# Base-Flow Yields of Watersheds in the Berkeley County Area, West Virginia

By Ronald D. Evaldi and Katherine S. Paybins

Prepared in cooperation with the Berkeley County Commission

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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 ($hm^2$) |
| | 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 minute (gal/min) | 0.06309 | liter per second (L/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

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

Vertical control information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Altitude, as used in this report, refers to distance above the vertical datum.

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## Abstract

Base-flow yields at approximately 50 percent of the annual mean ground-water recharge rate were estimated for watersheds in the Berkeley County area, W.Va. These base-flow yields were determined from two sets of discharge measurements made July 25–28, 2005, and May 4, 2006. Two sections of channel along Opequon Creek had net flow losses that are expressed as negative base-flow watershed yields; these and other base-flow watershed yields in the eastern half of the study area ranged from -940 to 2,280 gallons per day per acre ((gal/d)/acre) and averaged 395 (gal/d)/acre. The base-flow yields for watersheds in the western half of the study area ranged from 275 to 482 (gal/d)/acre and averaged 376 (gal/d)/acre.

## Introduction

Berkeley County, W.Va., is in the Eastern Panhandle of the State, about 65 mi northwest of Washington, D.C. The 2004 population of Berkeley County was 89,400 and had increased about 50 percent since 1990 (U.S. Census Bureau, 2006). The primary source of water for most domestic and community water-supply systems in Berkeley County is ground water (Shultz and others, 1995). State and local officials are concerned about the effects that the escalating demands for water are having on the ground-water resources of the county. Should long-term use of ground water exceed its rate of replenishment, water shortages could result. Estimates of ground-water-recharge rates throughout the county are needed for resource management planning. Ground-water recharge is a function of precipitation, temperature, runoff, infiltration rates, geology, topography, and vegetative cover. These factors are difficult to quantify by direct measurement and, as a surrogate, ground-water recharge can be estimated from stream-discharge data obtained during base-flow conditions. The base flow of streams is derived from ground-water outflow and, except for possible outflow differences caused by interbasin water transfers, the relative rates of base-flow yields from watersheds are assumed to be proportional to recharge.

Discharges of streams and a wastewater-treatment-plant outfall in the Opequon Creek Watershed in Berkeley County were measured during base-flow conditions in July 25–28, 2005 (Evaldi and Paybins, 2006). In order to extend the study area to describe the base flow of streams throughout the county, additional stream-discharge measurements were made during base-flow conditions on May 4, 2006. These included stream-discharge measurements in the Opequon Creek Watershed, in the Back Creek Watershed, and on small tributary streams that drain directly to the Potomac River (table 1, at back of report; fig. 1). Presentation of these measurements herein is the result of a cooperative effort by the U.S. Geological Survey (USGS) and the Berkeley County Commission.

### Description of the Study Area

Berkeley County, which encompasses a land area of 325 $mi^2$, is bounded by Jefferson County, W.Va., to the east; Morgan County, W.Va., to the west; the State of Virginia to the south; and the Potomac River to the north (fig. 1). As reported by Shultz and others (1995), the eastern half of Berkeley County is characterized by gently rolling topography, with altitudes ranging from about 310 to 800 ft. The western half of the county is characterized by northeastward-trending parallel ridges and valleys, with altitudes ranging from about 310 to 2,200 ft.

The Potomac River drains all of Berkeley County. The principal tributaries to the Potomac River are Meadow Branch, Cherry Run, Back Creek, Harlan Run, Opequon Creek, and Rockymarsh Run. Four tributaries of Opequon Creek are of significant size: Tuscarora Creek, Evans Run, Middle Creek, and Mill Creek. The base-flow discharges of all of these streams were measured, except for that of Meadow Branch (which flows through the Sleepy Creek Public Hunting and Fishing Area). Some tributaries to Opequon Creek that are entirely within Jefferson County are shown in this report because their flow contributions were used in the base-flow yield calculations for Berkeley County watersheds.

## Hydrologic Conditions

This study is based on stream discharge measurements obtained during similar base-flow conditions during July 25–28, 2005, and on May 4, 2006. During these periods, the base-flow discharge provided by ground-water outflow to streams in the study area was approximately half of the long-term mean annual ground-water recharge rate estimated by Kozar and Mathes (2001).

Streamflow at USGS gaging station 01616500 Opequon Creek near Martinsburg, W.Va. (site 37, table 1, fig. 1), averaged 106 $ft^3/s$ (47,600 gal/min) during July 25–28, 2005 a value that is approximately equivalent to the 40-percent duration (flow equaled or exceeded 40 percent of the time) of summer flows reported by Wiley (2006). The station recorded a hydrograph rise to 210 $ft^3/s$ (94,300 gal/min) on July 22; however, this rise in flow is believed to reflect runoff from that part of the 273-$mi^2$ drainage area that is upstream from the study area because rainfall totaled only 0.02 in. during July 16–24 at Martinsburg (National Climatic Data Center, 2005). Therefore, streamflows measured July 25–28, 2005, were assumed to be derived from base flow rather than from surface runoff. Although 0.12 in. of rain fell in Martinsburg on July 25 and 0.13 in. fell on July 27, most of this precipitation was believed to have been evapotranspired as a result of high temperatures (62 to 97°F) during July 25–28 in the Martinsburg area (National Climatic Data Center, 2005).

Streamflow at USGS gaging station 01616500 Opequon Creek near Martinsburg averaged 100 $ft^3/s$ (44,900 gal/min) on May 4, 2006, a value that is approximately equivalent to the 45-percent duration of summer flows reported by Wiley (2006). Streamflow at USGS gaging station 01614000 Back Creek near Jones Springs (site 5; table 1, fig. 1) averaged 71 $ft^3/s$ (31,900 gal/min) on May 4, 2006, a value approximately equivalent to the 70-percent duration of summer flows.

Streams were considered at base flow on May 4, 2006, because no measurable rainfall was reported at Martinsburg during April 26 through May 4, 2006 (National Climatic Data Center, 2006).

It was not possible to define all of the hydrologic factors affecting the results of this study. Pumps were noted as running July 25–28, 2005, at Kilmer Spring and at Lefevre Spring, but outflow measurements were not adjusted because the amount of diversion was unknown (Evaldi and Paybins, 2006). Other unknown diversions or interbasin transfers of water could have occurred during the study.

# Discharge Measurements

Discharge information was obtained during July 25–28, 2005, at 69 stream sites, 31 springs, and 1 wastewater-treatment-plant outfall in the Opequon Creek Watershed (Evaldi and Paybins, 2006). The wastewater-treatment-plant outfall measurement and 17 of the stream measurements were used in this study. Discharge measurements were made at 32 additional stream sites on May 4, 2006.

All sites during both time periods were measured by wading with current meters. Observations of width, depth, and velocity were made at intervals in 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 was within acceptable operational limits. The accuracy of individual discharge measurements was dependent on channel or outflow conditions, and error generally was estimated to be less than 10 percent.

A means of adjusting the measurements to similar conditions was employed because the stream-discharge measurements were obtained during slightly different flow conditions. The measurement adjustments were based on comparison of streamflow-gaging-station records for the dates of the Berkeley County discharge measurements to a flow statistic estimated from the long-term gaging-station records. The flow statistic chosen as the basis for the adjustments was the mean ground-water recharge rate estimates for USGS gaging stations 01616500 Opequon Creek near Martinsburg (9.8 in/yr) and 0161700 Back Creek near Jones Springs (8.5 in/yr) (Kozar and Mathes, 2001). These ground-water recharge rates can be expressed as mean watershed outflow rates, which for Opequon Creek near Martinsburg is 197 $ft^3/s$ and for Back Creek near Jones Springs is 147 $ft^3/s$.

The measurement adjustment factor used for Opequon Creek and other streams in the eastern half of the study area (sites 9–40, and 42–50) was the ratio of 50 percent of the long-term mean watershed outflow rate (98.5 $ft^3/s$) to the flow of Opequon Creek near Martinsburg at the time of data collection. The flow of Opequon Creek near Martinsburg averaged 106 $ft^3/s$ July 25–28, 2005, and 100 $ft^3/s$ on May 4, 2006. Discharge measurements of streams in the eastern half of the study area during July 25–28, 2005, were adjusted by a factor of 0.929, and measurements on May 4, 2006, were adjusted by a factor of 0.985. The measurement adjustment factor used for Back Creek and other streams in the western half of study area (sites 1–8) was the ratio of 50 percent of the long-term mean watershed outflow rate (73.5 $ft^3/s$) to the flow of Back Creek near Jones Springs at the time of data collection. The flow of Back Creek near Jones Springs averaged 71 $ft^3/s$ on May 4, 2006. Stream discharge measurements of Back Creek and other streams in the western half of the study area for May 4, 2006, were adjusted by a factor of 1.035.

## Base-Flow Yields

Base-flow yields equivalent to approximately 50 percent of the annual mean ground-water recharge rate were estimated for watersheds in Berkeley County (table 1, fig. 1). For headwater-channel sites, the base-flow yields were computed as the measured outflow divided by the watershed drainage area. Base-flow yields for other stream-channel sections were computed as the change in channel discharge between measurement sites divided by the amount of intervening drainage area between them. The base-flow yields were expressed in gallons per day per acre (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 and known wastewater-treatment-plant discharges were subtracted. Flow losses of -332 and -940 (gal/d)/acre were thus determined for two subwatersheds along Opequon Creek (sites 15 and 37, respectively). These negative watershed yields might indicate flow losses to the ground-water system, channel underflow, or possible discharge-measurement errors. The base-flow yield of watersheds in the eastern half of the study area, based on measurement sites 9–50, ranged from -940 to 2,280 (gal/d)/acre and averaged 395 (gal/d)/acre. The base-flow yield of watersheds in the western half of the study area, based on measurement sites 1–8, ranged from 275 to 482 (gal/d)/acre and averaged 376 (gal/d)/acre.

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**Table 1.** Discharge measurements of streams in the Berkeley County area, West Virginia, July 25–28, 2005, and May 4, 2006.

[---; unknown; ft³/s, cubic feet per second; gal/d, gallon per day. Horizontal coordinates are referenced to North American Datum of 1983 (NAD 83)]

| Site number | Date | Latitude | Longitude | Drainage area (acres) | Discharge | | [1]Adjusted discharge (gal/d) | [2]Base-flow yield [(gal/d)/acre] | Site name (in West Virginia unless otherwise noted) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | ft³/s | gal/d | | | |
| 1 | 5/4/06 | 393714.0 | 780142.0 | 5,570 | 2.82 | 1,823,000 | 1,886,000 | 339 | Cherry Run near Cherry Run |
| 2 | 5/4/06 | 392124.0 | 781116.0 | 110,000 | 47.7 | 30,830,000 | 31,910,000 | --- | Back Creek near DeHaven, Va. |
| 3 | 5/4/06 | 392608.0 | 780703.0 | 131,000 | 59.6 | 38,520,000 | 39,870,000 | 375 | Back Creek near Shanghai |
| 4 | 5/4/06 | 392711.0 | 780701.0 | 8,100 | 3.33 | 2,152,000 | 2,228,000 | 275 | Elk Branch near Shanghai |
| 5 | 5/4/06 | 393046.0 | 780212.0 | 150,000 | 71.0 | 45,890,000 | 47,490,000 | 482 | Back Creek near Jones Springs |
| 6 | 5/4/06 | 393522.0 | 780014.0 | 12,800 | 7.22 | 4,666,000 | 4,830,000 | 376 | Tilhance Creek near Johnsontown |
| 7 | 5/4/06 | 393536.0 | 780025.0 | 172,000 | 84.8 | 54,810,000 | 56,730,000 | 468 | Back Creek near Johnsontown |
| 8 | 5/4/06 | 393507.3 | 775713.1 | 10,500 | 4.61 | 2,980,000 | 2,935,000 | 280 | Harlan Run at Little Georgetown |
| 9 | 5/4/06 | 393542.2 | 775555.4 | 936 | 0 | 0 | 0 | 0 | Unnamed tributary near Prospect Hill |
| 10 | 5/4/06 | 393632.6 | 775216.1 | --- | 0 | 0 | 0 | 0 | Unnamed tributary near Marlowe |
| 11 | 5/4/06 | 393547.9 | 775207.9 | 703 | 0.103 | 66,570 | 65,570 | 93 | Jordan Run near Marlowe |
| 12 | 5/4/06 | 393358.0 | 775123.0 | 607 | 0.177 | 114,400 | 112,700 | 186 | Magruder Run near Marlowe |
| 13 | 5/4/06 | 391551.5 | 780159.8 | 90,900 | 52.4 | 33,870,000 | 33,360,000 | --- | Opequon Creek at Carters Ford |
| 14 | 5/4/06 | 391707.8 | 780310.2 | 1,530 | 0.096 | 62,050 | 61,120 | 40 | Dunean Run near Ridgeway |
| 15 | 5/4/06 | 391718.3 | 780118.0 | 94,900 | 51.2 | 33,090,000 | 32,560,000 | -332 | Opequon Creek near Ridgeway |
| 16 | 5/4/06 | 391725.7 | 780115.1 | 1,330 | 0.167 | 107,900 | 106,300 | 80 | Silver Spring Run near Ridgeway |
| 17 | 5/4/06 | 391808.7 | 780212.5 | 1,730 | 0.122 | 78,850 | 77,670 | 45 | Specks Run near Ridgeway |
| 18 | 7/25/05 | 391808.2 | 775924.7 | 3,960 | 2.71 | 1,752,000 | 1,627,000 | 411 | Turkey Run at Middleway |
| 19 | 7/25/05 | 391830.7 | 780010.0 | 10,200 | 3.82 | 2,469,000 | 2,294,000 | 107 | Turkey Run near mouth near Middleway |
| 20 | 7/26/05 | 392018.7 | 780326.4 | 10,200 | 3.49 | 2,256,000 | 2,095,000 | 205 | Mill Creek at Bunker Hill |
| 21 | 7/26/05 | 392000.3 | 780325.5 | 2,200 | 0.688 | 444,700 | 413,100 | 188 | Torytown Run at Bunker Hill |
| 22 | 7/26/05 | 391946.8 | 780225.9 | 14,100 | 7.90 | 5,106,000 | 4,743,000 | 1,360 | Mill Creek below Bunker Hill |
| 23 | 7/26/05 | 391854.3 | 780057.7 | 19,700 | 14.0 | 9,048,000 | 8,406,000 | 651 | Mill Creek near mouth near Middleway |
| 24 | 5/4/06 | 391840.8 | 775949.0 | 130,000 | 77.1 | 49,830,000 | 49,080,000 | 2,280 | Opequon Creek near Middleway |
| 25 | 5/4/06 | 392114.9 | 775759.2 | 136,000 | 93.1 | 60,170,000 | 59,270,000 | 1,660 | Opequon Creek near Egypt |
| 26 | 7/26/05 | 392234.0 | 780227.3 | 6,200 | 2.57 | 1,661,000 | 1,543,000 | 249 | Middle Creek near Darkesville |
| 27 | 7/26/05 | 392123.1 | 775813.8 | 9,440 | 4.92 | 3,180,000 | 2,954,000 | 435 | Middle Creek near mouth near Egypt |
| 28 | 7/26/05 | 392115.9 | 775808.8 | 1,200 | 0.080 | 51,700 | 48,030 | 40 | Goose Creek near mouth near Egypt |
| 29 | 7/26/05 | 392115.5 | 775601.3 | 1,760 | 2.06 | 1,331,000 | 1,237,000 | 701 | East Branch Hopewell Run near Leetown |
| 30 | 7/26/05 | 392115.4 | 775600.6 | 3,900 | 2.06 | 1,331,000 | 1,237,000 | 318 | South Branch Hopewell Run near Leetown |
| 31 | 7/26/05 | 392219.5 | 775625.0 | 7,090 | 5.56 | 3,594,000 | 3,338,000 | 604 | Hopewell Run near mouth near Leetown |
| 32 | 5/4/06 | 392312.4 | 775653.3 | 2,880 | 0.523 | 338,000 | 333,000 | 115 | Buzzard Run near Vanville |
| 33 | 5/4/06 | 392332.8 | 775706.6 | 891 | 0.254 | 164,200 | 161,700 | 181 | Sulphur Spring Branch near Vanville |
| 34 | 7/27/05 | 392416.4 | 775547.1 | 4,950 | 3.32 | 2,146,000 | 1,993,000 | 403 | Shaw Run near mouth near Grubbs Corner |
| 35 | 5/4/06 | 392434.7 | 775628.8 | 518 | 0.128 | 82,730 | 81,490 | 157 | Unnamed tributary near Grubbs Corner |
| 36 | 5/4/06 | 392445.5 | 775644.2 | 3,230 | 0.168 | 108,600 | 107,000 | 33 | Cold Spring Run near Douglas Grove |
| 37 | 5/4/06 | 392527.2 | 775616.1 | 172,000 | 100 | 64,630,000 | 63,660,000 | -940 | Opequon Creek near Martinsburg |
| 38 | 7/27/05 | 392528.8 | 775629.3 | 4,560 | 2.94 | 1,900,000 | 1,765,000 | 378 | Evans Run near mouth near Martinsburg |
| 39 | 5/4/06 | 392639.0 | 775546.3 | 426 | 0.044 | 28,440 | 28,010 | 66 | Unnamed tributary near Van Clevesville |
| 40 | 7/27/05 | 392801.9 | 775808.2 | 7,590 | 4.84 | 3,128,000 | 2,906,000 | 383 | Tuscarora Creek at Martinsburg |
| 41 | 7/27/05 | 392706.1 | 775713.6 | --- | 3.94 | 2,546,000 | 2,546,000 | --- | Wastewater-treatment-plant outfall |
| 42 | 7/27/05 | 392654.8 | 775607.7 | 16,900 | 17.0 | 10,990,000 | 10,210,000 | 509 | Tuscarora Creek near mouth near Blairton |
| 43 | 5/4/06 | 392655.3 | 775526.4 | 1,860 | 0.809 | 522,900 | 515,000 | 277 | Unnamed tributary near Blairton |
| 44 | 5/4/06 | 392735.8 | 775509.9 | 198,000 | 121 | 78,200,000 | 77,030,000 | 372 | Opequon Creek near Files Crossroad |
| 45 | 5/4/06 | 392748.4 | 775507.2 | 3,660 | 0.306 | 197,800 | 194,800 | 53 | Unnamed tributary near Files Crossroad |
| 46 | 5/4/06 | 392757.4 | 775506.1 | 901 | 0.414 | 267,600 | 263,600 | 293 | Eagle Run near Files Crossroad |
| 47 | 5/4/06 | 392925.6 | 775442.3 | 742 | 0.335 | 216,500 | 213,300 | 287 | Unnamed tributary near Berkeley |
| 48 | 5/4/06 | 393101.4 | 775325.4 | 207,000 | 126 | 81,440,000 | 80,210,000 | 572 | Opequon Creek near Bedington |
| 48 | 7/28/05 | 393115.1 | 775324.2 | 7,340 | 9.37 | 6,056,000 | 5,626,000 | 767 | Hoke Run near mouth near Bedington |
| 50 | 5/4/06 | 392913.9 | 774942.2 | 10,300 | 5.88 | 3,800,000 | 3,743,000 | 363 | Rockymarsh Run near Scrabble |

[1] Discharge measurements were adjusted to approximate outflow conditions at 50 percent of the long-term annual mean ground-water recharge rate. Discharge measurements of streams in the eastern half of the study area (sites 9–40, and 42–50) during July 25–28, 2005, were adjusted by a factor of 0.929, and measurements on May 4, 2006, were adjusted by a factor of 0.985. Discharge measurements of streams in the western half of the study area (sites 1–8) made on May 4, 2006, were adjusted by a factor of 1.035.

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