No. 1 to Shenandoah River near Kabletown	11/01/07	1310	39°13′29″	77°50′31″	0	0	---	---	238	0
86	Unnamed Tributary No. 2 to Shenandoah River near Kabletown	11/01/07	1255	39°13′47″	77°50′37″	0.065	42,000	14.0	770	122	345
87	Unnamed Tributary No. 3 to Shenandoah River near Kabletown	11/01/07	1200	39°14′16″	77°50′59″	0	0	---	---	276	0
88	Furnace Run near Riverside	11/01/07	1515	39°11′38″	77°49′18″	0.110	71,100	---	---	1,400	50.8
89	Furnace Run above Shannondale	10/31/07	1010	39°12′11″	77°49′12″	0.125	80,800	7.3	51	1,910	18.8
90	Furnace Run at Shannondale	10/31/07	1145	39°13′30″	77°49′01″	0.185	120,000	8.6	148	3,700	21.7
91	Unnamed Tributary No. 1 to Shanandoah River at Shannondale	10/31/07	1230	39°13′42″	77°48′35″	0.007	4,520	9.7	308	287	15.8
92	Evitts Run near Harewood	11/01/07	1530	39°17′47″	77°53′57″	1.20	772,000	12.0	544	2,210	349
93	North Branch Evitts Run near Harewood	11/01/07	1715	39°18′25″	77°53′14″	0	0	---	---	1,250	0
94	Evitts Run at Charles Town	11/01/07	1620	39°17′15″	77°51′54″	4.64	3,000,000	10.5	604	7,050	621
95	Evitts Run below Charles Town	11/01/07	1535	39°16′59″	77°51′50″	5.11	3,300,000	11.0	598	7,250	1,510
96	Unnamed Tributary to Evitts Run near Charles Town	11/01/07	1500	39°15′48″	77°51′58″	0.430	278,000	13.0	599	1,380	201
97	Evitts Run near Clips Mill	11/01/07	1418	39°15′06″	77°51′06″	8.43	5,450,000	13.0	661	10,900	815

Table 1. Characteristics of streams and springs in the Jefferson County area of West Virginia, October–November 2007.—Continued

[SOWV number is the Jefferson County spring identification number assigned in the report "Springs of West Virginia" by McColloch (1986); ft^3/s, cubic feet per second; gal/d, gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; °, degrees; ′, minutes; ″, seconds; ---, unknown]

Map identifier (plate 1)	Site name (SOWV number)	Date	Time	Latitude[1]	Longitude[1]	Discharge		Water temperature, in °C	Specific conductance, in µS/cm	Drainage area, in acres	Base-flow[2] yield, in (gal/d)/acre
						ft^3/s	gal/d				
98	Evitts Run at Bloomery	11/01/07	1045	39°15′19″	77°49′08″	8.79	5,680,000	11.0	664	12,800	126
99	Unnamed Tributary No. 1 to Shanandoah River near Bloomery	10/31/07	1240	39°15′21″	77°48′36″	0	0	---	---	83.0	0
100	Unnamed Tributary No. 2 to Shanandoah River near Bloomery	10/31/07	1300	39°15′28″	77°48′11″	0	0	---	---	86.9	0
101	Unnamed Tributary No. 3 to Shanandoah River near Bloomery	10/31/07	1320	39°15′29″	77°47′34″	0	0	---	---	14.1	0
102	Forge Run near Mannings	11/01/07	1400	39°15′27″	77°47′04″	0.147	95,000	10.0	292	1,790	53.0
103	Unnamed Tributary to Shenandoah River at Snyder Hill	11/01/07	1200	39°16′25″	77°47′09″	0	0	---	---	75.1	0
104	Cattail Run near Mechanicstown	11/01/07	1141	39°16′39″	77°49′07″	3.28	2,120,000	13.8	623	1,880	1,130
105	Cattail Run near Snyder Hill	11/01/07	0940	39°16′36″	77°47′20″	2.65	1,710,000	9.5	602	2,830	-434
106	Unnamed Tributary to Shenandoah River Millville (Quarry pumpage)	11/01/07	0835	39°17′23″	77°47′20″	26.4	17,100,000	16.3	427	1,680	10,200
107	Flowing Spring Run near Ranson	10/31/07	1737	39°18′36″	77°50′13″	5.20	3,360,000	13.5	723	2,190	1,530
108	Flowing Spring Run at Halltown	10/31/07	1705	39°18′49″	77°47′52″	4.70	3,040,000	13.0	630	3,860	-193
109	Flowing Spring Run at Millville	10/31/07	1606	39°17′33″	77°47′10″	2.26	1,460,000	11.0	646	5,540	-935
110	Unnamed Tributary No. 1 to Shenandoah River at Blue Acres	11/01/07	1245	39°17′31″	77°46′53″	0	0	---	---	99.7	0
111	Unnamed Tributary No. 2 to Shenandoah River at Blue Acres	11/01/07	1200	39°17′37″	77°46′37″	0	0	---	---	513	0
112	Unnamed Tributary to Shenandoah River at Silver Grove	11/01/07	1130	39°17′40″	77°46′14″	0	0	---	---	11.4	0
113	Unnamed Tributary No. 1 to Shenandoah River at Harpers Ferry	11/01/07	1030	39°18′26″	77°45′59″	0.023	14,900	10.0	674	199	74.6
114	Unnamed Tributary No. 2 to Shenandoah River at Harpers Ferry	11/01/07	0900	39°18′39″	77°45′15″	0	0	---	---	457	0
115	Unnamed Tributary No. 3 to Shenandoah River at Harpers Ferry	11/01/07	0830	39°18′46″	77°45′20″	0	0	---	---	57.1	0
	Springs										
A	Springdale Spring near Shepherdstown (2)	10/31/07	1345	39°28′30″	77°50′02″	0.200	129,000	12.0	607	---	---
B	Spring Hill Spring near Shepherdstown (3)	11/01/07	1025	39°28′01″	77°50′08″	1.56	1,010,000	12.8	595	---	---
C	Rock Spring near Shepherdstown (5)	10/31/07	1140	39°26′08″	77°50′51″	3.75	2,430,000	12.0	---	---	---
D	Falling Spring near Shepherdstown (10)	11/02/07	1215	39°25′15″	77°48′48″	1.09	703,000	12.2	588	---	---

Table 1. Characteristics of streams and springs in the Jefferson County area of West Virginia, October–November 2007.—Continued

[SOWV number is the Jefferson County spring identification number assigned in the report "Springs of West Virginia" by McColloch (1986); ft^3/s, cubic feet per second; gal/d, gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; °, degrees; ′, minutes; ″, seconds; ---, unknown]

Map identifier (plate 1)	Site name (SOWV number)	Date	Time	Latitude[1]	Longitude[1]	Discharge		Water temperature, in °C	Specific conductance, in µS/cm	Drainage area, in acres	Base-flow[2] yield, in (gal/d)/acre
						ft^3/s	gal/d				
E	Halverson Spring near Shepherdstown	10/31/07	1345	39°25′12″	77°48′34″	0.076	49,100	12.8	580	---	---
F	Southwood Spring near Kearneysville (12)	11/01/07	1400	39°24′51″	77°52′15″	1.28	825,000	14.0	689	---	---
G	Elmwood Spring near Shepherdstown (14)	10/31/07	1515	39°23′42″	77°48′49″	0.049	31,700	13.0	614	---	---
H	Rippling Spring near Bakerton (16)	11/01/07	1807	39°22′58″	77°45′11″	0.688	445,000	12.0	615	---	---
I	Springdale Spring near Leetown (24)	11/02/07	0750	39°20′37″	77°54′36″	0.596	385,000	12.0	645	---	---
J	Qwens Springs at Leetown (28)	11/01/07	1200	39°20′38″	77°56′06″	0	0	---	---	---	---
K	Harpers Ferry Spring near Harpers Ferry (29)	10/31/07	1800	39°20′11″	77°46′04″	0.011	7,110	---	---	---	---
L	Kane Flowing Springs near Ranson (32)	11/01/07	1120	39°18′42″	77°50′29″	0.121	78,200	13.0	656	---	---
M	Burns Flowing Springs near Ranson (33)	11/01/07	0950	39°18′36″	77°50′25″	0.746	482,000	13.0	958	---	---
N	Klein Spring near Harpes Ferry (34)	11/01/07	1645	39°18′31″	77°44′48″	0.002	1,290	12.0	22	---	---
O	Aldridge Spring at Aldridge (37)	11/01/07	1500	39°18′05″	77°55′05″	0.371	240,000	12.5	572	---	---
P	Priest Field Spring near Middleway (40)	10/31/07	1125	39°17′58″	78°00′39″	3.72	2,410,000	12.0	662	---	---
Q	Turkey Run Spring at Middleway (41)	10/31/07	0925	39°18′00″	77°58′08″	0.923	597,000	---	---	---	---
R	Capper Spring at Middleway (43)	11/01/07	1135	39°17′55″	77°59′59″	0.583	377,000	13.0	611	---	---
S	Engle Springs near Charles Town (45)	11/01/07	1315	39°17′49″	77°53′46″	2.55	1,650,000	13.5	659	---	---
T	Wysong Spring at Charles Town (48)	11/01/07	1715	39°17′33″	77°52′45″	0.056	36,200	12.0	574	---	---
U	Unnamed Spring at Charles Town	11/01/07	1750	39°17′31″	77°52′23″	0.170	110,000	12.0	550	---	---
V	Stonefield Springs near Charles Town (50)	11/01/07	1317	39°16′52″	77°49′35″	2.63	1,700,000	13.5	621	---	---
W	Russel Spring near Middleway (51)	11/01/07	1252	39°16′17″	78°01′19″	0	0	---	---	---	---
X	Claymont Springs near Charles Town (54)	11/01/07	0955	39°15′38″	77°54′17″	0.66	425,000	11.5	718	---	---
Y	Claymont Paige Spring near Charles Town (55)	11/01/07	1115	39°15′48″	77°54′06″	0.36	231,000	15.0	605	---	---
	Byrd Spring near Charles Town (56)	11/01/07	1115	---	---	---	---	---	723	---	---
Z	Clipp Spring near Charles Town (65)	11/01/07	1606	39°15′03″	77°50′23″	0.33	216,000	12.8	622	---	---
AA	Head Spring on Bullskin Run at Summit Point (76)	11/01/07	1400	39°14′13″	77°57′18″	0.15	95,700	13.0	527	---	---
BB	Bell Spring at Wheatland (79)	11/01/07	1530	39°14′08″	77°53′58″	0.38	244,000	12.0	688	---	---

[1]Horizontal coordinates are referenced to North American Datum of 1983 (NAD 83).

[2] Base-flow yields are computed between measurement sites as change in channel discharge divided by change in drainage area. Yields are negative for losing (influent) reaches and positive for gaining (effluent) reaches. See plate 1 for areas associated with the base-flow yield calculations for the indicated measurement sites.

Southeastern Jefferson County

The headwaters of streams in southeastern Jefferson County are in the Blue Ridge Mountains, and flow is toward the Shenandoah River. Base-flow yields of all watersheds in this area were less than 100 gal/d/acre, and several streams were not flowing at the time of the study. The low base-flow yields reflect the large depth to groundwater, which was greater in this area than anywhere else in the county as a result of low-permeability bedrock and steep topography.

Summary

Discharge, temperature, and specific conductance of streams and springs were measured during base-flow conditions from October 31 through November 2, 2007, in the Jefferson County area of West Virginia. Hydrologic conditions during this period were at approximately the 75-percent duration of annual flows. Five discharge measurements of Opequon Creek defined increased flow from 29,000,000 gallons per day (gal/d) at Carters Ford to 51,400,000 gal/d near Vanville. No flow was observed at 45 of 110 additional stream sites that were inspected for this study, and discharge at the 65 flowing stream sites ranged from 1,940 to 17,100,000 gallons per day (gal/d). Discharge at 28 springs ranged from no flow observed at two sites to 2,430,000 gal/d. Water temperature at the stream sites (excluding one affected by pumpage) ranged from 5.0 to 15.0 °C, and specific conductance ranged from 51 to 881 µS/cm. Water temperature at the springs ranged from 11.5 to 15.0 °C, and specific conductance ranged from 22 to 958 µS/cm. Channels in 51 watersheds were determined to have gained flow, and base-flow yields ranged from 3.4 to 235,000 gal/d/acre. Channels in 14 watersheds were determined to have lost flow, and base-flow yields ranged from -9.6 to -1,770 gal/d/acre.

Western Jefferson County is characterized by a relatively shallow water table, as indicated by the depth to water at 213 wells in the area; mean and median depths to groundwater were 33.4 and 29.3 ft below land surface, respectively. Groundwater flow in western Jefferson County is influenced by structural features, especially by thrust faults and cross-strike faults, and by low-permeability lithologic units. Large springs are in watersheds adjacent to other watersheds that have little or no surface-water discharge, most likely because of interbasin transfer of groundwater along faults that dissect the area.

The greatest base-flow yield measured in the northeastern area of the county was 651 gal/d/acre, but most other watersheds in this area yielded much less outflow. Mean and median depths to groundwater at the 69 wells measured in northeastern Jefferson County were 56.0 and 55.0 ft below land surface, respectively. However, mean and median depths to groundwater at the 28 wells within 1.5 miles of the Potomac River were 70.0 and 71.3 ft below land surface, respectively. In addition, most streams in watersheds adjacent to the Potomac River were not flowing during this study. The Potomac River is deeply incised; groundwater probably flows directly to it rather than to the local stream system in these areas. Depths to groundwater in areas within 1.5 miles of the Potomac River were greater than in other areas of the county with similar carbonate bedrock.

Base-flow yields in several watersheds exceeded 400 gal/d/acre in south-central Jefferson County. Mean and median depths to groundwater at 108 wells in the area were 53.9 and 52.8 ft below land surface, respectively. These are approximately the depths to groundwater in the carbonate-dominated bedrock of the northeastern part of the county; however, base-flow yields are much greater in south-central Jefferson County than in the northeastern part of the county. No flow was noted at several streams near their confluence with the Shenandoah River, but these streams are less areally extensive than those along the Potomac River. The hydraulic gradient to the Shenadoah River in south-central Jefferson County most likely is not as great as that to the Potomac River in the northeastern county area; if that is the case, then the Shenandoah River would have a smaller effect on the local stream systems than the Potomac River would in the northeastern area.

Southeastern Jefferson County is dominated by noncarbonate bedrock, and depth to groundwater is greater than in other areas of the county. Mean and median depths to groundwater at the 26 wells measured in this area of the county were 86.6 and 59.5 ft below land surface, respectively. The low permeability of the non-carbonate bedrock and steep relief in this area probably is the cause of the greater depths to groundwater. Several streams were not flowing, and yields from the flowing streams were less than 100 gal/d/acre.

Acknowledgements

The West Virginia Division of Water and Waste Management is thanked for their support of this study.

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