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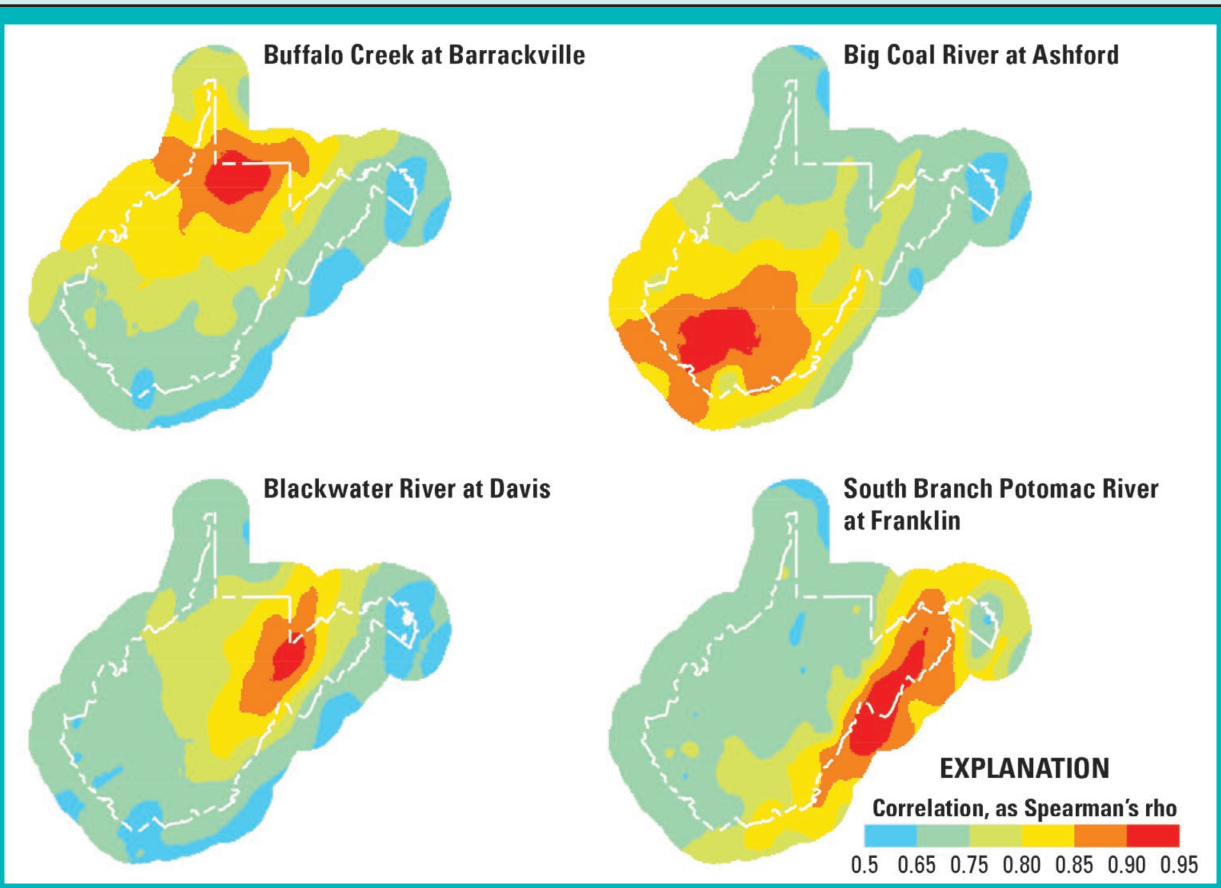
Prepared in cooperation with the West Virginia Department of Environmental Protection
Division of Water and Waste Management, Water Use Section

Correlations of Daily Flows at Streamgages in and near West Virginia, 1930–2011, and Streamflow Characteristics Relevant to the Use of Index Streamgages



Scientific Investigations Report 2014–5061
Version 1.1, August 2014

U.S. Department of the Interior
U.S. Geological Survey

Cover. Correlation of daily flows at unregulated streamgages with daily flows at four streams in West Virginia, as Spearman's rho, 1930–2011.

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By Terence Messinger and Katherine S. Paybins

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U.S. Department of the Interior
SALLY JEWELL, Secretary

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Conversion Factors, Acronyms, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Elevation, as used in this report, refers to distance above the vertical datum. A water year is defined as the 12-month period from October 1 of any given year through September 30 of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months.

Correlations of Daily Flows at Streamgages in and near West Virginia, 1930–2011, and Streamflow Characteristics Relevant to the Use of Index Streamgages

By Terence Messinger and Katherine S. Paybins

Abstract

Correlation of flows at pairs of streamgages were evaluated using a Spearman’s rho correlation coefficient to better identify gages that can be used as index gages to estimate daily flow at ungaged stream sites in West Virginia. Much of West Virginia (77 percent) is within areas where Spearman’s rho for daily streamflow between streamgages on unregulated streams (unregulated streamgages) is greater than 0.9; most withdrawals from ungaged streams for shale gas well hydraulic fracturing are being made in these areas. Most of West Virginia (>99 percent) is within zones where Spearman’s rho between streamgages on unregulated streams is greater than 0.85. Withdrawals for hydraulic fracturing are made from ungaged streams in areas where Spearman’s rho between streamgages on unregulated streams is less than 0.9, but because spatial correlation is partly a function of the density of the streamgaging network, adding or reactivating several streamgages would be likely to result in correlations of 0.90 or higher in these areas.

Seasonal differences in the strength and spatial extent of correlations of daily streamflows are great. The strongest correlations among streamgages are for fall, followed by spring, then winter. One possible explanation for the weak correlations for summer may be that precipitation and runoff associated with convective storms affect one basin and miss nearby basins. A comparison of correlation patterns during previously identified climatic periods shows that the strongest correlations occurred during 1963–69, a period of drought, and the weakest during 1970–79, a wet period. The apparent effect of frequent rain during 1970–79 overshadowed streamgage-network density, which was at its historic maximum in West Virginia at that time, so that the extent of areas with high correlation to at least one streamgage was smaller during 1970–79 than during 1963–69. Correlations for 1992 to 2011 were slightly weaker than those for 1963 to 1969.

The relation between correlation and distance between basin centroids was determined to be stronger for streamgage pairs in the Ohio River Basin than for pairs in the Atlantic Slope River Basins, which in turn was stronger than the relation between pairs of streamgages split between the two major basins. Quantile regression equations were developed for these three comparisons to estimate the Spearman’s rho correlation coefficient for streamgage pairs using distance between basin centroids as a predictor variable. The equations can be used for streamgage network planning. For the Ohio River Basin, the distance between basin centroids at which 50 percent of streamgage pairs would exceed a Spearman’s rho of 0.95 is 9 miles. The distance between basin centroids at which 50 percent of streamgage pairs would exceed a Spearman’s rho of 0.90 is 25 miles, and the distance at which 50 percent of streamgage pairs would exceed a Spearman’s rho of 0.85 is 48 miles. For the Atlantic Slope River Basins, the distance between basin centroids at which 50 percent of streamgage pairs would exceed a Spearman’s rho of 0.95 is 1 mile. The distance between basin centroids at which 50 percent of streamgage pairs would exceed a Spearman’s rho of 0.90 is 13 miles, and the distance at which 50 percent of streamgage pairs would exceed a Spearman’s rho of 0.85 is 41 miles. For pairs of streamgages split between the two major basins, the regression equation gives a value of 0.84 for the correlation coefficient at zero miles. On maps of correlations, the shape of strongly correlated areas for streamgages in the Ohio River Basin is generally round. In the Valley and Ridge Physiographic Province, which generally coincides with the Atlantic Slope River Basins within the study area, areas strongly correlated with streamgages generally coincide with major valleys.

Introduction

West Virginia has traditionally enjoyed an abundant supply of, and a fairly moderate demand for, water. Statewide water demand has remained generally consistent (Carr, 2013). However, localized water demands, especially from small streams, increased when the development of horizontal drilling and hydraulic fracturing led to the development of the Marcellus Shale gas field beginning about 2007. Hydraulic fracturing of a horizontal well in the Marcellus Shale requires large amounts of water. Typically, about 1 to 5 million gallons of water are used for each horizontal well, although the amount of water varies in relation to factors such as the length of the well and the condition and composition of the rock to be fractured.

The natural gas industry differs from municipal water suppliers, the electrical generation industry, and other major water users in the region in that water demands are large but intermittent and widely dispersed. Shale gas wells are commonly developed long distances from large streams but close to small, ungaged streams. Natural gas production and management companies that had worked in the region prior to the development of hydraulic fracturing had long histories of obtaining the modest amounts of water needed for development or reclamation of conventional gas wells and well sites from nearby small streams. As the volume of water withdrawn from small, ungaged streams increased during development of the Marcellus Shale, concern grew that withdrawals could adversely affect aquatic life, and so the West Virginia Department of Environmental Protection (WVDEP) developed first voluntary guidance and then permitting requirements under an emergency rule. The Natural Gas Horizontal Well Control Act, enacted by the West Virginia Legislature in 2011, required WVDEP to review Water Management Plans that include the source of water to be used for hydraulic fracturing.

The initial voluntary guidance was based on use of an online Water-Withdrawal Guidance Tool (WWGT; West Virginia Department of Environmental Protection, 2013c; *http://www.dep.wv.gov/WWE/wateruse/Pages/WaterWithdrawal.aspx*). Criteria were established to identify flow conditions under which withdrawals would be appropriate. Map zones were developed that referred to real-time index streamgages in the U.S. Geological Survey (USGS) streamgaging network, and potential water users were advised by the tool if streams in that zone, on that day, were expected to be too low to support water withdrawals.

The WWGT uses all active streamgages on unregulated streams (referred to in this report as "unregulated streamgages") to refer to map zones that were delineated using best professional judgment, principally considering regulation status, location and drainage area (M.I. Stratton, West Virginia Department of Environmental Protection, oral commun., 2010). Only unregulated streams are used for index streamgages, although information from streamgages on regulated streams is used to issue guidance for regulated stream reaches. The smallest streams available were preferred for the WWGT because flows (or more precisely, a proportion of mean annual flow) were to be estimated using a drainage-area ratio for the index streamgage to the ungaged site. A principal concern was that small streams typically rise and recede more quickly than large streams.

The WWGT is a convenient web-based tool that can be used to obtain streamflow information for ungaged stream sites using streamflow data from index streamgages. However, the streamgaging network in and near West Virginia has not been specifically designed for the purpose of estimating near real-time flow at ungaged stream sites. Currently, little information is available on when and where in West Virginia flows on ungaged streams could reasonably be estimated in near-real time on the basis of flow conditions at index streamgages. Coverage of index streamgages could presumably be improved by expanding the streamgaging network, but the number and locations of the additional streamgages would be required data for determining whether that expansion was more cost-effective than other available methods of obtaining flow information needed to assess water withdrawals.

To obtain this information, the USGS, in cooperation with the WVDEP Division of Water and Waste Management, assessed conventional and map correlations among streamgages. Spatial patterns of correlation of daily flows at paired streamgages have been determined, as have seasonal and long-term differences in flow correlation at paired streamgages. Differences in long-term flow correlation result from the effects of climate variation, land-use change, and streamgaging network density.

Purpose and Scope

The purpose of this report is to provide additional insight for the selection of index gages to estimate near real-time daily streamflow at ungaged stream sites. Correlation analysis is used to assess the representativeness of the streamgaging network in and near West Virginia for making near-real-time estimates of flow at ungaged streams. Seasonal, long-term, and spatial variations in streamflow correlations among streamgages are discussed. Aspects of stream hydrology that are relevant to the use of index streamgages for estimating flows in real time are discussed. Correlations of daily flows in unregulated streams during water years 1930–2011 as Spearman's rho are shown in illustrations. Predicted correlations for various periods of record also are shown. Correlation coefficients of Spearman's rho are listed in tables.

Description of Study Area

Most of West Virginia is within the Appalachian Plateaus [19,960 square miles (mi^2)] and Valley and Ridge (4,220 mi^2) Physiographic Provinces, although a small area (20 mi^2) at the easternmost tip of West Virginia is within the Blue Ridge Physiographic Province (fig. 1). The Appalachian Plateaus Physiographic Province is an area of flat-lying or gently folded rocks that formed when a peneplain was uplifted during the Appalachian Orogeny and then was dissected by stream erosion in the ensuing 300 million years (Fenneman, 1938). Elevation is highest in the east, where some peaks are higher than 4,000 ft (NAVD 88), and lowest in the west near the Ohio River, where the valley is lower than 600 ft (fig. 2). Relief is generally greatest at highest elevations. Most of the Appalachian Plateaus Physiographic Province within West Virginia is

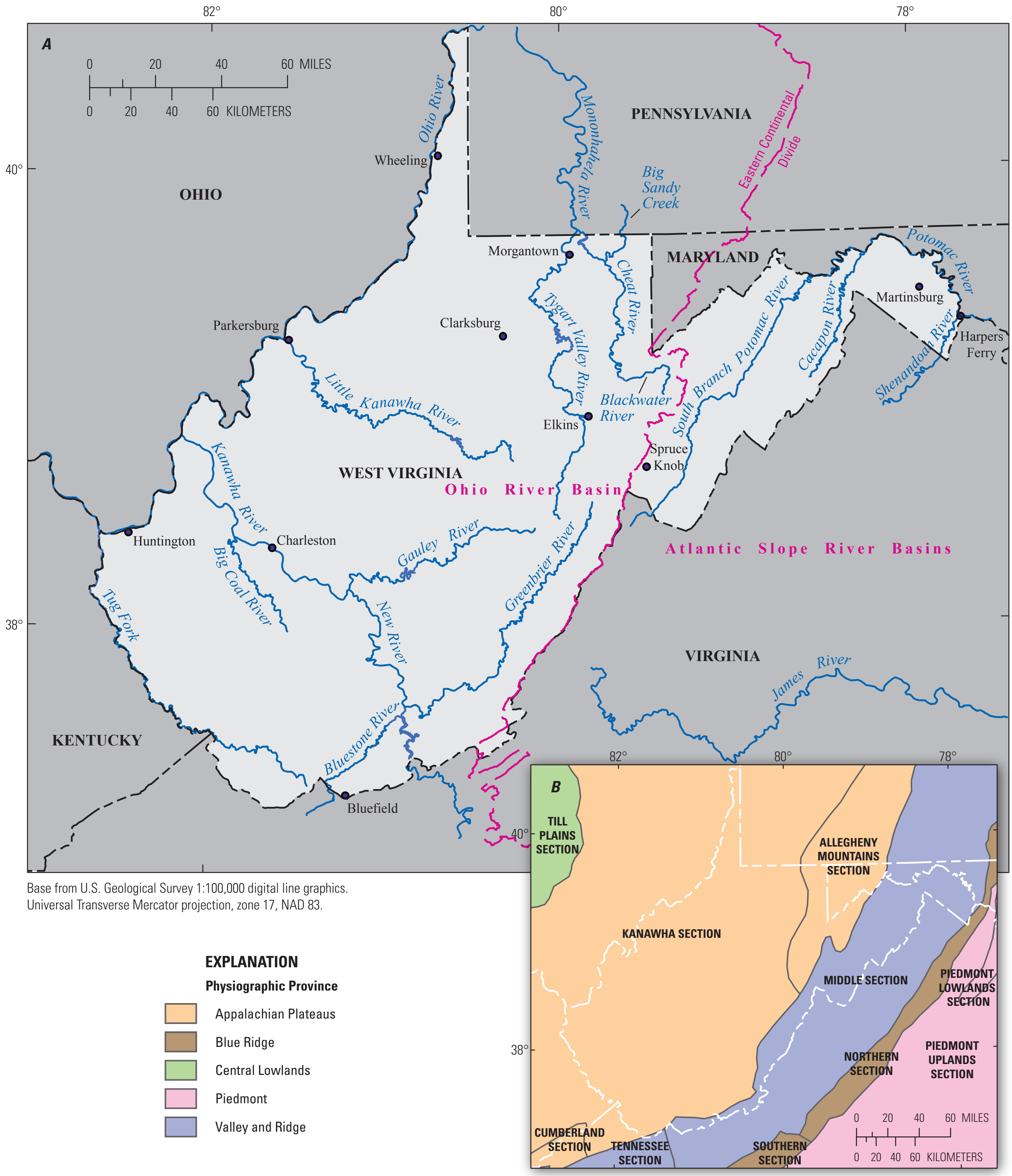


Figure 1. *A*, Selected towns, other locations, rivers, and major river basins in and near West Virginia, and *B*, physiography in and near West Virginia.

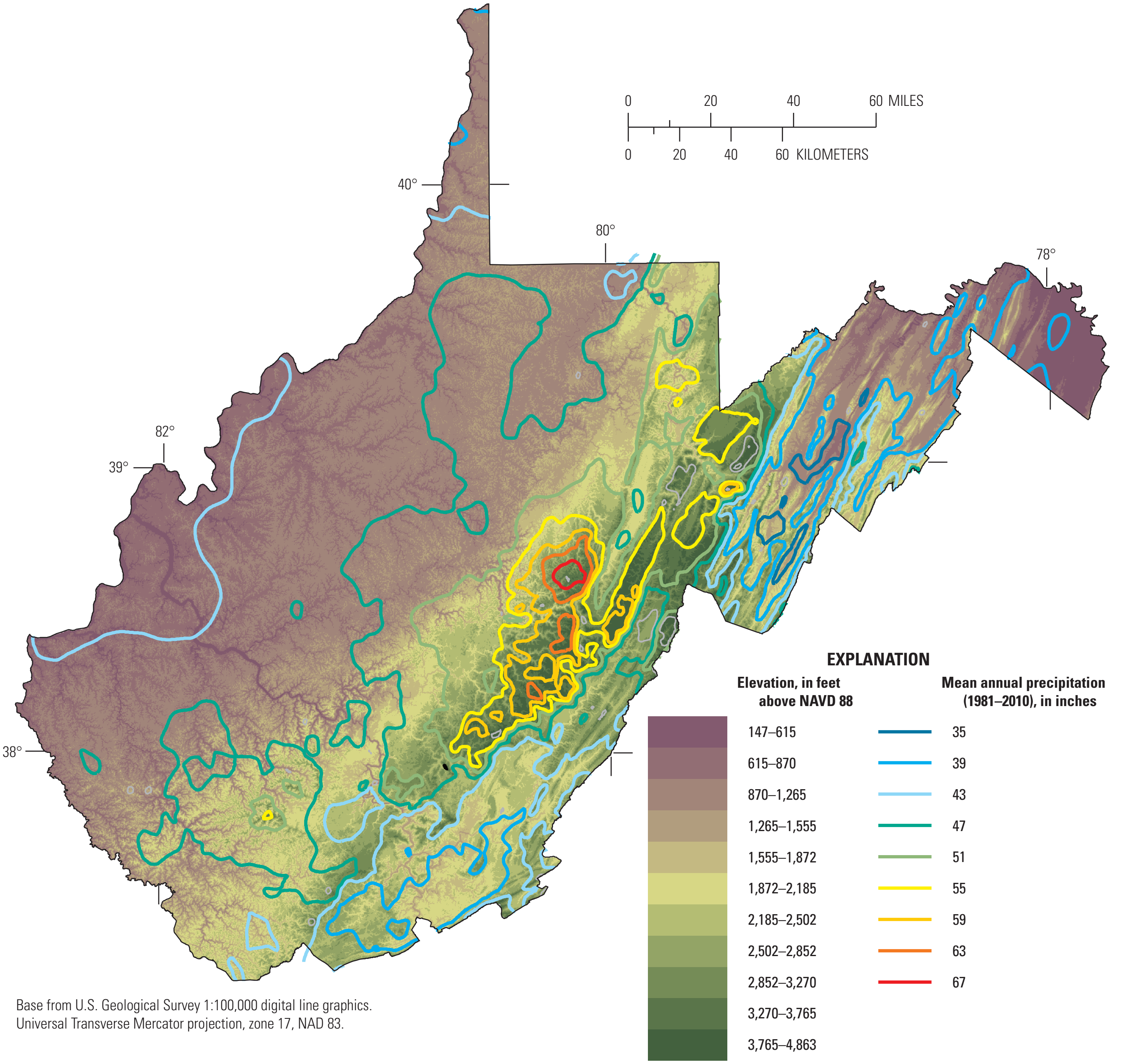


Figure 2. Elevation and mean annual precipitation in West Virginia, 1981–2010.

drained by the Ohio River (19,631 mi^2), and the rest (329 mi^2) is drained by the Potomac River.

In West Virginia, the Valley and Ridge Physiographic Province consists of layers of folded and faulted sedimentary rocks that are of Mississippian age or older (Cardwell and others, 1968). Rocks of the Valley and Ridge province were folded in the Appalachian Orogeny, the same event that uplifted the Appalachian Plateaus. Linear ridges that run from southwest to northeast alternate with valleys. Ridges are generally underlain by harder, more erosion-resistant rock than the rock underlying the valleys. Streams in this province drain in a trellised pattern. Generally, lithology in the Valley and Ridge is more complex than in the Appalachian Plateaus. Some of the valleys, predominantly near the eastern edge of the province, are underlain by karst developed in limestone and dolomite rocks.

Mean annual precipitation and maximum storm precipitation are not closely correlated. Maximum storm precipitation, as measured by any of several frequencies for storm intensity, is greatest in the southern and eastern parts of the study area and least in the northern and western parts of the study area (Hydrometeorological Design Studies Center, 2006a, 2006b). The eastern part of West Virginia is more frequently affected by Atlantic Ocean hurricanes than is the west, which accounts, in part, for the difference. Mean annual precipitation ranged from about 35 to 67 inches during 1980–2010 (PRISM Climate Group, 2012). Distribution of mean annual precipitation is closely related to elevation, and the greatest annual precipitation is received in the highest parts of the study area. The lowest mean annual precipitation in West Virginia is in the Valley and Ridge province and the southern Greenbrier River Basin in the southeastern part of the study area, which are affected by a pronounced rain shadow, and in the Northern Panhandle (fig. 1, fig. 2).

Precipitation varies seasonally throughout the three principal physiographic regions in West Virginia (fig. 3). Maximum precipitation is received in all areas during May–July. Minimum precipitation is received in the Allegheny Mountain and the Kanawha (Unglaciated) sections of the Appalachian Plateaus in October, with only slightly more precipitation in February. In the Valley and Ridge, precipitation is generally low during October and December through February. Normal monthly precipitation in the Allegheny Mountain section in the study area is greater than in the Kanawha section and the Valley and Ridge province during every month of the year. Normal monthly precipitation in the Kanawha section of the Appalachian Plateaus exceeds that of the Valley and Ridge during every month except September, a month when the Valley and Ridge is sometimes affected by Atlantic Ocean hurricanes.

Land use, surface geology, and soils all vary with elevation within the study area (Messinger and Hughes, 2000). Generally, the highest population density and concentration of urban land is in river valleys in the northern and western parts and in the eastern tip of West Virginia. Commercial agriculture is limited in scope, and most commercial farms are near the Ohio and Kanawha Rivers and throughout the Potomac and Greenbrier River Basins (fig. 1). Forest cover is most dense in the mountains in central West Virginia. The largest cities in the study area, all with populations less than 52,000, are Charleston, on the Kanawha River; Huntington, Parkersburg, and Wheeling, on the Ohio River; and Morgantown, on the Monongahela River (U.S. Census Bureau, 2009). Because the largest urban areas in the study area are in the valleys of major rivers, increases in peak storm runoff caused by impervious urban lands are generally localized and most pronounced on a few small streams.

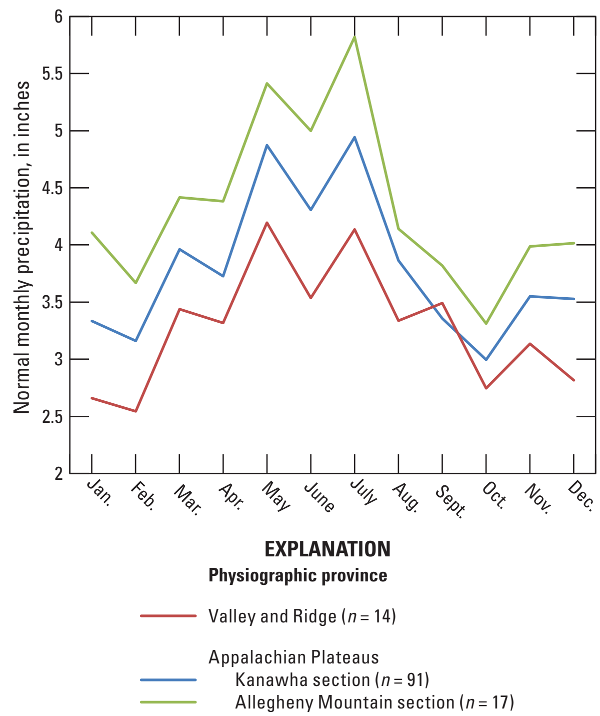


Figure 3. Thirty-year normal monthly precipitation by physiographic setting, in West Virginia, 1981–2010.

Principal economic activities include coal mining, forestry, and oil and gas production, which are widespread throughout most of the study area; manufacturing, which is most common in areas near the Monongahela, Ohio, and Kanawha Rivers; and agriculture, which is most important commercially near the Ohio and Kanawha Rivers and in the Greenbrier River Basin (Messinger and Hughes, 2000). Of these, forestry is nearly ubiquitous throughout West Virginia, the exception being urban areas. Some activities associated with timber harvesting may have strong effects on storm hydrographs and peak flows but smaller effects on medium and low flows.

Oil and gas have been produced in West Virginia since 1859 (Eggleston, 1996). As of 2013, records exist for 55,000 active and 12,000 abandoned oil and gas wells, many of them decades old, in 53 of West Virginia's 55 counties (West Virginia Department of Environmental Protection, 2013a).

Development of hydraulic fracturing and horizontal drilling technology led to extensive development of shale gas beginning about 2007, principally in the Marcellus Shale (fig. 4*A*; Soeder and Kappel, 2009). Shale gas wells that have been drilled to the Marcellus Shale in West Virginia include many vertical wells that were not hydraulically fractured; some of these wells were principally targeted at a different formation. Most horizontally drilled, hydraulically fractured wells in the Marcellus Shale are in northern West Virginia (fig. 4*A*). Horizontal wells have also been drilled in Devonian siltstone and shales, particularly in the Huron Member of the Ohio Shale (informally referred to as the Lower Huron), although because those wells are typically air-fractured, they require much less water than Marcellus Shale wells. The Utica Shale (fig. 4*B*), which underlies much of West Virginia and is being developed extensively in Ohio, has been the target for only one well in West Virginia through 2013 (West Virginia Department of Environmental Protection, 2013b).

Surface and underground coal mining are widespread throughout much of the study area (fig. 5). Coal mines alter flow in a complex way. Surface mines increase water yield and low and medium flows (Messinger and Paybins, 2003). Runoff from intense storms is increased by some, but not necessarily all, surface mines, although runoff from moderate storms, including long, sustained storms, is reduced (Messinger, 2003). Small basins and streams may either gain water from, or lose water to, underground mines, depending on the stratigraphic position of the mine relative to the stream or aquifer, dip of the bedrock, and other factors (Hobba, 1981; Kozar and others, 2013). In general, large streams (drainage area > ~50 mi^2) underlain by underground coal mines usually have increased base flow and water yield compared to streams draining unmined areas.

The Streamgaging Network in West Virginia

The streamgaging network, both nationally and within West Virginia, was developed over decades to meet a variety of goals and serve multiple stakeholders. As technology, knowledge of hydrology, and societal priorities have changed, new uses for streamgages have emerged. The addition of streamgages to the network has largely been opportunistic, and the existing network represents the needs both of the USGS and of other stakeholders.

The goal of the USGS streamgaging program is to provide hydrologic information needed to define, use, and manage the Nation's water resources (Wahl and others, 1995). The program provides a continuous, well-documented, well-archived, unbiased, and broad-based source of reliable and consistent water data. Streamflow information is used for flood warnings; current and short-term (days to months) operational decision making for withdrawals, hydropower production, and navigation; assessing and mitigating flood risks and determining floodplains; planning and designing water infrastructure; managing and improving water quality and assessing stream habitat; monitoring legal agreements on the allocation of water resources; recreational uses; and improving the scientific understanding of the environment and how it is changing over time (Bales and others, 2004). Streams that are important for water supply, flood warning, or other critical operational needs are directly gaged; these include most major rivers. For many smaller streams, streamflow information is provided in the form of regional equations for selected flow characteristics. To provide the information needed to develop, maintain, and refine these equations, streamgages are operated on small streams draining basins that represent larger areas. Understanding regional hydrology requires information on the variability of streamflow regionally, as well as over time. Because many critical streamflow events are infrequent, such as major droughts and floods, streams must be continuously gaged for long periods in order to reliably measure trends. Currently, streamflow is measured continuously at 85 stations. The maximum number of stations, 115, was operated in 1969 and 1977. Historic data, including that for discontinued stations, is critically important for developing regional equations, and streamgages with extended periods of record are among the most valuable because they provide baseline information for detecting future changes (National Hydrologic Warning Council, 2006).

History of the Streamgaging Network in West Virginia

The first streamgage in West Virginia, Kanawha River at Kanawha Falls (streamgage 03193000), was established in 1877, and the second through fifth were established in 1895 (fig. 6). The streamgaging network was expanded to 47 streamgages by 1930, following the development of strip-chart recorders that enabled collection of continuous-stage data. The number of streamgages operated in West Virginia has not dropped below 40 since 1930, and 15 streamgages have been in continuous or near-continuous operation on still-unregulated streams since the 1930s. To be useful for regional analysis, a streamgage must be on an unregulated stream. Among the unregulated streamgages lost for regional analysis since the 1930s are those on streams that became regulated, such as Kanawha River at Kanawha Falls in 1939, with the completion of Claytor Dam on the New River in Virginia. However, the unregulated period of record for such streamgages remains available for analysis and comparison with records from other unregulated streamgages that were operated contemporaneously.

The number of active unregulated streamgages operated in West Virginia increased to 77 in 1947, remained generally stable until 1968, and then increased to 94. West Virginia had the greatest coverage of unregulated streams from 1968 through about 1980. Beginning in 1980, Federal program cuts, including the end of the Coal Hydrology Program, led to the

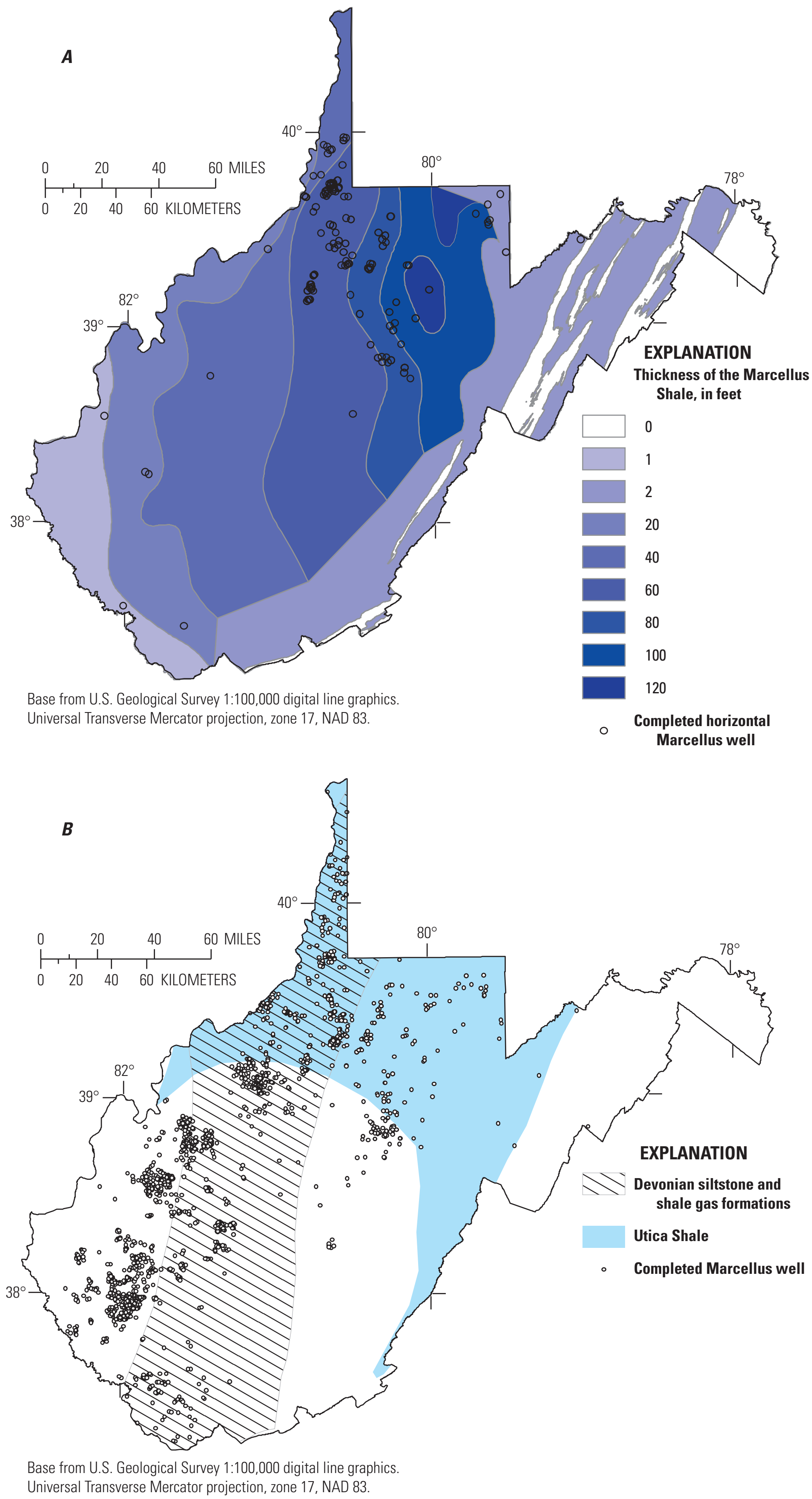


Figure 4. *A*, Thickness of the Marcellus Shale and horizontal gas wells completed in the Marcellus Shale, and *B*, all Marcellus Shale gas wells and the extent of the Utica Shale and gas-bearing Devonian siltstone formations in West Virginia.

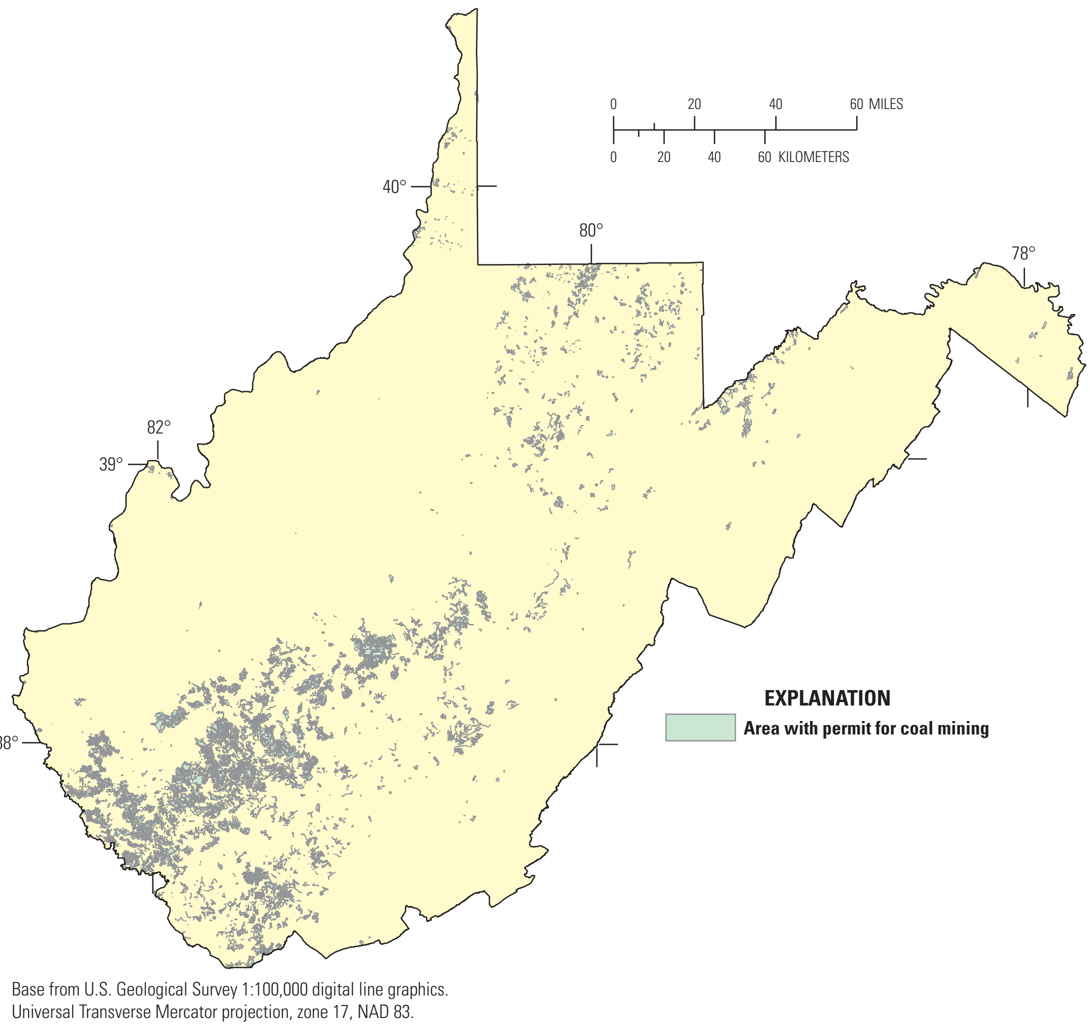


Figure 5. Coal mine permit boundaries in West Virginia.

loss of 41 unregulated streamgages in West Virginia by 1984. The number of unregulated streamgages fluctuated between 43 and 57 until 2003 and was fairly stable at about 60 unregulated streamgages between 2003 and 2010. Thirteen unregulated streamgages were added to West Virginia's network between 2011 and 2013, although not all are intended to be long-term streamgages.

Previous Regional Analysis

The USGS uses records from the streamgaging network to develop regional regression equations for selected flow characteristics. For many small streams, typical needs for streamflow information are satisfied by these regional equations. For West Virginia, regional equations have been developed for flood frequency discharges (Wiley and Atkins, 2010a), annual and seasonal low-flow statistics (Wiley, 2006; Wiley, 2008; Wiley and Atkins, 2010b), and bankfull channel characteristics (Wiley and others, 2002; Keaton and others, 2005; Messinger, 2009). To provide the information needed to develop and refine these equations as more data become available, streamgages are operated on small streams draining basins that represent larger areas.

Understanding regional hydrology requires information on the variability of streamflow over time, as well as spatially. Because many of the critical streamflow events are infrequent, such as major droughts and floods, streams must be continuously gaged for long periods in order to reliably define trends. Developing and refining regional equations is among the most important uses for streamgaging information, and insight gained from regional analyses is used to make decisions about the allocation of resources among potential streamgaging sites.

Of the various regional equations that have been developed for West Virginia, those pertaining to low-flow magnitude and frequency are the most relevant for managing water withdrawals. Equations have been published for a variety of statistics, including selected flow-duration quantiles (Wiley, 2008). For the equations, West Virginia was separated into

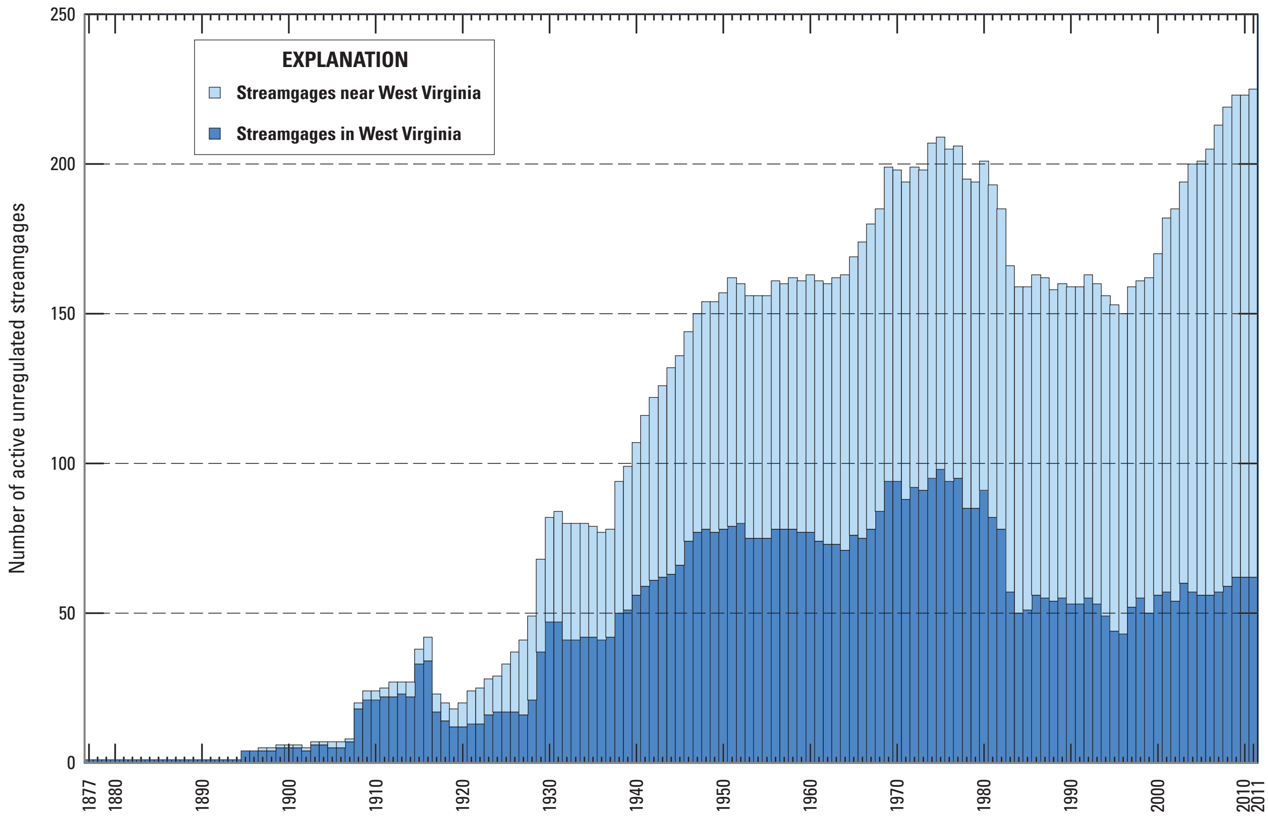


Figure 6. Number of streamgages operated on unregulated streams in or within 50 miles of West Virginia, 1877–2011.

three low-flow regions—North, South, and East. The East Region generally coincides with the part of West Virginia in the Valley and Ridge Physiographic Province and is separated from the North and South Regions by a boundary that is close, but not identical, to the rain shadow along the Allegheny Front.

The low-flow regional study evaluated patterns in the annual minimum daily mean flows and low-flow statistics for streamgages in or near West Virginia (Wiley, 2006). Five periods consisting of similar patterns in minimum flows between 1930 and 2002 were identified: 1930–1942, a period of drought; 1943–1962, which included both dry and wet years; 1963–1969, a period of drought; 1970–1979, a 10-year period when every year had an annual low-flow value greater than the long-term average; and 1980–2002, which included both wet and dry years. The period 1970–1979 is important for efforts to analyze historic flow records because it is the historic period with both the most extensive coverage of unregulated streamgages and the wettest period on record.

Previous Network Analyses for West Virginia

Several streamgaging network analyses have been performed since 1970. Frye and Runner (1970) analyzed the West Virginia streamgaging network when it was near its maximum number of stations and cuts to the program were anticipated. All streamgages were classified according to their purpose. Four categories were designated: gages operated (1) for current uses, such as managing day-to-day operations of a dam or another specific facility, (2) for planning and design or to provide statistical estimates of streamflow characteristics to be used on ungaged streams, (3) to determine long-term trends for 11 designated streams, and (4) to monitor stream environments or to describe the hydrologic environment of stream channels or drainage basins. Categories 2 and 4 seem to overlap; the principal difference is that specific analytical goals were set for category 2. For the planning and design category, eight statistics (mean annual flow, standard deviation of annual flow, mean monthly flow, standard deviation of monthly flow, 50-year flood, 7-day 2-year low flow, 7-day 20-year low flow, and 7-day 50-year high flow) and their accuracy goals were designated (standard errors of prediction equal to those achieved by 10 years of record on streams draining less than 500 mi^2 and 25 years of record on streams draining more than 500 mi^2).

Runner and others (1989) applied optimization algorithms for two goals, (1) to minimize the total error in estimating values for various streamflow characteristics for all streamgages then in operation in West Virginia, and (2) to reduce operational costs. The study is part of a series of studies intended to optimize the national streamgaging network. The study concluded that none of the 60 streamgages, including regulated streamgages, still in operation in 1985 could be discontinued without increasing total error. The principal consideration in minimizing total error was compensating for instrument failure at a time when few streamgages had telemetry and instrument failure shortly after a site was visited could result in weeks or months of lost record. The compensation principally took the form of providing enough redundancy in the network that missing records could be estimated effectively. Now that continuous streamgages in the West Virginia network are routinely equipped with telemetry so that instrument failure is known in near-real time, the risk of extensive lost record resulting from instrument failure has decreased greatly.

Straub (1998) evaluated the streamgaging network for effectiveness in providing regional flow information for Ohio. Regression equations were developed for selected streamflow characteristics. The contribution from each station to the predictive power of the equations was determined, and stations were ranked on the basis of a cost-weighted reduction of the mean square error associated with each equation. Typically, continuing data collection at unregulated streamgages with less than 11 years of record and drainage areas of less than 200 mi^2 contributed the largest cost-weighted reduction to the average sampling-error variance of the regional estimating equations. The greatest spatial gap was in southern Ohio, along the border with West Virginia, owing to sparse coverage of streamgages both in Ohio and nearby parts of West Virginia.

The various plans to redesign or streamline the streamgaging network for West Virginia have not been implemented. Of the 11 long-term trend stations recommended by Frye and Runner (1970), one became regulated in 1973, five were discontinued by 1984, and one was discontinued in 1995. In contrast, 8 of the 15 streamgages that Frye and Runner (1970) indicated could be discontinued have remained in continuous operation through 2013. Runner and others (1989) identified a need for streamflow data for minor tributaries of the Ohio and Kanawha Rivers, a gap that Straub (1998) documented again and that remains unfilled in 2012. The failure to implement these plans resulted partly from technological, analytical, or environmental changes that made the recommendations obsolete and partly from changes in the manner that water data are used, which was difficult to anticipate.

Previous Index-Streamgage Analysis

Although index streamgages have long been used to estimate or infer flow conditions at ungaged streams, most systematic approaches to their use have traditionally concentrated on transferring flow statistics to ungaged sites (Stedinger and Thomas, 1985). In West Virginia, Wiley (2008) determined that, for ungaged locations on gaged streams, better estimates of low-flow statistics can be obtained for ungaged sites within specified ranges of drainage area by transferring the flow statistics to the ungaged site from a gaged site upstream or downstream by using a drainage-area ratio than by using regional equations. For low-flow statistics, the drainage-area ratio ranges from 0.5 to 2.0 for the drainage area of the streamgage, and for high-flow statistics, the drainage-area ratio ranges from 0.21 to 4.76 for the drainage area of the streamgage.

American Whitewater (2013) operates an Internet application intended for whitewater boaters that relates water levels of various streams that are deemed suitable for kayaking, canoeing, or rafting, to water levels at USGS streamgages (*http://www.americanwhitewater.org/content/River/state-summary/state/WV/*). Reaches of most streams of a stream order of 3 or more in West Virginia are described and related to an index gage. Volunteer commenters, including anonymous and pseudonymous commenters, have verified the relations between flow at streamgages and flow at many ungaged reaches. This application has limitations. Comments on and corrections to the stream descriptions for this application are informal. The number of comments is related to the popularity of the reach so that most discussion is of the most popular stream reaches among boaters. Little or no information is available for many streams of regulatory interest, especially for flatwater streams. The relations between favorable boating conditions on small streams and threshold conditions for withdrawal are likely to be imprecise. However, the application represents an extensive collection of observations on common relations between flows at index streamgages and those in ungaged streams made by interested, experienced observers.

Streamflow and Basin Characteristics Relevant to the Use of Index Streamgages

The WWGT was developed by WVDEP to allow potential water users to know whether a proposed water withdrawal was environmentally safe. The WWGT uses an index streamgage to estimate flow for an ungaged stream site. Flow estimates for ungaged sites that are derived from flow at index streamgages will always be imperfect. Understanding the differences in flow characteristics among sites is necessary to make the most of the streamflow data that are available. Nearly all flow characteristics are affected by the size of the basin, even when they are normalized by drainage area. Nearby large and small streams with basins having similar basin characteristics and the same weather patterns will have different flow characteristics, such as the magnitude, timing, and duration of flow.

Streamflow in and near West Virginia varies throughout the year. At the 45 long-term unregulated streamgages in and near West Virginia with continuous or nearly continuous daily record since 1930 (nearly continuous defined as fewer than 3 years of missing record; tables 1 (at end of report) and 2), the annual minimum daily flow was most frequently recorded in September and October. For more than 82 years, the annual minimum daily flow was recorded only 10 times in January, twice in February, and never during March, April, or May. Floods can occur during any month of the year. Instantaneous annual peaks have been recorded in every month, although substantially more have been recorded during January through April than during the rest of the year. Typically, the highest sustained flows occur during late winter or early spring, following the season of maximum recharge, and the lowest sustained flows occur during late summer and early fall.

Many differences in flow characteristics can be summarized using flow duration curves and unit flow (flow per unit drainage area; fig. 7). Even when flow is normalized by drainage area, the duration of flow differs between large and small basins. Flow-duration values representative of 1930 to 2002 were compared for three pairs of adjacent streamgages (Wiley, 2006). For all three pairs, unit flows for most or all of the flow-duration values were smaller for the small stream than for the nearby large stream; only one value of unit flow for the 5-percent flow duration at one site, Panther Creek near Panther (streamgage 03213500), exceeded unit flow for the adjacent larger stream, Tug Fork at Litwar (streamgage 03213000).

Flow characteristics for six pairs of nested streamgages from 2006 to 2010 were evaluated. Drainage areas of the smaller stream of the pair ranged from 1.9 to 16 percent of the drainage area of the larger site (table 3). Although mean annual precipitation was clearly related to water yield (total annual flow normalized by drainage area), basin size or other characteristics also affected flow. Differences in flows between large and small streams within the same basin are not always consistent, especially when the basin is heterogeneous. Five of the six pairs of nested streamgages had a higher water yield at the upstream basin (smaller stream) than at the downstream basin (larger stream). In the Cheat River Basin, water yield from Shavers Fork near Cheat Bridge (streamgage 03067510; drainage area, 60.2 mi^2) slightly exceeded water

Table 2. Number of times that instantaneous annual peak and annual daily minimum flow were recorded, by month, at 45 selected streamgages in and near West Virginia, 1930–2011.

[Annual peaks were computed by water year, October 1–September 30, and annual minima were computed by climatic year, April 1–March 31]

Month	Instantaneous annual peak flow	Annual daily minimum flow
January	135	10
February	150	2
March	249	0
April	140	0
May	94	0
June	69	35
July	29	125
August	40	312
September	24	786
October	60	639
November	50	76
December	103	32

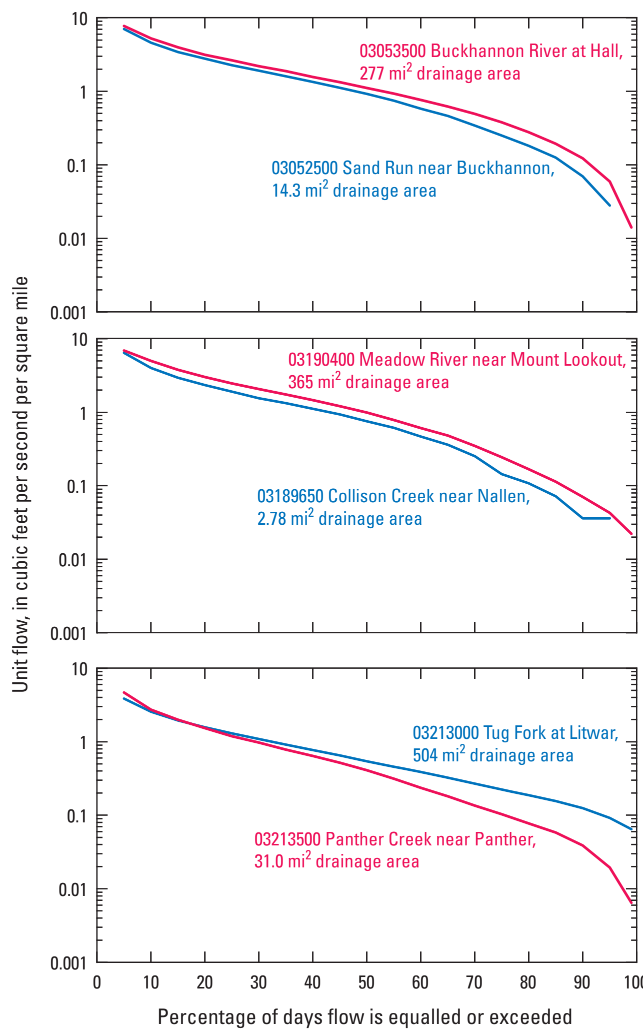


Figure 7. Flow duration of selected pairs of small and large streams with streamgages that are near each other. (Data from Wiley, 2006; mi^2, square miles)

Table 3. Annual water yield, drainage area, and mean annual precipitation for selected pairs of nested streamgages, 2006–2010.

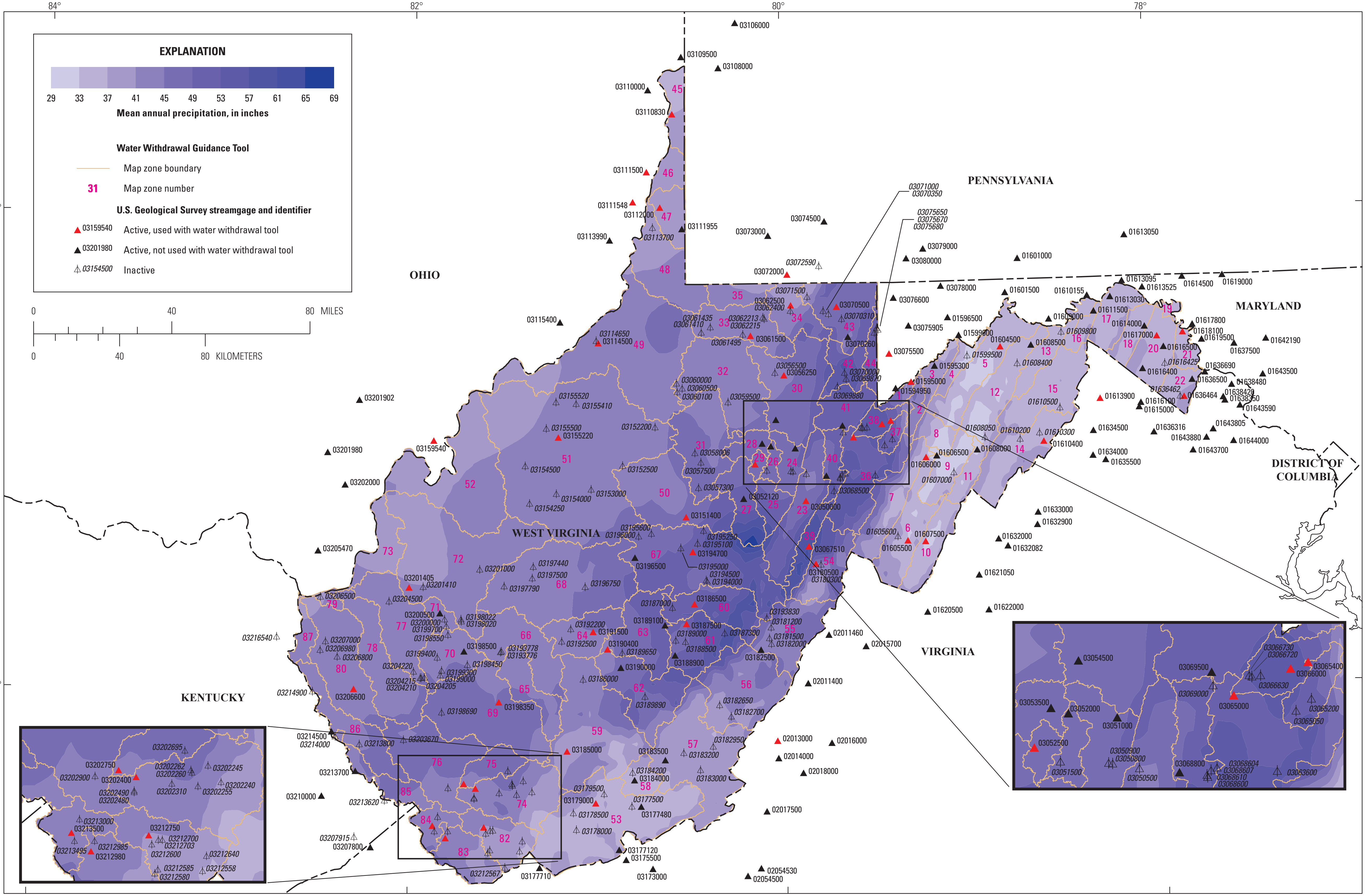
[mi^2, square miles; NA, Not available. Precipitation data from PRISM Climate Group, 2012]

Station number	Streamgage name	Drainage area (mi^2)	Mean annual precipitation, in inches	Annual water yield, in cubic feet per second per square mile					
				2006	2007	2008	2009	2010	Average
03052500	Sand Run near Buckhannon, WV	14.3	51.0	2.01	1.55	2.23	1.99	1.78	1.91
03053500	Buckhannon River at Hall, WV	277	54.9	2.16	1.88	2.44	2.19	1.91	2.12
03067510	Shavers Fork near Cheat Bridge, WV	60.2	58.8	2.61	2.97	2.95	2.54	2.92	2.80
03069500	Cheat River near Parsons, WV	722	54.5	2.28	2.53	2.98	2.31	2.11	2.44
03213500	Panther Creek near Panther, WV	31	43.8	0.59	1.00	0.65	1.55	1.74	1.10
03214500	Tug Fork at Kermit, WV	1,280	44.7	0.71	1.00	0.68	1.38	1.26	1.01
03198350	Clear Fork at Whitesville, WV	62.8	48.3	NA	1.18	1.01	1.25	1.62	1.26
03198500	Big Coal River at Ashford, WV	391	47.3	0.89	1.19	1.05	1.43	1.60	1.23
01610400	Waites Run near Wardensville, WV	12.6	43.8	0.87	1.20	0.87	0.75	1.25	0.99
01611500	Cacapon River near Great Cacapon, WV	675	39.3	0.56	0.81	0.76	0.72	0.95	0.76
03177710	Bluestone River at Falls Mills, VA	44.3	43.3	1.15	1.10	0.98	1.21	1.85	1.26
03179000	Bluestone River near Pipestem, WV	395	40.6	0.89	1.02	0.85	1.20	1.59	1.11

yield from Cheat River near Parsons (streamgage 03069500, drainage area 722 mi^2, table 3). At the two Bluestone River streamgages, Falls Mills (streamgage 03177710, drainage area 44.3 mi^2) and Pipestem (streamgage 03179000, 395 mi^2), the headwater stream showed substantially greater water yield. In both of these examples, mean annual precipitation was greater in the headwater basin than in the main stem basin. For the pair of basins at which water yield was greater in the larger basin, mean annual precipitation in the larger basin was nearly 4 inches per year greater than in the smaller basin.

Mean annual precipitation was determined for the 86 map zones in the WWGT (fig. 8). Five map zones are referenced to index streamgages in basins that receive at least 10 percent more mean annual precipitation than the map zone, and three map zones are referenced to index streamgages in basins that receive at least 10 percent less mean annual precipitation than the map zone. These zones include areas with extensive Marcellus Shale development. One streamgage used in the WWGT as an index for drier areas with extensive Marcellus Shale development is Little Kanawha River near Wildcat (streamgage 03151400, map zone 31); this basin receives a mean precipitation of 53 inches per year (in/yr) (table 4). Map zones representing drier parts of the Little Kanawha River Basin (map zone 31, 48 in/yr) and the West Fork Basin (map zone 50, 48 in/yr) are referenced to the Wildcat streamgage, resulting in an overestimation of available water. Map zones 27 and 48, referenced to Sand Run near Buckhannon, WV (streamgage 03052500), and Wheeling Creek below Blaine, OH (streamgage 03111548), respectively, receive at least 10 percent more mean annual precipitation than the index basins; in these map zones, available water is likely to be underestimated.

Heterogeneous areas can also lead to problematic flow estimates. Estimating flows on an ungaged stream using a basin that receives precipitation more frequently than the ungaged basin could lead to inaccurate flow estimates. WWGT map zones were drawn along basin boundaries, and heterogeneity among index streamgage basins was generally comparable to that among map zones. As a result of this, 36 of 86 map zones include areas in which mean annual precipitation differs by 10 in/yr or more. Seven map zones (map zones 7, 23, 27, 54, 56, 57, and 67) include areas in which mean annual precipitation differs by 20 in/yr or more (table 4). Because mean annual precipitation generally increases with elevation, the greatest differences in precipitation among nearby areas tend to be in mountainous areas. Among the map zones with large differences in mean annual precipitation are some in areas with Marcellus Shale development (map zones 27, 30, 36, 42, 43, and 50). The most uncertainty in flow estimates exists in areas where the precipitation distribution is uneven across the designated map zones. Incorrect estimates of flow are likely when flows have risen at an index streamgage draining a relatively large basin from an event in the headwaters of that basin, but estimates are being made for an ungaged stream near the streamgage that did not receive precipitation in the same event.



Base from U.S. Geological Survey 1:100,000 digital line graphics.
Universal Transverse Mercator projection, zone 17, NAD 83.

Data from West Virginia Department of Environmental Protection, 2013;
U.S. Geological Survey, 2013; and National Oceanic and Atmospheric Administration, 2013.

Figure 8. West Virginia Department of Environmental Protection Water-Withdrawal Guidance Tool map zones, 1981–2010 mean annual precipitation, and streamgages on unregulated streams in and near West Virginia.

Table 4. Water-withdrawal tool map zones and associated index streamgages, and minimum, maximum, and mean annual precipitation, 1981–2010.

[Percentage difference mean precipitation; difference between index basin and map zone, as a percentage of the index basin. Data from PRISM Climate Group, 2012; Min, minimum; Max, maximum]

Map zone	Annual precipitation for indicated map zone, in inches				Index gage	Annual precipitation for the index streamgage basin, in inches				Percentage difference, mean precipitation
	Min	Max	Range	Mean		Min	Max	Range	Mean	
1	45	56	12	51	North Branch Potomac River at Steyer, MD	46	56	10	51	-1
2	43	56	12	48	North Branch Potomac River at Steyer, MD	46	56	10	51	6
3	37	46	9	43	North Branch Potomac River at Steyer, MD	46	56	10	51	14
4	37	45	8	40	Patterson Creek near Headsville, WV	36	46	10	37	-6
5	36	46	10	37	Patterson Creek near Headsville, WV	36	46	10	37	-0
6	31	47	17	39	South Branch Potomac River at Franklin, WV	35	47	12	42	7
7	35	63	28	42	North Fork South Branch Potomac River at Cabins, WV	35	63	28	43	1
8	33	48	14	38	North Fork South Branch Potomac River at Cabins, WV	35	63	28	43	11
9	32	41	9	36	South Branch Potomac River at Franklin, WV	35	47	12	42	14
10	33	49	16	39	South Fork South Branch Potomac River at Brandywine, WV	34	49	15	40	4
11	33	46	13	39	South Fork South Branch Potomac River at Brandywine, WV	34	49	15	40	3
12	33	49	16	37	Patterson Creek near Headsville, WV	36	46	10	37	1
13	37	42	5	38	Patterson Creek near Headsville, WV	36	46	10	37	-2
14	35	49	14	40	Waites Run near Wardensville, WV	39	47	8	44	8
15	36	46	9	39	Hogue Creek near Hayfield, VA	38	41	2	39	1
16	35	41	6	37	Hogue Creek near Hayfield, VA	38	41	2	39	4
17	37	41	4	39	Hogue Creek near Hayfield, VA	38	41	2	39	1
18	39	41	3	39	Hogue Creek near Hayfield, VA	38	41	2	39	-0
19	39	41	2	40	Tuscarora Creek above Martinsburg, WV	39	39	1	39	-1
20	38	40	1	39	Tuscarora Creek above Martinsburg, WV	39	39	1	39	0
21	39	40	1	39	Rockymarsh Run at Scrabble, WV	39	39	0	39	-0
22	39	41	2	39	Bullskin Run below Kabletown, WV	39	40	1	39	-1
23	45	67	23	51	Tygart Valley River near Dailey, WV	45	67	23	52	2
24	48	53	5	50	Sand Run near Buckhannon, WV	50	52	3	51	1
25	52	66	14	55	Sand Run near Buckhannon, WV	50	52	3	51	-9
26	50	52	2	51	Sand Run near Buckhannon, WV	50	52	3	51	-0
27	48	70	22	57	Sand Run near Buckhannon, WV	50	52	3	51	-12
28	48	51	3	49	Sand Run near Buckhannon, WV	50	52	3	51	4
29	49	52	3	51	Sand Run near Buckhannon, WV	50	52	3	51	1
30	45	56	11	49	Three Fork Creek near Grafton, WV	48	53	5	49	0
31	46	52	7	48	Little Kanawha River near Wildcat, WV	48	63	15	53	11
32	44	50	6	47	Buffalo Creek at Barrackville, WV	46	49	2	47	2
33	44	49	5	47	Buffalo Creek at Barrackville, WV	46	49	2	47	1
34	42	51	9	45	Deckers Creek at Morgantown, WV	42	51	9	48	5
35	43	47	4	45	Dunkard Creek at Shannopin, PA	42	47	5	44	-2
36	45	63	18	54	Dry Fork at Hendricks, WV	45	63	18	54	0
37	52	59	7	54	Blackwater River near Davis, WV	52	59	7	54	0
38	50	58	8	56	Blackwater River at Davis, WV	50	59	9	55	-2
39	53	63	9	58	Shavers Fork near Cheat Bridge, WV	53	63	9	59	2
40	50	57	8	52	Shavers Fork near Cheat Bridge, WV	53	63	9	59	11
41	50	57	7	52	Three Fork Creek near Grafton, WV	48	53	5	49	-6
42	45	57	12	53	Three Fork Creek near Grafton, WV	48	53	5	49	-9
43	42	54	12	48	Big Sandy Creek at Rockville, WV	47	53	6	49	2

Table 4. Water-withdrawal tool map zones and associated index streamgages, and minimum, maximum, and mean annual precipitation, 1981–2010.—Continued

[Percentage difference mean precipitation; difference between index basin and map zone, as a percentage of the index basin. Data from PRISM Climate Group, 2012; Min, minimum; Max, maximum]

Map zone	Annual precipitation for indicated map zone, in inches				Index gage	Annual precipitation for the index streamgage basin, in inches				Percentage difference, mean precipitation
	Min	Max	Range	Mean		Min	Max	Range	Mean	
44	49	54	5	52	Youghiogheny River near Oakland, MD	47	54	7	50	-4
45	38	41	2	40	Kings Creek at Weirton, WV	39	41	1	40	1
46	38	40	2	39	Short Creek near Dillonvale, OH	39	41	2	40	2
47	39	43	4	41	Wheeling Creek at Elm Grove, WV	39	45	5	41	2
48	40	48	9	45	Wheeling Creek below Blaine, OH	40	41	1	41	-10
49	42	50	8	46	Middle Island Creek at Little, WV	44	49	5	46	0
50	45	62	17	48	Little Kanawha River near Wildcat, WV	48	63	15	53	9
51	42	49	7	46	South Fork Hughes River below Macfarlan, WV	45	47	1	46	1
52	40	45	5	43	Shade River near Chester, OH	40	42	2	41	-4
53	36	50	14	39	Bluestone River near Pipestem, WV	37	53	15	41	4
54	40	62	22	49	Greenbrier River at Durbin, WV	43	57	14	50	2
55	41	60	19	47	Greenbrier River at Durbin, WV	43	57	14	50	7
56	39	64	24	44	Dunlap Creek near Covington, VA	37	48	10	41	-8
57	37	59	22	41	Dunlap Creek near Covington, VA	37	48	10	41	0
58	37	45	8	39	Piney Creek at Raleigh, WV	40	47	7	43	9
59	39	53	15	45	Piney Creek at Raleigh, WV	40	47	7	43	-4
60	51	65	13	58	Williams River at Dyer, WV	51	65	13	60	2
61	49	65	16	57	Cranberry River near Richwood, WV	49	65	16	60	5
62	43	61	18	50	Meadow River near Mount Lookout, WV	43	61	18	50	-0
63	46	60	14	51	Peters Creek at Lockwood, WV	46	49	3	47	-8
64	44	50	5	46	Peters Creek at Lockwood, WV	46	49	3	47	2
65	42	50	7	46	Clear Fork at Whitesville, WV	46	52	6	48	5
66	43	48	5	45	Peters Creek at Lockwood, WV	46	49	3	47	4
67	48	71	23	55	Elk River below Webster Springs, WV	49	71	21	58	6
68	43	53	9	47	Peters Creek at Lockwood, WV	46	49	3	47	1
69	42	55	14	47	Clear Fork at Whitesville, WV	46	52	6	48	2
70	45	48	3	47	Hurricane Creek at Hurricane, WV	41	43	2	42	-10
71	43	46	3	45	Hurricane Creek at Hurricane, WV	41	43	2	42	-5
72	40	46	6	43	Hurricane Creek at Hurricane, WV	41	43	2	42	-2
73	41	42	2	42	Hurricane Creek at Hurricane, WV	41	43	2	42	2
74	41	52	10	47	Guyandotte River near Baileysville, WV	41	52	10	47	0
75	46	56	10	49	Clear Fork at Clear Fork, WV	46	56	10	49	0
76	44	52	7	47	Clear Fork at Clear Fork, WV	46	56	10	49	5
77	42	48	6	44	Hurricane Creek at Hurricane, WV	41	43	2	42	-5
78	42	48	5	45	East Fork Twelvepole Creek near Dunlow, WV	46	47	1	47	3
79	42	43	1	42	Hurricane Creek at Hurricane, WV	41	43	2	42	-0
80	42	47	5	45	East Fork Twelvepole Creek near Dunlow, WV	46	47	1	47	4
82	41	48	6	44	Tug Fork at Welch, WV	41	48	6	44	-0
83	42	45	3	44	Dry Fork at Beartown, WV	42	47	5	44	0
84	43	46	2	44	Panther Creek near Panther, WV	43	44	1	44	-1
85	43	47	4	46	Panther Creek near Panther, WV	43	44	1	44	-4
86	44	47	4	45	East Fork Twelvepole Creek near Dunlow, WV	46	47	1	47	2
87	43	44	1	43	East Fork Twelvepole Creek near Dunlow, WV	46	47	1	47	7

Effects of Basin and Channel Characteristics on Flow Timing

Estimating flow by use of index streamgages is also complicated by the effects of the channel size and the basin shape on the timing of flows. Smaller basins rise and fall more quickly in response to precipitation than do large basins. Basin shape also affects timing of rises and recessions, in that distances along a stream within a compact basin are shorter than distances within a long, narrow basin. Within a compact basin, large and small streams are likely to rise and recede at the same times (fig. 9). As an example, rises and recessions, shown by hourly (or more frequent) observations, on the Blackwater River at Davis (streamgage 03066000) and Dry Fork at Hendricks (streamgage 03065000, fig. 9*B*) are nearly simultaneous, despite the difference in basin areas (85.9 mi^2 for Blackwater River and 349 mi^2 for Dry Fork). These streams, tributaries to the Black Fork of the Cheat River, are in a mountainous part of the Appalachian Plateaus. The drainage pattern is dendritic, the basins are compact, and the distance between the basin centroids is small. The centroids of the basins are 17.4 miles apart, and the streamgages themselves are 9.12 miles apart.

In contrast, Waites Run at Wardensville, a tributary of the Cacapon River, typically recedes many hours before the Cacapon River rises at the streamgage near Great Cacapon. The centroids of these two basins are 10.6 miles apart, but the gages are 40.3 miles apart. The Cacapon River is in the Valley and Ridge Physiographic Province, drainage is trellised, and the basin is long and narrow. Distribution of precipitation during a storm is among the factors affecting flow timing. During rain events, precipitation distribution within basins is likely to cause the greatest variation in flow timing in large basins. Differences in the timing of runoff from the same storms, among and within basins, are among the aspects of streamflow that are reflected in correlation of daily flows.

Relation of Flow Duration, Timing, and Correlation to Hypothetical Seasonal and Annual Withdrawal Criteria

Annual, seasonal, and monthly flow statistics have been proposed as criteria for thresholds for withdrawing water from streams (Poff and others, 2010; Richter and others, 2011; New York Department of Environmental Conservation, 2011). Assessing the effects of flow magnitude and alteration on aquatic life is outside the scope of this report. However, the coverage and resolution of the streamgaging network may influence the practicality of selecting among an annual, seasonal, or monthly flow statistic for withdrawal criteria. As an example, annual and seasonal 75-percent flow-duration values (D75) are compared; annual and seasonal statistics representative of 1930 to 2002, as determined by Wiley (2006), were used for these comparisons.

The D75 is the daily flow, in cubic feet per second, which is equaled or exceeded on 75 percent of the days. Over the long term, the same average number of days per year, 91, have flows that are less than either the annual or seasonal D75. The distribution of those days is different; few years have exactly 91 days with flows less than either the annual or monthly D75 (fig. 10). Commonly in West Virginia, flow is greater than the annual D75 for several months in winter and spring, even during dry years, but falls below the annual D75 for most of the late summer and fall, even during wet years. At Sand Run near Buckhannon during water years 2006–10, flow was less than the annual D75 for several months every year, but flow on many days during those months exceeded the seasonal D75. During 2007, 2009, and 2010, spring flows exceeded the annual D75 but were less than the seasonal D75.

In addition to when water may be withdrawn under different scenarios, the length of time between withdrawal opportunities is of potential interest to water users. The maximum numbers of days between exceedances of the 75-percent flow durations are listed in tables 5–8 (at end of report) for 15 streamgages in West Virginia with nearly continuous, unregulated record during the 1930–2011 water years. There is a difference in the number of days per year that annual and seasonal flow-duration values of the same nominal value are exceeded. In some years, the seasonal 75-percent flow durations are exceeded on more days, and in some years, the annual statistics are exceeded on more days.

During water years 1930–2011, the average number of days per water year that the 15 streamgages exceeded the annual D75 ranged from 178 in 1999 to 346 in 2003 (table 5). The average number of days per water year that flow at 15 streamgages exceeded the seasonal D75 ranged from 164 in 1966 to 353 in 1974 (table 6). The annual D75 value was exceeded on more days than the seasonal D75 value in 37 of 82 years. For the annual averages at the 15 streamgages, the number of days when flow exceeded annual and seasonal D75 values differed by 7 or fewer days during 30 of 82 years and 14 or fewer days during 57 of 82 years. The maximum difference was 42 days in 1930, when the annual D75 value was exceeded on an average of 238 days, but seasonal D75 values were exceeded on only 196 days.

For individual streamgages, the annual D75 was exceeded the fewest days (91) during any water year at Shenandoah River at Millville (01636500) in 2002; annual D75 was exceeded the second fewest days (127) at the same streamgage in 1966. Flow at three streamgages was greater than the annual D75 for entire water years: Shenandoah River at Millville in 1949 and 1973, and Big Coal River at Ashford (03198500) and Tug Fork near Kermit (03214000), both in 2004. The seasonal D75 was exceeded the fewest (51) and second fewest (89) days during any water year at Shenandoah River near Millville in 2002 and 1966, respectively; in 1966, seasonal D75 was exceeded on only 3 more days at Cacapon River near Great Cacapon (01611500) than at Shenandoah River near Millville. The seasonal D75 value was exceeded

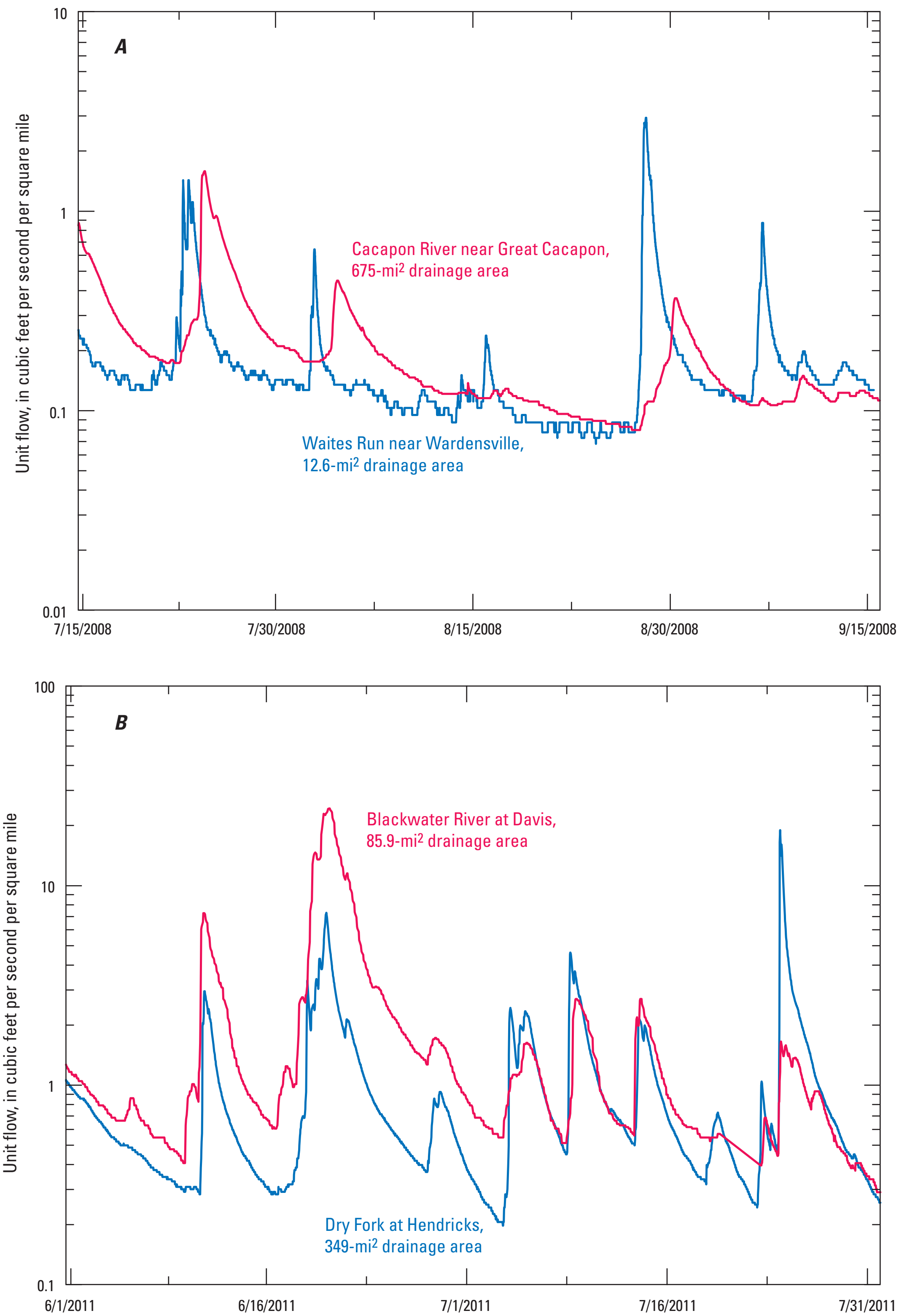


Figure 9. Timing of rises and recessions of flow at *A*, Waites Run near Wardensville and Cacapon River near Great Cacapon, 2008, and *B*, Blackwater River at Davis and Dry Fork at Hendricks, 2011, in West Virginia. (mi^2, square miles)

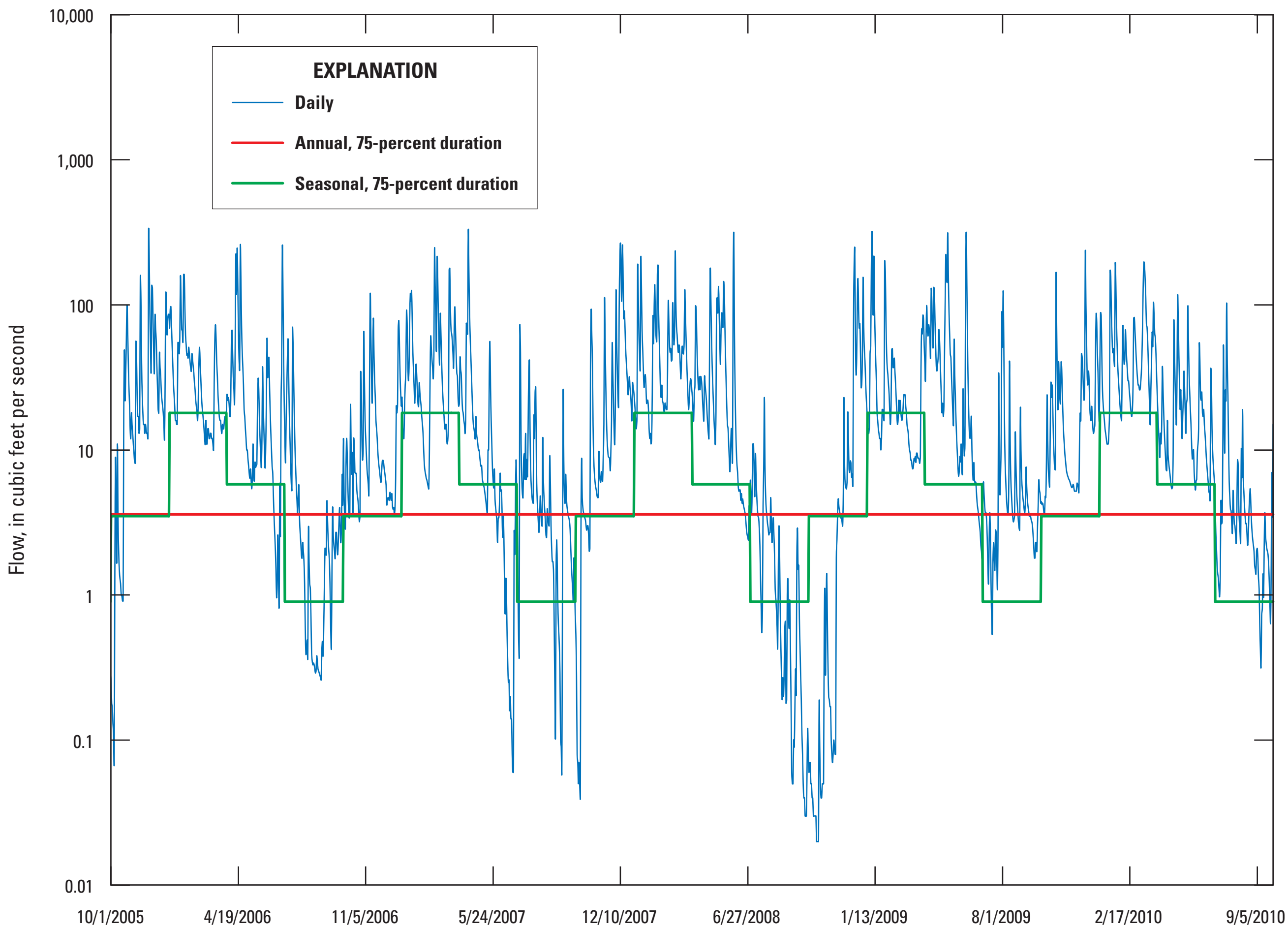


Figure 10. Daily flow and annual and seasonal 75-percent flow durations at Sand Run near Buckhannon, West Virginia, water years 2006–2010.

for entire water years at four streamgages: Cacapon River near Great Cacapon (01611500 in 1964 and 2004), Shenandoah River near Millville (01636500 in 1973, 1996, and 1997), Williams River at Dyer (03186500 in 1950), and Tug Fork near Kermit (03214000 in 1974).

In contrast to the inconsistent numbers of days when the annual and seasonal D75 were exceeded, the interval between exceedance of annual D75 values was consistently greater than the interval between exceedance of seasonal D75 values. For individual streamgages, the maximum interval between exceedances of annual D75 values was 222 days at Big Coal River at Ashford (03198500) in 1931 (table 7). All 15 of the streamgages had an interval of at least 130 days between exceedances of annual D75 values during the 1930–2011 water years. At four streamgages (South Branch Potomac River near Springfield, 01608500; Shenandoah River at Millville, 01636500; Big Sandy Creek at Rockville, 03070500; and Big Coal River at Ashford, 03198500) the interval between exceedances of the annual D75 values was greater than 180 days at least once. The maximum interval between exceedances of seasonal D75 values was longer than 180 days at only one streamgage during only one year (Big Sandy Creek at Rockville, 03070500, in 1954; table 8). The minimum interval between exceedances of annual and seasonal D75 values, zero days, occurred at the streamgages where flow remained above the annual and seasonal D75 for entire years.

For averages of the 15 streamgages, the maximum number of days between exceedances of annual D75 values was greater than or equal to the maximum number of days between exceedances of seasonal D75 values in 79 of 82 years. The three exceptions are 1977, 1994, and 2003. Averages were equal in 1978 and 1980. Differences in the number of days between exceedances of annual and seasonal D75 values were 7 or fewer during 15 of 82 years and 14 or fewer during 42 of 82 years. The maximum difference was 32 days, in 1999.

Use of monthly or seasonal flow statistics may require greater accuracy and precision from the streamgaging network than the use of annual flow statistics. Because the magnitudes of many monthly or seasonal values for D75 are less than those for the annual D75, precision of the stage-discharge relations (the rating) for low flows at index streamgages is of great importance. Small changes in the stage-flow rating resulting from intermittent scour, and especially from annual leaf accumulation in the fall, are common and would be of consequence in assessing the data used to estimate flows at ungaged sites in real-time. The relatively weak correlations of daily flows in summer compared to fall, winter, and spring are relevant in determining how flows are to be estimated, particularly if frequent decisions are to be made concerning flows close to the threshold. Management options that would not require the use of index streamgages during times when they are unlikely to provide accurate estimates include the use of off-stream storage and direct measurement of flow at the time of proposed withdrawal.

Correlation of Daily Flows at Streamgages

Index streamgages typically have been selected by location or by best professional judgment. If index streamgages are to be used for withdrawal-management purposes, a systematic method is desirable.

Analytical Approach and Site Selection

A systematic method, the Map Correlation Method, for determining appropriate index streamgages to be used for estimating daily flows has been developed and applied in Massachusetts (Archfield and others, 2010; Archfield and Vogel, 2010), the Connecticut River Basin (Archfield and others, 2013), Iowa (Linhart and others, 2012), and Pennsylvania (Stuckey and others, 2012). The Map Correlation Method relies on spatial patterns in the correlation of daily flows among streamgages. Correlations of daily flows are computed among a group of streamgages, and spatial patterns in correlation are determined by ordinary kriging. A set of correlation maps is produced that depict the predicted correlation of daily flows for each streamgage that was included in the analysis. Index streamgages are selected using map correlation and flow-duration exceedance probability regression equations to estimate daily mean flow for an ungaged location. The streamgage for which daily flows are most likely to be correlated with those at any ungaged stream location of interest can be determined by referring to the maps. Previous applications of the Map Correlation Method have been used to estimate time series of daily flows for ungaged stream locations.

Stuckey and others (2012) tested several modifications to the Map Correlation method and reported two that generally improved results. The first modification was in the metric used to describe the location of the streamgage. Areas of predicted correlation with the index streamgages are determined by ordinary kriging of the correlation coefficients. Stuckey and others (2012) compared, for two basins, the use of the coordinates of the centroid of the gaged basin to the use of coordinates of the gage location at the basin outlet for kriging; centroid distance made little difference in one basin, but improved results in the other.

The second modification, which made less difference to the final results, was the selection of a correlation coefficient. Archfield and others (2010) determined correlation by using Pearson's r for log-transformed daily flows. Stuckey and others (2012) compared the accuracy of synthesizing flows in two basins by using Spearman's rho, a rank-based correlation coefficient, to that achieved by using Pearson's r on log-transformed daily flows. Spearman's rho is computed by ranking the observations from smallest to largest, and then performing the same computation as used for Pearson's r on the pairs of ranks instead of the pairs of observations. Both correlation coefficients can range from -1 for a perfect negative correlation to 1 for a perfect positive correlation, and both equal zero for a perfectly uncorrelated dataset. In 10 tests, five scenarios tested in two basins, Nash-Sutcliffe efficiency values of flows synthesized using Spearman's rho were the same as those synthesized using Pearson's r for five tests, were greater for three tests, and were less for two tests. Although the results achieved by Stuckey and others (2012) were generally similar using either correlation coefficient, Spearman's rho offers several logical advantages over Pearson's r. Spearman's rho, unlike Pearson's r, does not rely on the assumption that a relation between two sets of observations is linear. A major advantage of Spearman's rho relative to Pearson's r performed on log-transformed daily flow values is that days with zero flow may be analyzed using a rank transformation, but days with zero flow are excluded from analysis that uses a logarithmic transformation.

For this study, correlations were determined using Spearman's rho. Kriging was done from basin centroids. Several different groups of index streamgages with different periods of record were used (table 1). Details of site and period selection are included in the discussion of analyses. Kriging was done using the ArcGIS 10.1 Geostatistical Analyst (Esri, 2012). Using ordinary kriging, a spherical semivariogram model was optimized for a target index streamgage and its correlations with other streamgages for a target period (Buffalo Creek at Barrackville, WV, 03161500, for 1992–2011). To ensure consistency among sites, the kriging parameters of the nugget, lag size, and partial sill determined for this streamgage were applied to all subsequent correlation maps (table 9). Root mean square error for the semivariogram model was 5.1 percent, and average standard error was 6.8 percent. Sensitivity testing was done for the dataset used to develop the semivariogram model; the nugget was varied by 10 percent and recomputed three times for each of the 222 points in the model. Standard errors for predictions generated during the sensitivity testing ranged from 2.0 percent to 5.0 percent.

In general, previous studies have not examined changes in the correlation of daily flows over time. Because managing withdrawals during summer and fall was an important consideration in this study, a comparison was made of seasonal differences in flow correlations and the manner in which those differences might affect the expected spatial correlation patterns. Comparisons also were made of flow correlations at long-term sites during periods previously identified as representing climatic variation in West Virginia (Wiley, 2006).

Site Selection

Flow data from streamgages operated in or near West Virginia were retrieved from the USGS National Water Information System: Web Interface (NWIS-Web) for 1930–2011. Data and coordinates for streamgages with a year or more of approved data were retrieved. Data were retrieved for all streamgages operated in West Virginia, and the parts of Kentucky, Ohio, and Pennsylvania within 50 miles of West Virginia. Data were retrieved for streamgages in Virginia and Maryland within 50 miles of West Virginia that have been active during the 20 years prior to this study (1992–2011).

Table 9. ArcGIS method report giving kriging parameters used to develop correlation maps.

[%, percent]

Method:	Kriging
Type:	Ordinary
Output type:	Prediction
Trend type:	None
Searching neighborhood:	Standard
Neighbors to include:	5
Include at least:	2
Sector type:	Four and 45 degree
Major semiaxis:	2.491609
Minor semiaxis:	2.491609
Angle:	0
Number of lags:	12
Lag size:	0.235945
Variogram type:	Semivariogram
Nugget:	0.002273
Measurement error %:	100
Model type:	Spherical
Range:	2.491609
Anisotropy:	false
Partial sill:	0.016786

Information on regulation status was compiled from state low-flow frequency reports (Ruhl and Martin, 1991; Straub, 2001; Stuckey, 2006; Wiley, 2006; Roland and Stuckey, 2008; Doheny and Banks, 2010; Martin and Arihood, 2010; Austin and others, 2011; Koltun and Kula, 2013). Additional information on regulation status was compiled from Annual Water-Data Reports and NWIS-Web pages and to determine periods of unregulated record (U.S. Geological Survey, 2013a, 2013b). Regulated periods that could be identified were removed from the database, although data were retained for unregulated periods at these streamgages. Streamgages at sites in basins altered by coal mining, urbanization, or other land uses known to affect flow characteristics were included so that their correlations could be explored, as were sites with basins that drain karst areas or urban areas.

Basin polygons were needed in order to obtain basin centroids. Basin polygons were obtained from Krstolic (2006), Falcone and others (2010), and the U.S. Environmental Protection Agency and USGS National Hydrologic Dataset Plus, version 2 (McKay and others, 2013). Basins were digitized for the streamgages in West Virginia that are not included in those reports. The six non-West Virginia basins were digitized for this study using the USGS web application StreamStats (U.S. Geological Survey, 2013c). Basins that are smaller than 2 mi^2 were not digitized, and the coordinates of their streamgages were substituted for the centroid coordinates. Basins without a published drainage area were excluded from analysis; these basins drain karst areas where the contributing drainage area is believed to differ from the surface drainage area. Basin polygons were available for most unregulated streamgages in West Virginia (table 1; Paybins, 2008).

Correlation Computation

Spearman's rho was determined using R, version 2.15.1 (R Core Team, 2012; table 10, available for download at *http://dx.doi.org/10.3133/sir20145061*). There were 55,737 pairs of sites with 365 or more days of concurrent record during 1930–2011 (table 11, available for download at *http://dx.doi.org/10.3133/sir20145061*). Values of rho range from 0.9977 to -0.02849, and the overall median is 0.7066. Although the correlations of all but 3 of the 55,737 pairs of sites were significantly different from 0 ($p < 0.05$), differences between correlations are of greater interest.

The significance of differences between correlation coefficients is closely linked to the number of observations (table 12). In general, the stronger the correlations are, the more likely that differences between them are to be statistically significant. For instance, with 365 observations, correlation coefficients of 0.90 and 0.85 are significantly different ($p < 0.01$), as are correlation coefficients of 0.85 and 0.80 ($p = 0.03$), but correlation coefficients of 0.80 and 0.75 are not significantly different ($p = 0.09$). With greater numbers of observations, even small differences between weak correlations may be significantly different; with 3,652 observations (10 years of daily flows), the difference between correlation coefficients of 0.25 and 0.20 is significant ($p = 0.02$).

Table 12. Statistical significance of selected pairs of correlation coefficients at selected numbers of observations.

[*n*, number of observations; <, less than]

Correlation coefficient		P value			
r1	r2	*n* = 90	*n* = 180	*n* = 365	*n* = 730
0.95	0.90	0.02	<0.001	<0.001	<0.001
0.95	0.85	<0.001	<0.001	<0.001	<0.001
0.90	0.85	0.15	0.04	<0.001	<0.001
0.90	0.80	0.01	<0.001	<0.001	<0.001
0.90	0.75	<0.001	<0.001	<0.001	<0.001
0.85	0.80	0.30	0.14	0.03	<0.001
0.85	0.75	0.06	0.01	<0.001	<0.001
0.85	0.70	0.01	<0.001	<0.001	<0.001
0.80	0.75	0.41	0.24	0.09	0.02

Uncertainty associated with correlations decreases with the strength of the correlation, and the spatial extent of areas depicted at a given level of correlation is strongly influenced by the uncertainty of that underlying correlation. Because the strong correlations are more precise than the weak correlations, smaller differences between strong correlations are more meaningful than they would be between weak correlations. Maps in this report show strong correlations with finer resolution than weak correlations.

Spatial coverage of flow correlation would be limited if analysis were limited to streamgages with complete or nearly complete records for the entire period of interest; one of the principal questions of the study is "Which new or discontinued streamgages might be useful for filling spatial gaps in the existing network?" As the discussion of statistical power in relation to the number of observations indicates, minimum thresholds exist for a period of record to be significant. Because land use, climate, and other factors likely to affect flow correlation have changed over time, flow data obtained for a short period may not represent long-term flow characteristics; however, land-use and climate changes may cause long-term flow characteristics to be unrepresentative of present conditions.

Comparison of Flow at Two Selected Streamgages

Daily flows at nearby streamgages are often strongly correlated, although the correlation between a given pair of streamgages is likely to vary over time (fig. 11). As an example, daily flows in the 2009 water year for Buffalo Creek at Barrackville, WV (streamgage 03061500), and Dunkard Creek at Shannopin, Pennsylvania, generally compare well.

The basins are adjacent and of similar sizes (table 1). The Dunkard Creek Basin received an average of 44.2 in/yr of precipitation during 1980–2010, whereas the Buffalo Creek Basin received 47.3 in/yr of precipitation (table 4). The basin centroids are 13.7 miles apart, and the streamgages are 20.6 miles apart. Both basins have been, and continue to be, extensively mined for coal.

Unit flow at Dunkard Creek was generally slightly greater than that at Buffalo Creek (fig. 11). By mid-November, after evapotranspiration had decreased, unit flows at the two streamgages began to match closely. Throughout the rest of the fall, winter, and early spring, nearly every rise or recession on one stream was accompanied by a similar rise or recession on the other, although sometimes the magnitudes were slightly different. Several times, one stream rose when the other did not, apparently, because one received precipitation when the other did not. This pattern is common in West Virginia. During fall, winter, and early spring, precipitation usually results from frontal events that are evenly distributed throughout large areas, but during late spring and summer, scattered thunderstorms or differences in thunderstorm intensities result in greatly different amounts of rain in nearby areas.

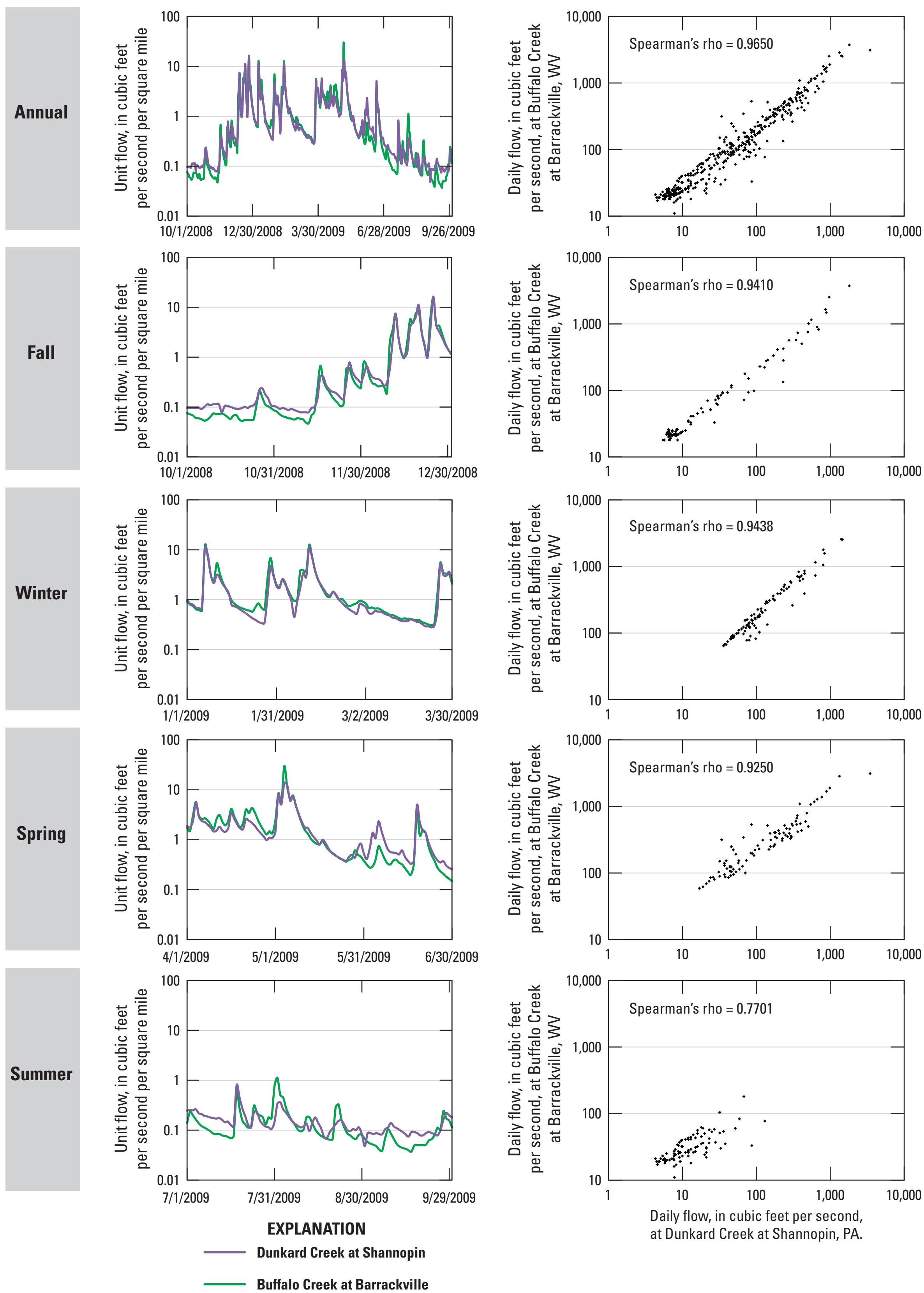


Figure 11. Annual and seasonal hydrographs, and scatterplots of daily flow at Dunkard Creek at Shannopin, Pennsylvania, in relation to Buffalo Creek at Barrackville, West Virginia, water year 2009.

The strength of correlation of the daily flows could be measured by any of several statistics, but for comparison to a flow-duration value, which is based on the ranks of daily flows, a rank-based correlation coefficient such as Spearman's rho is appropriate. Spearman's rho values are shown in figure 11 with scatterplots of daily flow during water year 2009 for Buffalo Creek at Barrackville, WV, and Dunkard Creek at Shannopin, PA, for the entire year and for each of the four seasons.

At the beginning of water year 2009, flows were low at both streamgages. This condition began to change in late May, and during June 3–6, unit flow for Dunkard Creek was about three times that of Buffalo Creek. Throughout the rest of the spring and the summer, flows on the two streams were sometimes similar. Correlation between the two sites for the entire year (0.9650) is slightly stronger than for any of the seasons because the seasonal differences in precipitation and base flow overshadow some of the smaller day-to-day fluctuations. Correlations between the two sites during fall (0.9410), winter (0.9438), and spring (0.9250) were generally strong and similar to each other, and correlation was weaker during the summer (0.7701). Inspection of the scatterplot for summer shows substantial differences in all flows with the greatest differences associated with the manner in which storms moved through the region.

Relation of Correlation Coefficients to Flow Estimation

To assess the relevance of different correlations, a comparison was made for the same 15 streamgages in West Virginia with nearly continuous unregulated records for 1930 to 2011 that were used to assess low-flow trends by Wiley (2006). The analysis was limited to streamgages from West Virginia because low-flow statistics were developed for West Virginia to be representative of 1930 to 2002 and are not directly comparable to statistics developed for a different period (Wiley, 2006).

Correlation coefficients were determined for each pair of streamgages for those 82 years of record and compared to the average number of days when flow at one streamgage of the pair (the estimator streamgage) exceeded one of three selected flow duration values—D75, D60, or D50 (the index flow)—but flow at the other streamgage of the pair (the estimated streamgage) did not exceed the D75 (table 13, at end of report). This tests how frequently an incorrect estimate would be made of whether D75 was exceeded if one streamgage of each pair was to be used as an index for the other. For this comparison, published annual values of D50, D60, and D75 representative of 1930 to 2002 were used (Wiley, 2006).

Incorrect estimates of flow would have been made even between pairs of streamgages with the strongest correlations (fig. 12). Numbers of incorrect estimates differed depending on which streamgage of the pair was the estimator streamgage and which was the estimated streamgage. Incorrect estimates were made less frequently by using the D60 as an index flow rather than the D75 and, in turn, by using the D50 as the index flow rather than the D60. Variances between Spearman's rho and incorrect estimates were generally less at relatively high levels of Spearman's rho (>0.85). The most accurate 82-year average estimates based on exceedances of the D75 were 7.7 and 9.2 days per year with incorrect estimates for a pair of streamgages with a correlation coefficient of 0.9696 (table 13). The most accurate 82-year average based on exceedances of the D60 were 0.1 and 1.2 days per year with incorrect estimates for the same pair of sites, and the most accurate 82-year average based on exceedances of the D50 was 0.1 day for two pairs of sites—the previously mentioned pair of sites and a second pair of sites with a correlation coefficient of 0.9601. For selected threshold values of rho of 0.95, 0.90, and 0.85, the least accurate estimates were, respectively, 11.4, 19.8, and 25.4 days per year, or 3.1, 5.4, and 6.9 percent, for estimates made from exceedances of the D75; 2.0, 4.8, and 9.5 days per year, or 0.6, 1.3, and 2.6 percent, for estimates made from exceedances of the D60; and 1.0, 2.64, and 5.7 days per year, or 0.3, 0.7, and 1.6 percent, for estimates made from exceedances of the D50.

Linear regression equations were developed to relate rho and days of incorrect estimates using each of the three flow duration values (table 14; fig. 12). These equations can be used to estimate the frequency of incorrect estimates of flow using the three flow duration values as index flows among stream sites with known or estimated levels of correlation. For selected threshold values of rho of 0.95, 0.90, and 0.85, the rates of incorrect estimation of flow exceeding the annual D75 predicted from the regression equations were 3.9, 4.9, and 5.9 percent, respectively, when using the D75 as the index flow; 0.4, 1.2, and 1.9 percent when using the D60 as the index flow; and 0.02, 0.5, and 1.0 percent when using the D50 as the index flow.

At the highest flow correlation levels that were observed (>0.95), estimates from the regression equation for the D50 index flow are less than the observations. However, the error rate predicted by the regression equation using the D60 as the index flow for a correlation of rho of 0.95 is 0.4 percent, which may be conservative enough for many purposes.

Table 14. Regression equations and diagnostics relating incorrect estimation of the 75-percent flow duration value at three selected index flows to correlation of daily flows for 15 selected streamgages in West Virginia, 1930–2011.

[R^2, coefficient of determination; P, probability value; D75, 75-percent flow duration; D60, 60-percent flow duration; D50, 50 percent flow duration; rho, Spearman's rho; <, less than]

Index flow	Regression equation	R^2	P
D75	$y = -0.206551(rho) + 0.234892$	0.9325	<0.001
D60	$y = -0.153122(rho) + 0.149549$	0.9010	<0.001
D50	$y = -0.097988(rho) + 0.093265$	0.7789	<0.001

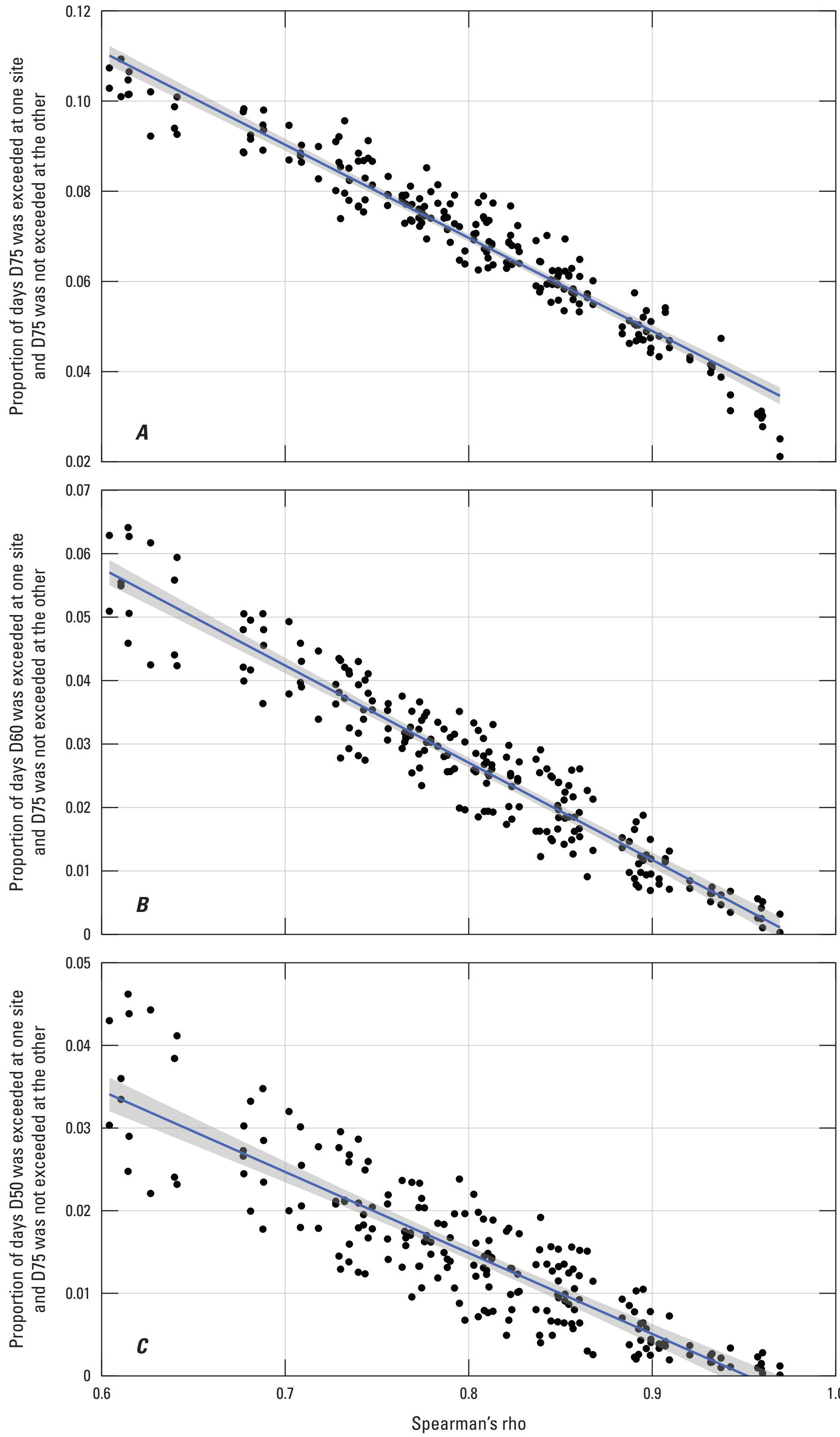


Figure 12. Proportion of days when flow at one site of a pair exceeded the *A*, D75, *B*, D60, and *C*, D50 and flow at the other site was less than the D75 in relation to Spearman's rho correlation coefficient for daily flows with line of regression and confidence interval for 15 selected streamgages in West Virginia, 1930–2011.

Relation of Flow Correlation and Record Length

Annual flow correlations were computed for all pairs of sites from the set of 45 streamgages in and near West Virginia with nearly complete flow records for water years 1930–2011. Correlations were computed for the entire 82-year period and for all possible subsets of 1-, 2-, 5-, 10-, 20-, and 40-year periods. For the 1-year subset, a correlation matrix was generated for all pairs of sites for all 82 years, 1930–2011. For the 2-year subset, a correlation matrix was generated for all 42 2-year periods beginning with an even-numbered year. For the 5-year subsets, a correlation matrix was generated for the 16 5-year periods during 1930–2009, beginning with 1930–1934. For the 10-year subsets, 8 correlation matrices were generated for the 10-year periods during 1930–2009, beginning with 1930–1939; 4 correlation matrices were generated for 20-year subsets in the same way, as were 2 correlation matrices for 40-year subsets.

Simple linear regression between correlations of the subsets and 82-year correlations for all pairs of streamgages in this group showed decreasing variability with increasing length of the subset period. The coefficients of determination (R^2) for the relations of the 1-, 2-, 5-, 10-, 20-, and 40-year subset correlations to the 82-year correlations were 0.431, 0.627, 0.782, 0.891, 0.945, and 0.980, respectively. The relations of the 2-, 5-, and 10-year subset correlations to the 82-year correlations (fig. 13) show that subsets are different from each other even with increasing record length. Variation among time periods is generally greater in the range of values representing pairs of sites with weak correlations, but variation is substantial even at rho greater than (>) 0.90.

These relations indicate that substantial uncertainty exists as to whether correlations determined between streamgages with relatively short (<5 years) periods of concurrent record represent long-term correlation. However, because relations among streamgages change over time, it is unclear that the longest-term periods of record are representative of present conditions.

In an attempt to balance spatial resolution and temporal variability, streamflow records of different lengths are used in this report for different purposes. Correlation coefficients for flow for entire years, as opposed to seasons, are presented for all pairs of streamgages with at least 1 year of concurrent record during 1930–2011, as is the number of days of concurrent record between each pair (tables 10–11). For delineation of the extent of expected correlations of flow at ungaged stream sites with flow at active streamgages and for evaluation of discontinued streamgages as candidates for reactivation to fill spatial gaps in the present streamgaging network, spatial resolution of historic correlation is critical. Short-term streamgages are included in map correlation analysis to maximize spatial resolution, even though the correlations to other streamgages might not be representative of long-term correlations. For analyses intended to identify patterns, exploratory analysis was done with pairs of streamgages with different lengths of record to determine whether including or excluding short-term streamgages clarified patterns; some of the analyses included in this report excluded short-term streamgages. Record lengths of streamgages included in different analyses are given with the discussion of those analyses.

Relation between Flow Correlation and Distance

Spearman's rho for all pairs of streamgages with at least one concurrent year of record was plotted as a function of the distance between basin centroids (fig. 14). Distance between centroids was square-root transformed because the relation between the highest values of rho and distance was linear after transformation. Quantile regression equations were developed for the 25th, 50th, 75th and 99th quantiles, (which are functionally equivalent to percentiles) using the R package quantreg (Koenker, 2013) and plotted to clarify patterns. Variance was greater among pairs of sites with correlations less than the 50th percentile (the median) relative to distance than among those with correlations greater than the median relative to distance.

Factors possibly affecting the relation between correlation and distance that were explored include length of record, streamgage location, basin size, and differences between distance between basin outlets (streamgage locations) and centroids. Effects of differences in distance between centroids and outlets are not shown but were negligible.

Variation in the relation between correlation and distance was greater among pairs of streamgages with short concurrent periods of record than among pairs of streamgages with long concurrent periods of record (fig. 15). For pairs of streamgages with 2 or fewer concurrent years of record (n = 9,684), correlations were both stronger and weaker relative to distance than for pairs of sites with 40 or more concurrent years of record (n = 9,326); although not shown, the variation in the relation between distance and correlation for pairs of sites with intermediate periods of concurrent record generally decreased as record increased. Much of the difference in variation between short-term and long-term streamgages is likely related to year-to-year differences in flow correlation, as shown with the subsets of long-term record at 15 selected streamgages (fig. 13). However, the populations of short-term and long-term streamgages are different. Long-term streamgages may be operated for many purposes, but among them is characterization of regional hydrology (Bales and others, 2004). In contrast, many short-term streamgages were operated as part of an interpretive study designed to characterize the effects of land-use change, management practices, or unique conditions, so that they were selected specifically because they were unrepresentative of regional conditions. Some of the streamgages with one or no correlations with any other streamgage exceeding 0.90, though they were near other streamgages, were identified as having been operated during a short-term interpretive study. Among these are Robinson Run near Petroleum (0315520; Ward and others, 1991), Trace Fork at Ruth (03198020)

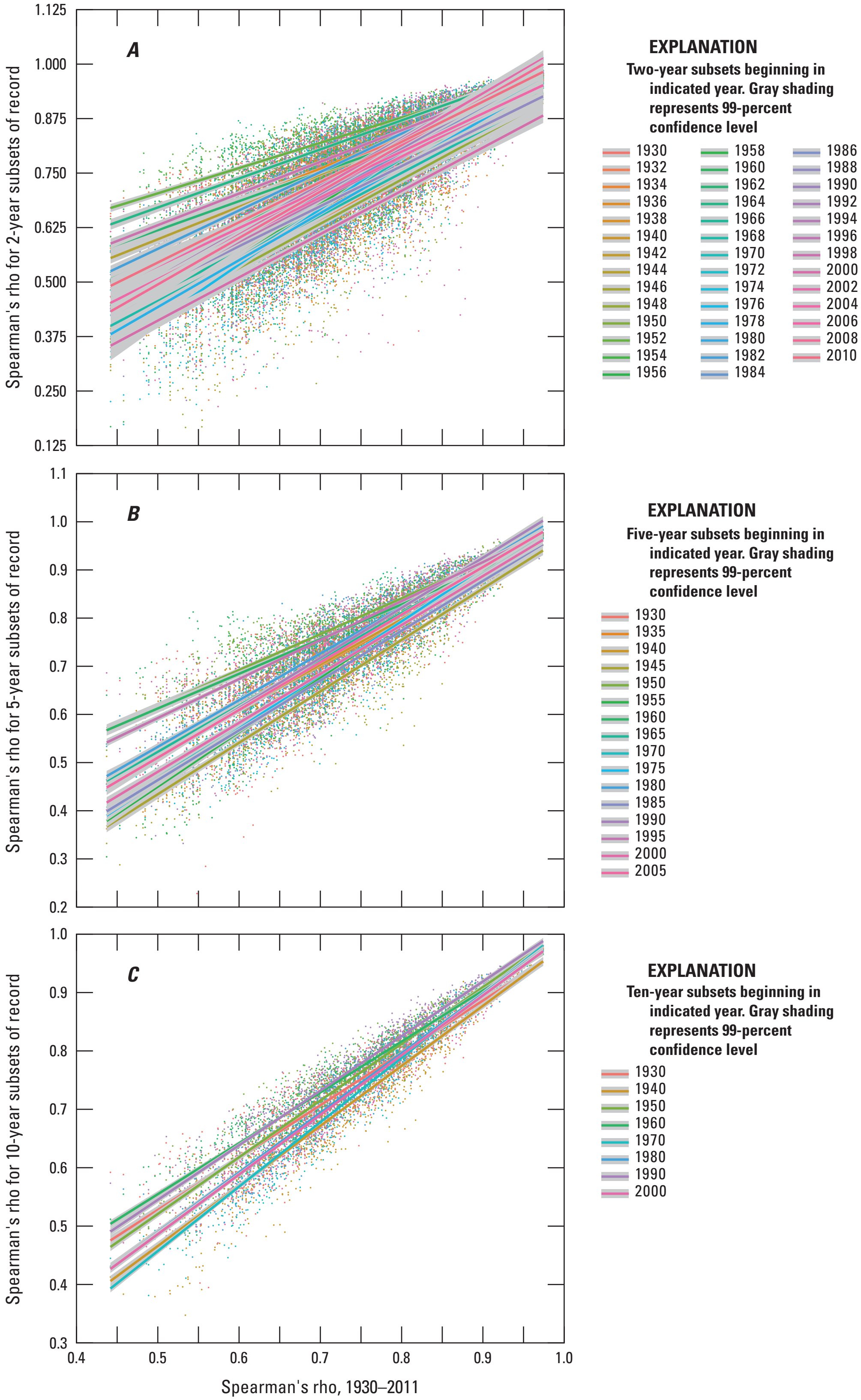


Figure 13. Relation of flow correlation for A, 2-year, B, 5-year, and C, 10-year subsets to flow correlation for the entire period of record for 15 selected streamgages in West Virginia, 1930–2011.

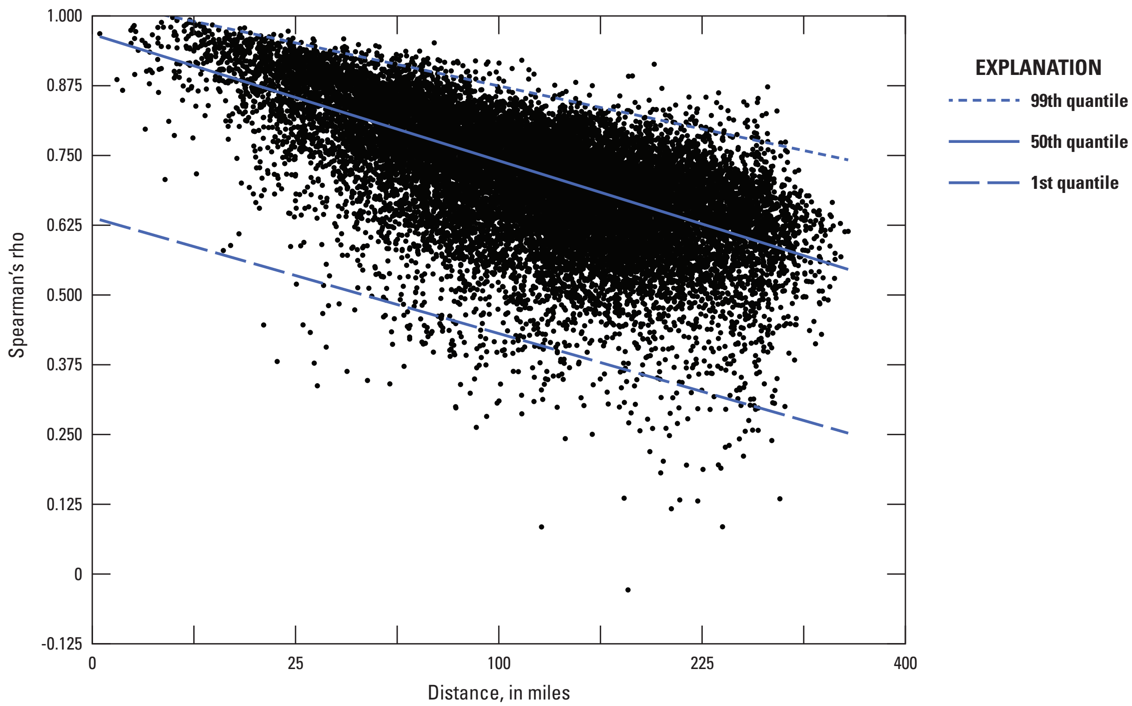


Figure 14. Relation of distance between basin centroids to correlation coefficients of daily flow for pairs of streamgages in and near West Virginia, 1930–2011, with regression lines for the 99th, 50th, and 1st quantiles.

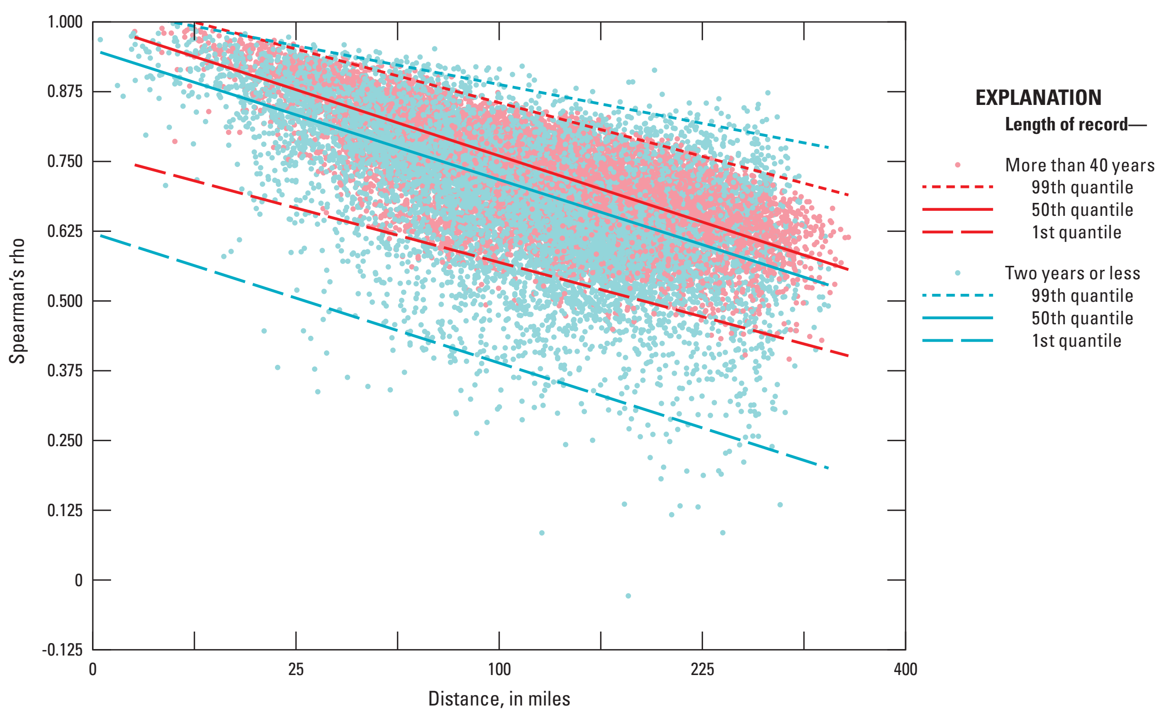


Figure 15. Relation of distance between basin centroids to correlation coefficients of daily flow for pairs of streamgages with more than 40 years of record to pairs of streamgages with fewer than 2 years of record in and near West Virginia, 1930–2011, with regression lines for the 99th, 50th, and 1st quantiles.

and Trace Fork downstream from Dryden Hollow at Ruth (03198022; Downs and Appel, 1986), Unnamed Tributary of Ballard Fork near Mud (03204205; Messinger and Paybins, 2003), Johns Knob Branch near Elkhorn (03212640; Kozar and others, 2013), and Elkhorn Creek Tributary at Welch (03212703; Scott, 1984), all in West Virginia.

The relation between location and correlation was analyzed for pairs of streamgages with 10 or more years of concurrent record following exploratory analysis that included pairs of streamgages with shorter concurrent records. This length of record was selected because it is the shortest period of record for which patterns were evident when relations among all pairs of streamgages were compared; pairs of streamgages with 1, 2, 5, 10, and 20 years of record were compared.

The relation between correlation and centroid distance was stronger for pairs of streamgages in the Ohio River Basin ($R^2 = 0.6758$, $n = 9{,}148$) than in the Atlantic Slope River Basins ($R^2 = 0.3162$, $n = 4{,}813$) or for pairs of streamgages in which one streamgage was in one basin but the other streamgage was in the other basin ($R^2 = 0.2221$, $n = 13{,}109$; fig.16; referred to as “streamgages compared across major basins”). Although the overall relation did not fit a linear model well, linear regression was used to estimate variance among the three pairs of streamgages. Quantile regressions for the 99th, 50th, and 1st quantiles were developed for each set of data. Median quantile regressions for the Ohio River Basin and Atlantic Slope River Basin were outside the 99-percent confidence interval for their respective linear regression, although this was not the case for the streamgages compared across major basins.

The differences in the relations between correlation and distance for major basins are likely related to physiography. Within the study area, the Ohio River Basin is predominantly in the Appalachian Plateaus Physiographic Province, and the Atlantic Slope River Basins are predominantly within the Valley and Ridge Physiographic Province. Streams in the Appalachian Plateaus are characterized by dendritic drainage patterns. Weather systems tend to cross the area from west to east, and though they are affected by orographic uplift, weather systems generally face few barriers until they cross the mountains. In the Valley and Ridge province, stream drainages are trellised. Precipitation from individual weather systems often varies more between valleys than within valleys. Streamgages compared across major basins likely have the weakest relation among the three groups that were compared because of the pronounced rain shadow that, for the most part, coincides with the division between the Atlantic Slope and Ohio Basins and the division between physiographic provinces.

Quantile regression equations were developed for the 99th, 75th, 50th, and 25th quantiles to determine the relation between distance and correlation for the Atlantic Slope and Ohio River Basins and for the relation between the two major basins; all equations are significant ($p < 0.000001$; table 15). These equations can be used to estimate typical, excellent, or poor relations that could be expected between pairs of streams at various distances within the study area for the purpose of streamgage network analysis.

For a distance of 50 miles between basin centroids, the 99th quantile of Spearman’s rho of 0.9128 for the Ohio River Basin represents the strongest correlation seen among sites, and only 1 percent of ungaged sites would be expected to relate to an index streamgage this strongly. The Spearman’s rho predicted by quantile regression for the 50th quantile, or median, 0.8472, is typical of the correlation among sites at this distance, and the Spearman’s rho predicted by quantile regression for the 25th percentile, 0.8140, represents the correlation likely to be observed between at least 75 percent of paired sites with centroids 50 miles apart. For the Ohio River Basin, the distance between centroids at which 50 percent

Table 15. Quantile regression equations and standard errors for the 25th, 50th, 75th, and 99th quantiles of the relation between distance and Spearman’s rho correlation coefficient among pairs of streamgages for the Atlantic Slope and Ohio River Basins in and near West Virginia, 1930–2011.

[All equations are significant at P < 0.00001; SE, standard error; D, distance in miles; <, less than]

Streamgage pair	25th quantile			50th quantile		
	Equation	SE, intercept	SE, slope	Equation	SE, intercept	SE, slope
Ohio River Basin	$1.006 - 0.0271(D^{-0.5})$	0.0028	0.0003	$1.028 - 0.0256(D^{-0.5})$	0.0019	0.0002
Atlantic Slope River Basins	$0.91 - 0.0176(D^{-0.5})$	0.0069	0.0007	$0.968 - 0.0185(D^{-0.5})$	0.0031	0.0004
Cross-basin pairs	$0.763 - 0.0114(D^{-0.5})$	0.0045	0.0003	$0.841 - 0.0134(D^{-0.5})$	0.0038	0.0003

Streamgage pair	75th quantile			99th quantile		
	Equation	SE, intercept	SE, slope	Equation	SE, intercept	SE, slope
Ohio River Basin	$1.044 - 0.0244(D^{-0.5})$	0.0015	0.0002	$1.057 - 0.0204(D^{-0.5})$	0.0022	0.0003
Atlantic Slope River Basins	$0.987 - 0.0167(D^{-0.5})$	0.0029	0.0003	$1.017 - 0.014(D^{-0.5})$	0.0041	0.0005
Cross-basin pairs	$0.907 - 0.0147(D^{-0.5})$	0.0038	0.0003	$1.012 - 0.0163(D^{-0.5})$	0.0141	0.0011

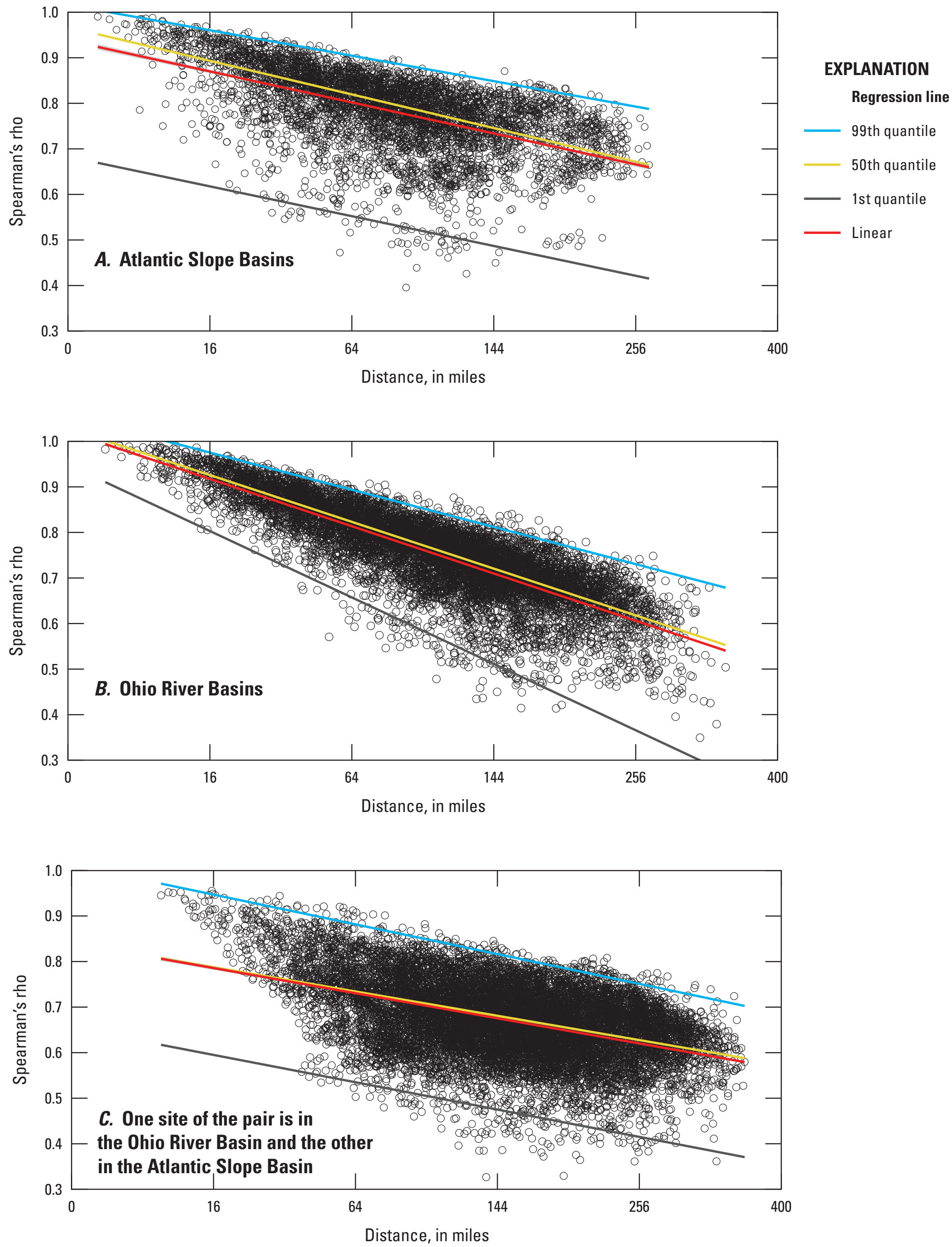


Figure 16. Relation of distance between basin centroids to correlation of daily flows among streamgages, with 10 or more years of concurrent records, on unregulated streams in the *A*, Atlantic Slope Basin, *B*, the Ohio River Basin, and *C*, one streamgage each in the Atlantic Slope and Ohio River Basins, in and near West Virginia, 1930–2011, and linear and 99th, 50th, and 1st quantile lines of regression.

of streamgage pairs would exceed a Spearman's rho of 0.95 is 9 miles. The distance at which 50 percent of streamgages would exceed a Spearman's rho of 0.90 is 25 miles, and the distance at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.85 is 48 miles. For the Atlantic Slope River Basins, the distance between centroids at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.95 is 1 mile. The distance at which 50 percent of streamgages would exceed a Spearman's rho of 0.90 is 13 miles, and the distance at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.85 is 41 miles. For streamgages compared across major basins, the median quantile regression line crosses the y-axis at a value of 0.84, indicating that less than one-half of streamgage pairs compared across major basins at any distance would be expected to have correlation coefficients of about 0.84; the plot in figure 16 shows that this regression is strongly affected by a preponderance of streamgage pairs with basin centroids separated by 25 miles or more and that, if the analysis were restricted to streamgage pairs closer to each other, a relation could be developed among the handful of adjacent, strongly correlated streamgage pairs.

Spatial Patterns in Flow Correlation

The difference in the relation between correlation and distance is reflected in correlation maps of daily flows, the maps that were developed by using ordinary kriging of correlation coefficients between basin centroids (figs. 17–20). The correlation maps were clipped to a polygon created by buffering the outline of West Virginia plus 25 miles so that all the correlation zones depicted on the maps are fully defined. A correlation map was developed for each unregulated streamgage within 50 miles of West Virginia that was active as of September 2012 and had more than 1 full year of flow data during 1930–2011. The maps show full-year correlations with all unregulated streamgages within 50 miles of West Virginia with which the selected stream shares at least 1 year of concurrent record during 1930–2011 (appendix 1, available for download at *http://dx.doi.org/10.3133/sir20145061*). This approach allows the areas of historic flow correlation to recently reactivated streamgages, including one that was reactivated in water year 2012, to be determined to evaluate them for use as index streamgages. The inclusion of short-term streamgages resulted in the inclusion of more areas of weak correlation than of strong correlation because the relation between correlation and distance is weaker for the short-term streamgages than for the long-term streamgages (fig. 15).

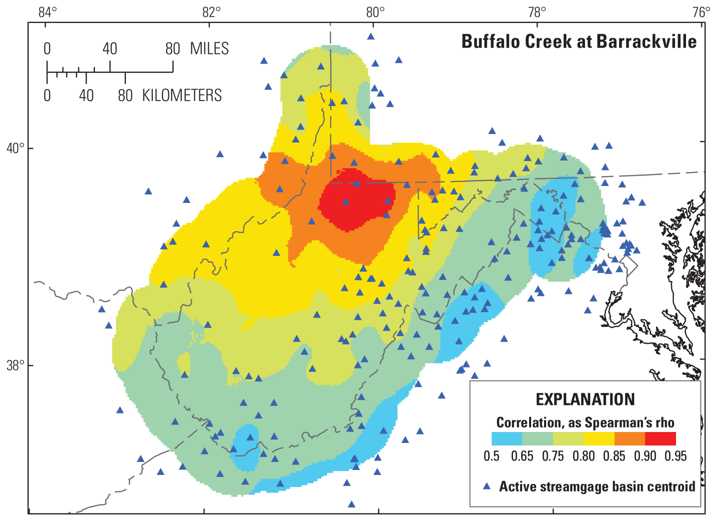
Spatial correlation patterns for streamgages in the Appalachian Plateaus appear to be generally related to elevation and mean annual precipitation (fig. 19). For Buffalo Creek at Barrackville (streamgage 03061500), the zone of strongest correlation (rho >0.90) was approximately circular with the streamgage centroid near the center of the zone; the zone of second strongest correlation (rho >0.85), although not round in shape, encompasses areas with generally similar ranges of elevation (fig. 2). For Big Coal River at Ashford (streamgage 03198500; fig. 18) in southern West Virginia and in the Appalachian Plateaus, spatial correlation patterns are generally similar to those for Buffalo Creek. The zone of strongest correlation is approximately circular, and the basin centroid for the streamgage is near the center of the zone. The zone of correlation between rho 0.85 and 0.90 for Big Coal River is generally centered at the basin centroid, although there is an area of low correlation to the south.

In comparison, the zone of strongest correlation for Blackwater River at Davis (streamgage 03066000; fig. 19) located in the Appalachian Plateaus province but near the border with the Valley and Ridge province, and in some of the highest elevations of the study area, conforms to areas similar in elevation and precipitation as the Blackwater River Basin. Zones of strongest correlation trend from southwest to northeast, as do the Allegheny Mountains. The areas of stronger correlation to this streamgage extend farther to the west into the Appalachian Plateaus province and within the Ohio River Basin than to the east and into the Valley and Ridge province. The zone of strongest correlation for Blackwater River includes streamgages on two tributaries to the North Branch Potomac River Basin within the Appalachian Plateaus.

The zones of strongest correlation to South Branch Potomac River at Franklin (streamgage 01605500) are oblong and, like those for Blackwater River, trend southwest to northeast (fig. 20). The zone of strongest correlation for this streamgage on the South Branch Potomac River extends farther to the north, along the river, than to the south, across the basin divide into the James River Basin and to some eastern tributaries of the Greenbrier River; it extends farther to the east, into the Valley and Ridge province and the South Fork South Branch Potomac River Basin, than to the west across the basin and physiographic divides.

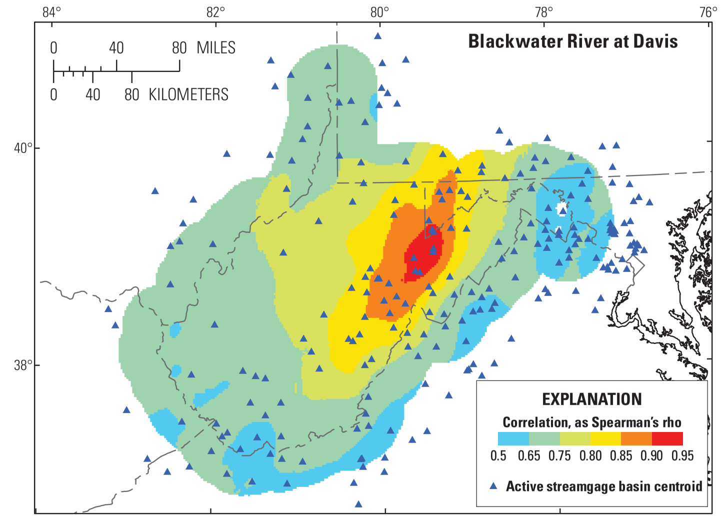
A set of summary maps was developed that depict the number of active streamgages with correlation zones at each grid point in the study area that have a correlation value greater than thresholds of rho of 0.95, 0.90, and 0.85 (figs. 21–23). Little of West Virginia (6 percent) is within zones correlated with any streamgage above the threshold of rho 0.95; these areas are generally in river basins in which several streamgages have been operated along the same stream. Most of West Virginia (77 percent) is within zones correlated with at least one active streamgage at greater than the threshold of rho of 0.90, and much of West Virginia (32 percent) is within zones correlated at greater than this threshold with five or more active streamgages. Only a small area within West Virginia (<1 percent) is outside areas correlated with any active streamgage at greater than the threshold of rho of 0.85, and most of West Virginia (88 percent) is within areas correlated with five or more streamgages at greater than rho of 0.85.

Two areas with the weakest correlations are in western West Virginia and the eastern tip of West Virginia (fig. 23). The eastern area contains several active streamgages that are weakly correlated with each other (table 10). This area is underlain by karst, which probably affects flow timing and



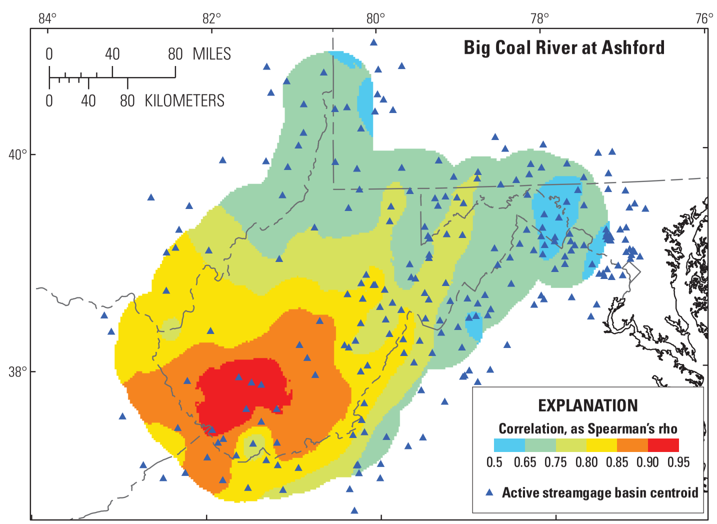
Base from U.S. Geological Survey 1:100,000 digital line graphics.
Universal Transverse Mercator projection, zone 17, NAD 83.

Figure 17. Correlation of daily flows at unregulated streamgages with daily flows at Buffalo Creek at Barrackville, West Virginia, as Spearman's rho, 1930–2011.



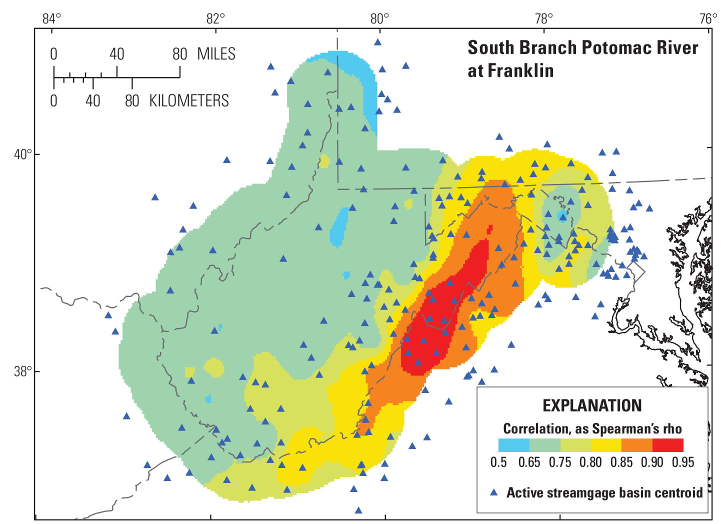
Base from U.S. Geological Survey 1:100,000 digital line graphics.
Universal Transverse Mercator projection, zone 17, NAD 83.

Figure 19. Correlation of daily flows at unregulated streamgages with daily flows at Blackwater River at Davis, West Virginia, as Spearman's rho, 1930–2011.



Base from U.S. Geological Survey 1:100,000 digital line graphics.
Universal Transverse Mercator projection, zone 17, NAD 83.

Figure 18. Correlation of daily flows at unregulated streamgages with daily flows at Big Coal River at Ashford, West Virginia, as Spearman's rho, 1930–2011.



Base from U.S. Geological Survey 1:100,000 digital line graphics.
Universal Transverse Mercator projection, zone 17, NAD 83.

Figure 20. Correlation of daily flows at unregulated streamgages with daily flows at South Branch Potomac River at Franklin, West Virginia, as Spearman's rho, 1930–2011.

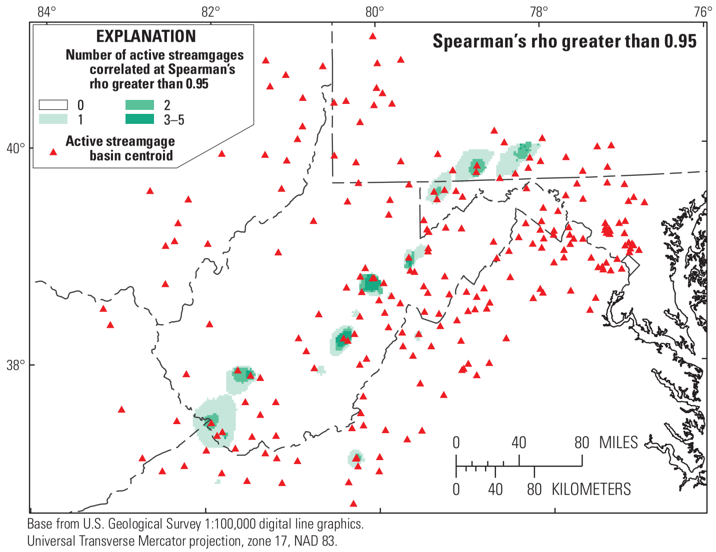


Figure 21. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.95 for daily flows during water years 1930–2011.

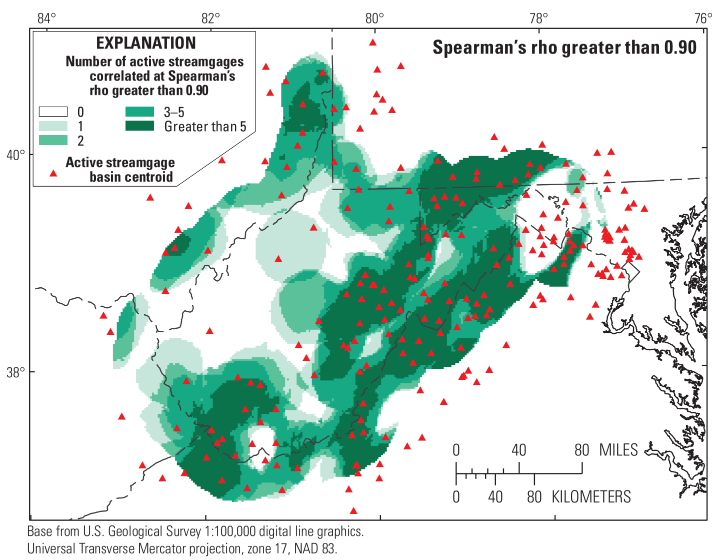


Figure 22. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.90 for daily flows during water years 1930–2011.

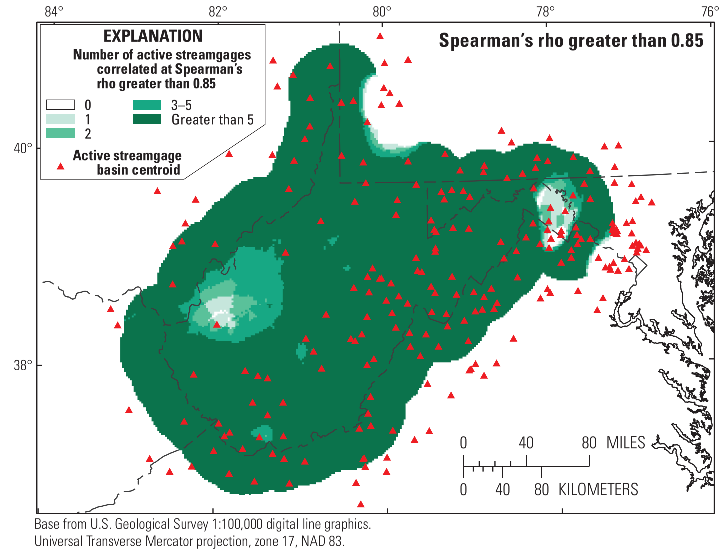


Figure 23. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.85 for daily flows during water years 1930–2011.

magnitude, and streamgages in this area, although near other streamgages, generally are poorly correlated among each other. The weak correlations depicted on correlation maps for the western area are likely an artifact of streamgage distribution. This area contains one active streamgage, Hurricane Creek near Hurricane (streamgage 03201405), which began operating in 1998. During 1998–2012, it was among the most spatially isolated streamgages in the West Virginia network. One historical streamgage, Poplar Fork at Teays (streamgage 03201410), was operated near this area during the 1970s; it was correlated at values of rho >0.85 with three now discontinued streamgages and had correlation coefficients generally similar to those for Hurricane Creek with those streamgages that were in operation during both the 1970s and 1998–2012 (table 10).

Two areas in southern West Virginia are outside correlation zones where rho is greater than 0.90 with any active streamgage (fig. 22). One area is approximately bisected by the New River and represents an area where few streamgages have ever been operated. The other area, near the southern tip of West Virginia, was the location of several historical streamgages, including Johns Knob Branch near Elkhorn (streamgage 03212640; Kozar and others, 2013) and Elkhorn Creek Tributary at Welch (streamgage 03212703; Scott, 1984), previously identified as short-term streamgages operated to characterize hydrologic alteration, in this case, alteration resulting from coal mining. Although the hydrology of this area may be unique because it represents the southernmost and most updip limit of coal mining in West Virginia (Kozar and others, 2013), it may instead be an example of a cluster of small streams affected by a land use, coal mining, in ways that are different from the effects on large streams.

Seasonal Differences in Flow Correlation

The strength and extent of correlation varies with season (tables 16–19, available for download at *http://dx.doi.org/10.3133/sir20145061*). The extent of correlation at a threshold of rho >0.90 is less in each season than for a full year (figs. 24–27; appendixes 2–5, available for download at *http://dx.doi.org/10.3133/sir20145061*). The strongest and most extensive correlations are for fall (October 1–December 31) when 72 percent of West Virginia is within a zone with correlation of rho >0.90 to one or more active streamgages (fig. 24). Flows are generally at their lowest during late summer and early fall. Precipitation is dominated by frontal systems, and large areas receive similar amounts of rain at about the same time. Slow, soaking rain events with a broad extent cause generally similar streamflow responses from large and small basins (Black, 1991).

Correlation strength and extent are the next strongest during winter. Most (62 percent) of West Virginia is within correlation zones where at least one streamgage had a correlation greater than rho of 0.90 (fig. 25). Areas of correlation are different during winter than during fall. Precipitation type often varies greatly with elevation, with the same storm system producing rain in the lowlands but snow in the mountains. Timing of snowmelt also varies greatly with elevation, as does the freezing of streams and soil. Correlations for spring generally are weaker and less extensive than are correlations for winter. Less than one-half (42 percent) of West Virginia is within correlation zones where at least one streamgage had a correlation > 0.90 (fig. 26). During spring, dominant precipitation patterns shift from frontal systems to convective events. Within areas with generally similar elevation and temperature, convective storms cause uneven precipitation distribution. For summer, correlations between pairs of streamgages were found to be >0.90 in very little of West Virginia (3 percent; fig. 27). By summer, precipitation is dominated by convective thunderstorms. Rainfall is frequently scattered or isolated. A moderate rise on a medium-size stream may be caused by rain received in a tributary basin and is frequently not accompanied by rises on nearby streams. Once convective storms have begun, runoff from different streams may vary greatly even during large frontal systems that produce generally uniform amounts of rain throughout the region because antecedent conditions may differ according to which areas received prior rain from thunderstorms. These phenomena result in correlations for summer being the weakest and least extensive among correlations for all seasons.

Not only does the strength of correlation vary among seasons, but the relative ranking of correlations among sites also varies by season. As shown by the summary maps, the specific areas with strong correlations for active streamgages change seasonally in response to weather patterns (figs. 24–27). Because correlations among streamgages change greatly with season, selection of index streamgages made on the basis of seasonal correlations could be more accurate than selection made on the basis of annual correlation, particularly if predictions regarding seasonal statistics are desired.

Seasonal and annual correlations computed from all full years of data for the 391 unregulated streamgages operated in and near West Virginia during 1930–2011 were compared for their concurrent periods of record (fig. 28). Correlations between the annual and each of the four seasonal correlation coefficients were weak but were especially so for those pairs of streamgages with less than 5 years of concurrent record. Comparison of the 99th and 1st quantile regression lines computed for the relation between the seasonal and annual correlations for the pairs of sites with 5 or more years of concurrent record and those computed for sites with less than 5 years of concurrent record shows much more variation for the pairs of streamgages with shorter records. Many of the correlation coefficients for short-term streamgages were higher than those determined among pairs of streamgages with long periods of record; the 50th quantile (median) regression line for the pairs of short-term streamgages plotted higher than that for the pairs of long-term streamgages for the entire range of values for fall and all but the highest annual correlations for winter and summer but slightly lower for spring. Variation in the relation between seasonal and annual correlations

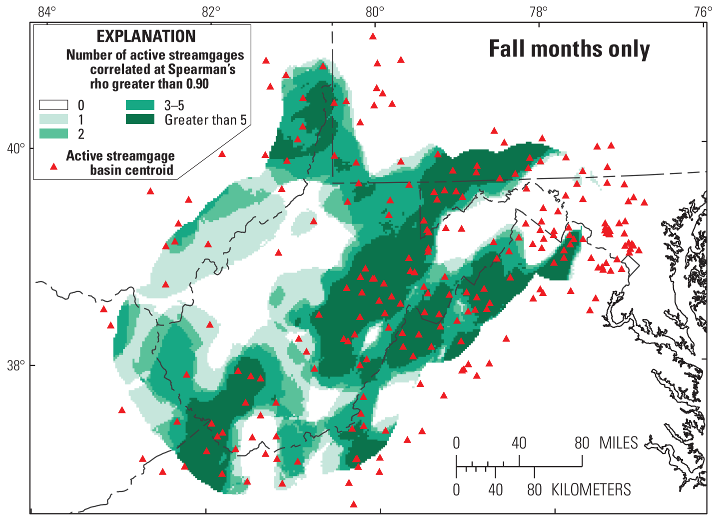


Figure 24. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.90 for daily flows during fall months only, water years 1930–2011.

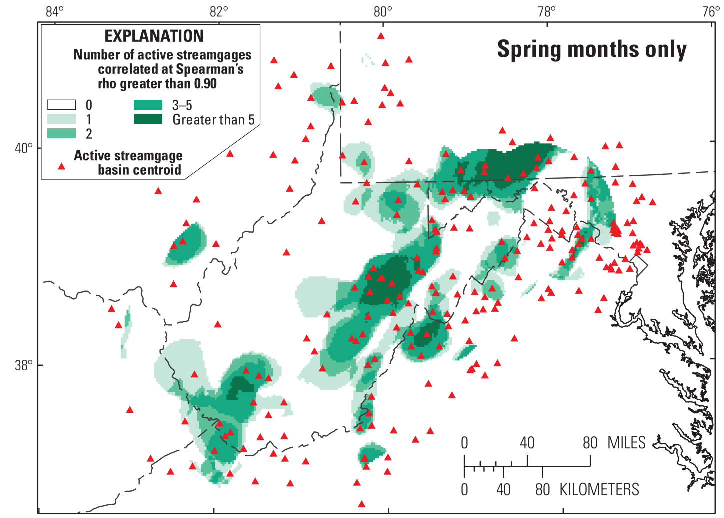


Figure 26. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.90 for daily flows during spring months only, water years 1930–2011.

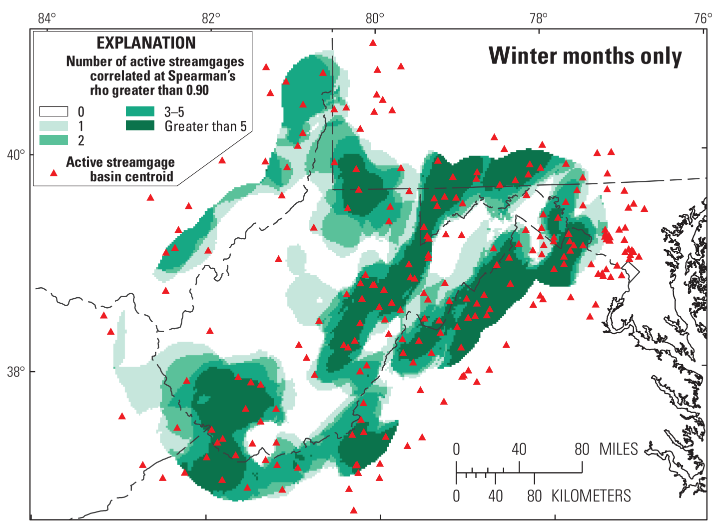


Figure 25. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.90 for daily flows during winter months only, water years 1930–2011.

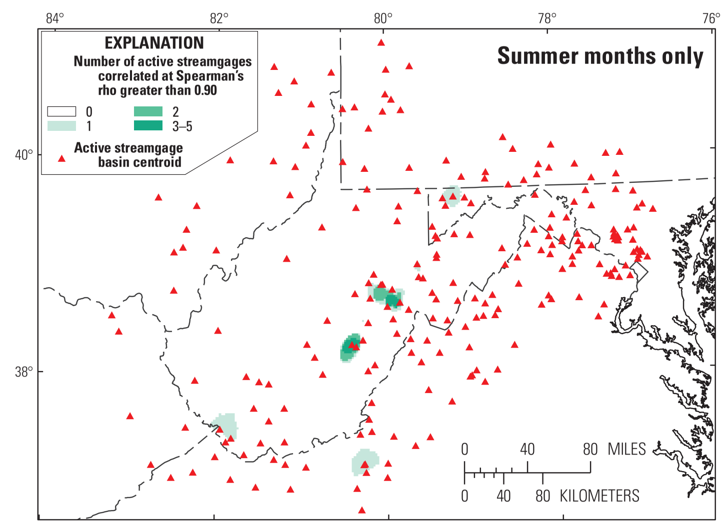


Figure 27. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.90 for daily flows during summer months only, water years 1930–2011.

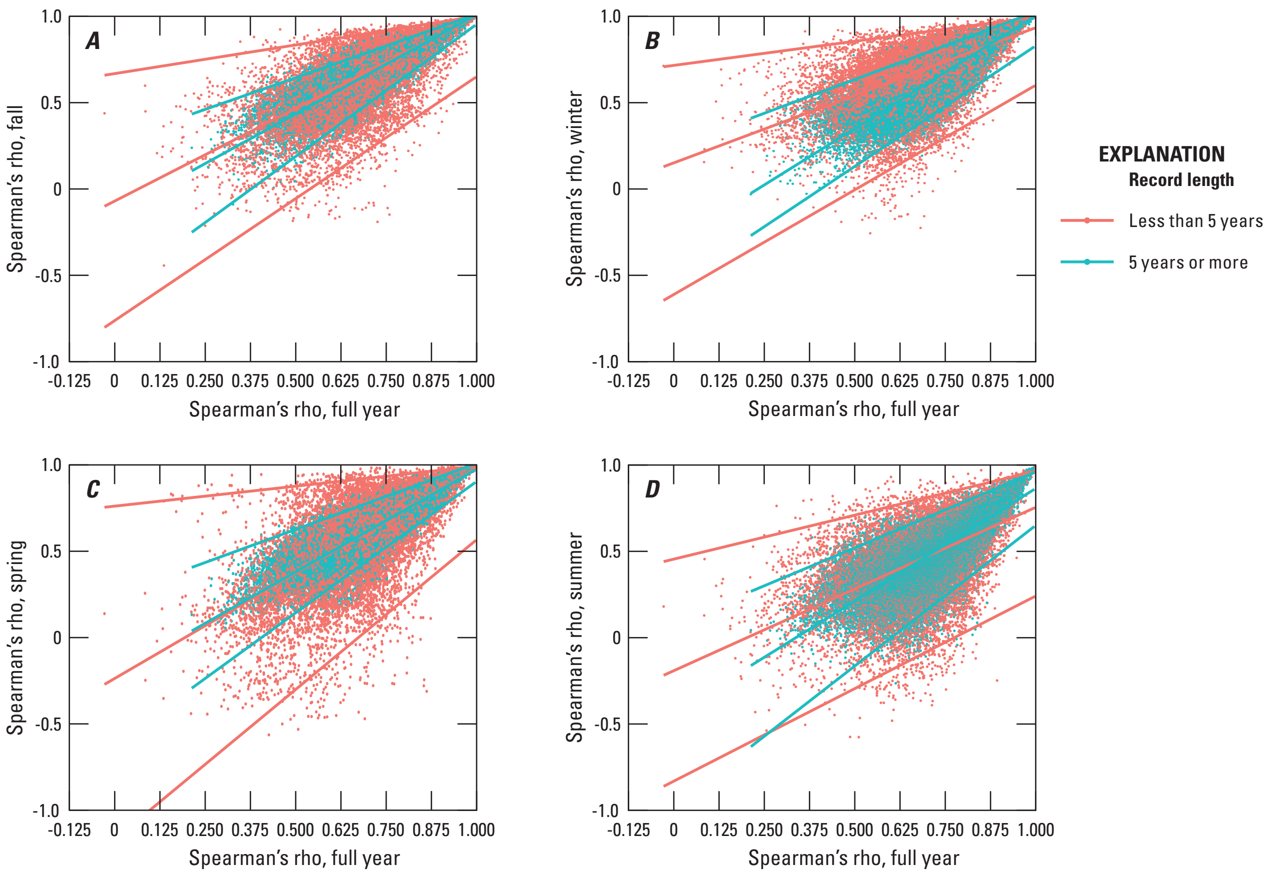


Figure 28. Relation of correlation coefficients of daily flow for the full year to that of *A*, fall, *B*, winter, *C*, spring, and *D*, summer at 391 selected streamgages in and near West Virginia, 1930–2011.

among the pairs of short-term (less than 5 years of concurrent record) streamgages, however, was much greater than among the pairs of long-term streamgages; R^2 values for short-term and long-term pairs of streamgages, respectively, were 0.4538 and 0.8092 for fall, 0.2920 and 0.7218 for winter, 0.4181 and 0.7778 for spring, and 0.2714 and 0.6097 for summer.

Decadal Differences in Flow Correlation

A comparison was made among correlation maps for the 1963–1969, 1970–1979, and 1992–2011 groups of streamgages (appendixes 6–8, available for download at *http://dx.doi.org/10.3133/sir20145061*). The overall period of about 1960–1980 was of interest because the streamgaging network in West Virginia was at or near its maximum number of streamgages, and analysis of this period could provide information on the spatial extent of flow correlation that might be expected if a streamgage were to be reactivated. Because the periods 1963–1969 and 1970–1979 were climatically distinct, they were analyzed separately from each other. The 20-year period preceding the study, 1992–2011, was selected to represent recent conditions. Correlation values for streamgage pairs with 1 year or more of concurrent record were determined for the period of interest. Spearman's rho matrices for each of the three periods (tables 20–22) were prepared; cross-correlation was determined for each pair of streamgages. Correlation maps for the three time periods were prepared and summarized as described previously. Examples of predicted correlations of daily streamflow at selected streamgages with flow at Middle Island Creek at Little, WV, are shown in figures 29–31 for each period.

Long-term differences in the strength, extent, and pattern of streamflow correlations are related to long-term climate variation and changes in the streamgaging network. The strongest and most extensive correlation patterns found in this study were for 1963 to 1969, a period of historic drought, rather than 1970 to 1979, the wettest extended period on record for West Virginia, but the 1963–1969 period overlapped with the 1970–1979 period when the greatest number of streamgages was active on unregulated streams in West Virginia (figs. 32 and 33). The 10-year running average for the number of unregulated streamgages in West Virginia was slightly greater for 1969–1978, 92.6, and 1968–1977, 92.5, than for 1970–1979, 91.7 (fig. 6). The numbers of streamgages operated outside West Virginia, but within the 50-mile buffer,

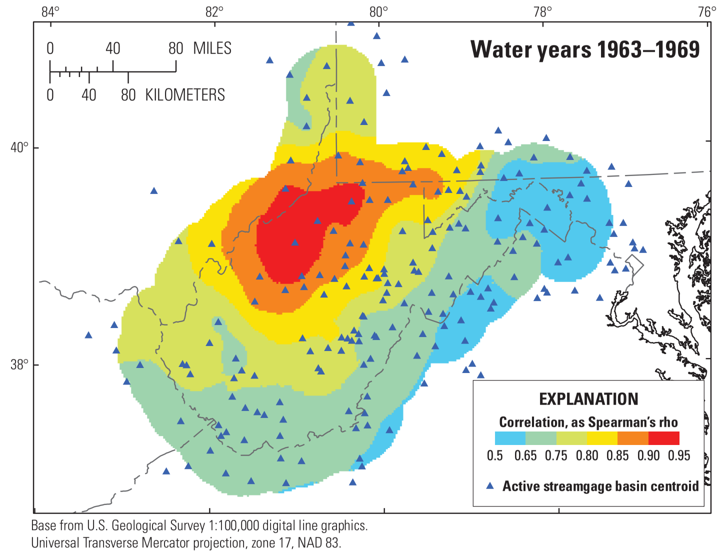


Figure 29. Correlation of daily flows at unregulated streamgages with daily flows at Middle Island Creek at Little, West Virginia, as Spearman's rho, water years 1963–1969.

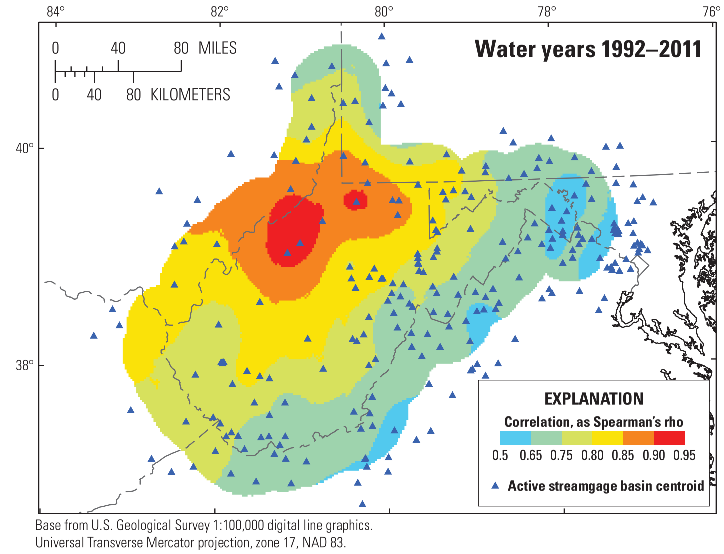


Figure 31. Correlation of daily flows at unregulated streamgages with daily flows at Middle Island Creek at Little, West Virginia, as Spearman's rho, water years 1992–2011.

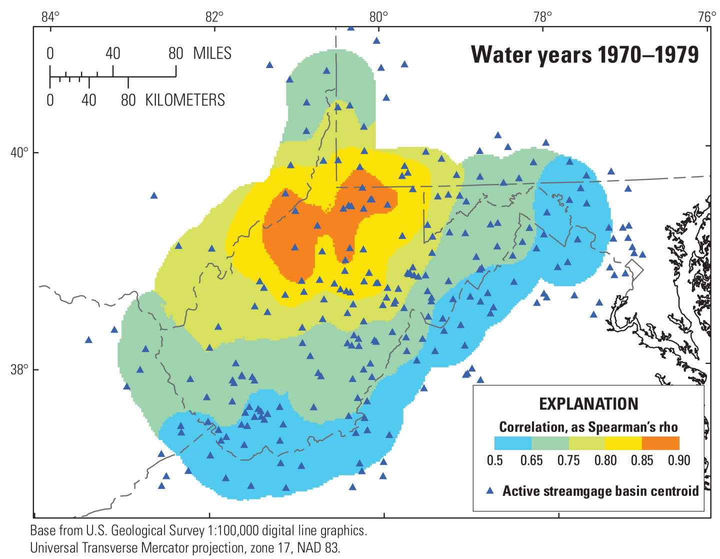


Figure 30. Correlation of daily flows at unregulated streamgages with daily flows at Middle Island Creek at Little, West Virginia, as Spearman's rho, water years 1970–1979.

did not track the numbers operated inside West Virginia; overall numbers of streamgages included in the analysis were 198 for 1963–1969, 244 for 1970–1979, and 223 for 1992–2011.

As indicated by the correlation maps for 1963–1969, 1970–1979, and 1992–2011, patterns are related to the specific streamgages in operation at that time (figs. 32–34). Strength and spatial extent of flow correlation were greater during the 1963–1969 period, a time of drought, than during 1992–2011, a period when flows were more variable. Flow correlations for periods 1963–1969 and 1992–2011 were stronger and more extensive than flow correlations for the period 1970–1979.

During the 1963–1969 period, most (89 percent) of West Virginia was within zones correlated with at least one streamgage above a threshold of rho >0.90, and much (29 percent) of West Virginia was within zones correlated above that threshold with 10 or more streamgages. During the 1970–1979 period, less of West Virginia was within zones correlated with at least one streamgage above a threshold of rho >0.90 (68 percent) than during 1963–1969, and less of West Virginia (21 percent) was within zones correlated above that threshold with 10 or more streamgages. During the 1992–2011 period, about the same amount (29 percent) of West Virginia was within zones correlated with one or more streamgages above a threshold of rho >0.90 as during the 1970–1979 period, but slightly less (17 percent) of West Virginia was within zones correlated above that threshold with 10 or more streamgages.

Generally, the areas with the strongest correlations (Spearman's rho ≥0.95) are in places with the greatest density of streamgages, in parts of the Cheat, Tygart Valley, Gauley, Coal, and Tug Fork River Basins. The parts of West Virginia where correlations are weaker (Spearman's rho <0.90 and >0.85) coincide with areas in western and west-central West Virginia and near the Kanawha River, where few streamgages are operated on unregulated streams. However, differences in correlation among sites throughout the year, and in response to climatic conditions, affect correlations among streamgages and therefore the extent of predicted correlation.

Even during 1970–1979, when West Virginia's streamgaging network included nearly double the number of unregulated streamgages that were active in 2011, large parts of West Virginia were likely to be only weakly correlated with one or more of the streamgages in the network at that time. This weak correlation could be caused by several factors. Climatic conditions seem likely to affect flow correlation. Although exploratory analysis relating various summaries of correlation to flow statistics found no relation, this might change if improved summary metrics for correlations were available.

Flow correlation is strongly related to the location and other characteristics of sites in the streamgaging network. Adding streamgages that are redundant with existing streamgages seems unlikely to do much to extend areas of flow correlation, as is evidenced by the large areas during the 1963–1969 period where 10 or more streamgages were strongly correlated. Adding streamgages in areas with few streamgages would be more likely to extend the range of flow correlation. Also, adding streamgages to disturbed or unusual areas, or at least understanding their flow characteristics, would be important because, if unaccounted for, small-scale local variability may result in poor flow estimates even if correlation maps indicate a homogeneous, strongly correlated area.

Map Correlation and Possible Expansion of the Present Streamgaging Network

The decadal-scale analysis was intended to take advantage of the greater density of unregulated streamgages during the period 1970–1979 than during any other time in the history of the West Virginia streamgaging network with the anticipation that correlations to the inactive or now-regulated streamgages would prove to be a convenient method to assess the manner in which their reactivation might enhance the existing network.

The summary correlation map for 1992–2011 shows correlation exceeding 0.90 for much of West Virginia (fig. 34). The average number of active, unregulated streamgages within West Virginia was 55 during 1992–2011 and increased to 62 during 2009–2011. Three streamgages were established or reactivated in parts of West Virginia with predicted correlations less than 0.90; Birch River at Herold (streamgage 03196500; figs. 18–19) in central West Virginia and new USGS streamgages East River at Willowton (streamgage 03177120) and Indian Creek at Red Sulfur Springs (streamgage 03177480) in southern West Virginia are located in these areas, although they are recent enough so that no final data were available for the present analysis. The largest remaining area with relatively low correlation is in western and west-central West Virginia.

Correlations maps are shown for West Fork Little Kanawha River at Rocksdale (streamgage 03154000), 1970 to 1979, and for Elk Creek near Quiet Dell (streamgage 03059500), 1963 to 1969 (fig. 35). Both are in or near an area where active streamgages are absent. The contemporary correlation map shows generally weak correlation to active streamgages. Gas wells have been completed in the Marcellus Shale. Elk Creek at Quiet Dell is in an area with extensive shale-gas development. West Fork at Little Kanawha River at Rocksdale is in an area with shale-gas development, although its strongest zones of correlation include areas where many vertical but few horizontal gas wells have been completed in the Marcellus Shale.

The streamgage West Fork Little Kanawha River at Rocksdale (03154000) showed historically strong correlations with several presently discontinued or currently regulated streamgages in central West Virginia (tables 10, 16–22). The discontinued streamgages at Pocatalico River at Sissonville and Reedy Creek near Reedy (streamgages 03201000 and 03154500, respectively) were near the West Fork Little Kanawha River at Rocksdale, are strongly correlated with it, and have similar correlation maps. If reactivated, any of these

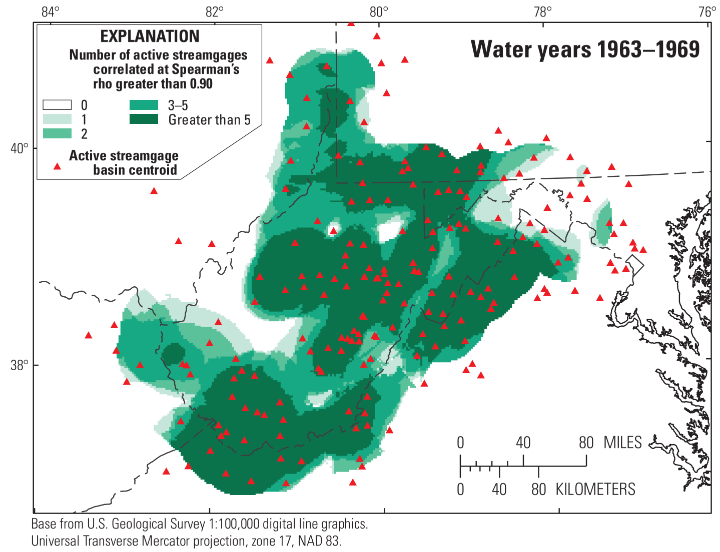


Figure 32. Number of streamgages active in and near West Virginia during 1963–1969 that correlated at Spearman's rho greater than 0.90 for daily flows during water years 1963–1969.

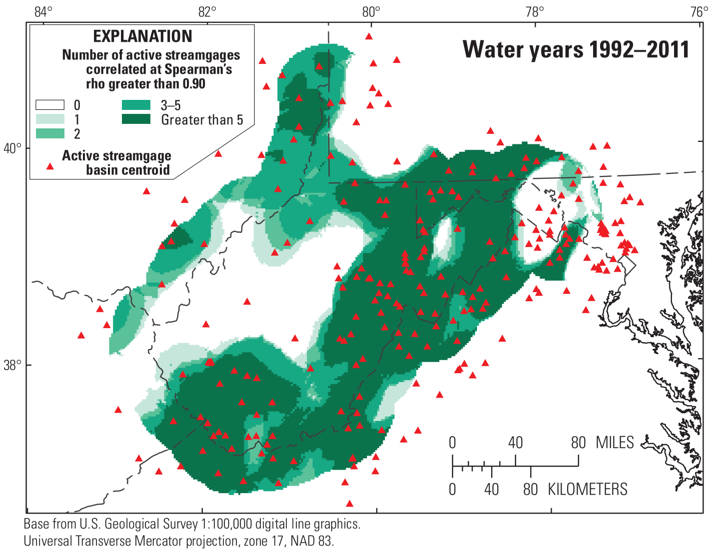


Figure 34. Number of streamgages active in and near West Virginia during 1992–2011 that correlated at Spearman's rho greater than 0.90 for daily flows during water years 1992–2011.

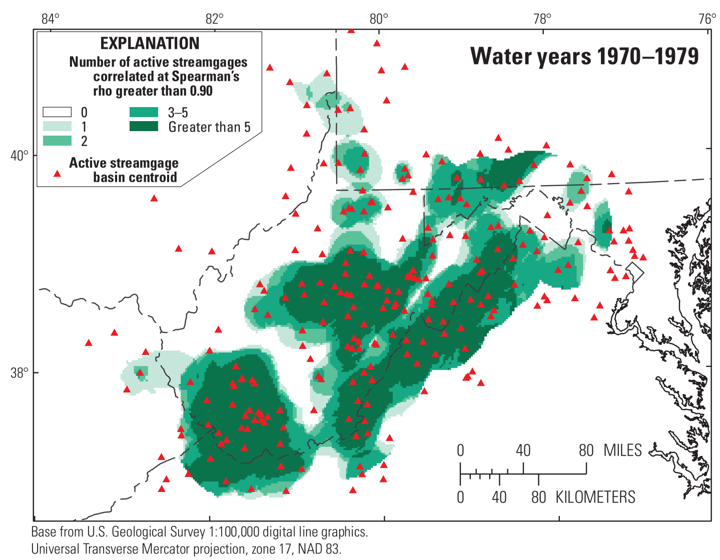


Figure 33. Number of streamgages active in and near West Virginia during 1970–1979 that correlated at Spearman's rho greater than 0.90 for daily flows during water years 1970–1979.

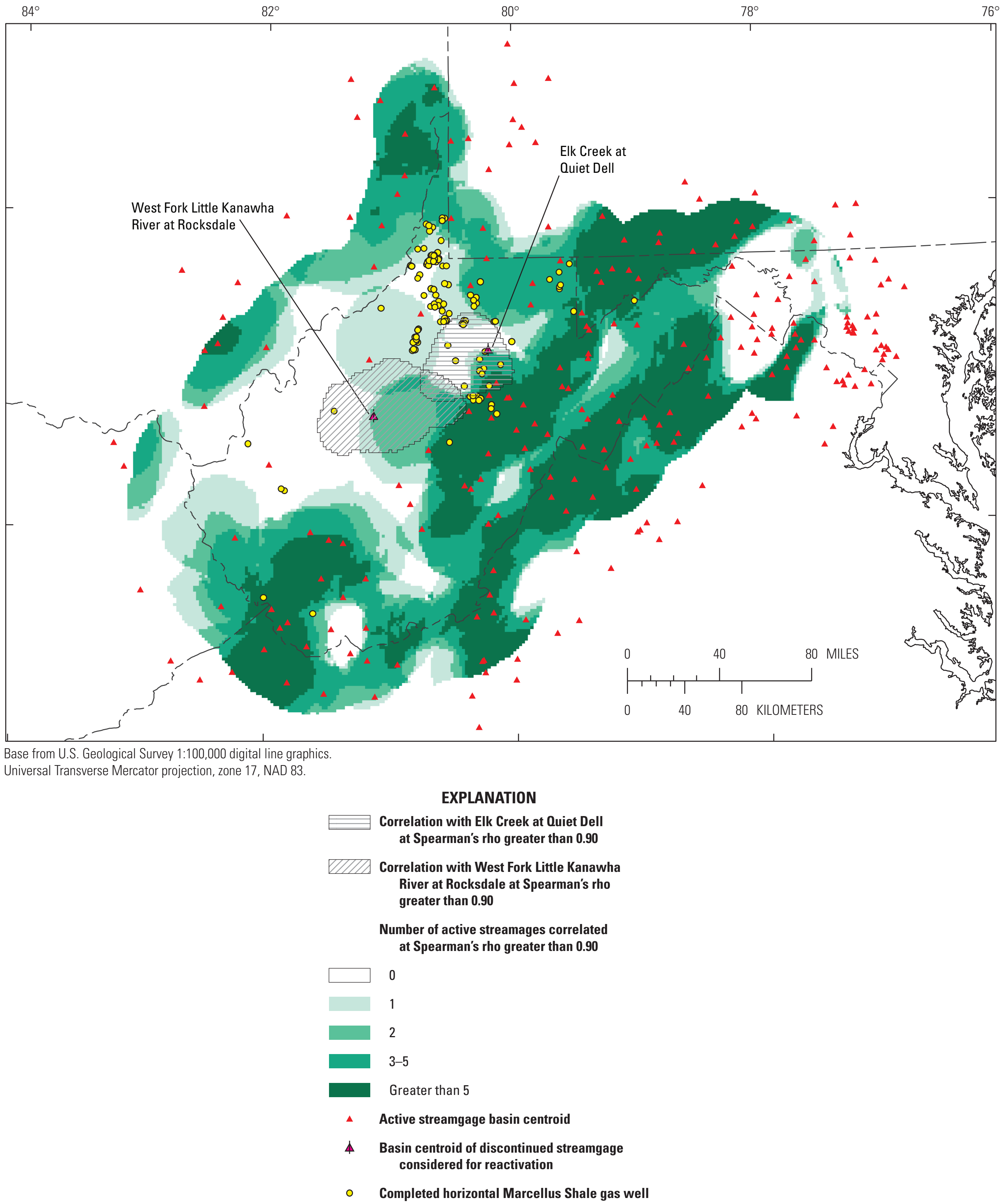


Figure 35. Number of streamgages active in and near West Virginia during 2012 that correlated at Spearman's rho greater than 0.90 for daily flows during water years 1930–2011, historic correlation to two discontinued streamgages, and horizontal Marcellus Shale gas well completed through 2012.

streamgages could fill a gap in the network. The historic correlation maps for West Fork Little Kanawha River at Rocksdale shows slightly better agreement with the areas where the 1992–2011 summary map shows no areas of predicted high correlation. Additionally, continuous stage data are already being collected there (as of 2013), so that the West Fork Little Kanawha River at Rocksdale streamgage could be reactivated at less expense than other streamgages.

If an additional index streamgage is needed specifically for managing withdrawals for hydraulic fracturing in the area undergoing Marcellus Shale development, Elk Creek near Quiet Dell (streamgage 03059500) would be a strong candidate for reactivation. It is within map zone 50, one of the map zones discussed previously that refers to an unrepresentative streamgage (table 4). Although it is probably less suitable than West Fork Little Kanawha River at Rocksdale for filling a spatial gap in the overall network, Elk Creek near Quiet Dell, discontinued in 1969, had correlations of rho greater than or equal to (≥) 0.90 with several other streamgages in the West Fork Basin that are now regulated or discontinued. Among active streamgages, it had correlations near rho of 0.90 with two unregulated streamgages, Tygart Valley River at Belington (streamgage 03051000) and Buffalo Creek at Barrackville (streamgage 03061500). Other discontinued streamgages in the general area had lower maximum correlations or were closer to presently active streamgages.

An area in northwestern West Virginia has heavy shale-gas development but demonstrated neither correlation greater than rho 0.90 to active streamgages nor a promising discontinued streamgage to evaluate for reactivation. A discontinued streamgage on the fringes of the area, Buffalo Run near Little (streamgage 03114650), did not have strong correlations with any other streamgages (maximum rho 0.8603). Part of this area is in WWGT map zone 48, which was previously identified as a map zone that receives 10 percent more annual precipitation than the basin of its index streamgage (table 4). Withdrawals in this area could be managed by requiring a conservative index flow, directly measuring flows when appropriate, a combination of these, or establishing a new streamgage and determining areas to which it is correlated.

Outside the area of active shale-gas development, with little demand for water from small ungaged streams, flow estimates derived from an index streamgage with average daily flow correlations of rho ≥0.85 might meet most needs. If additional spatial resolution in the streamgaging network is desired, however, western West Virginia includes areas with relatively low correlations. Hurricane Creek near Hurricane (streamgage 03201405; table 1) is the most isolated streamgage in the network; its two nearest neighbors, both with centroids 35 miles away from the Hurricane Creek centroid, are East Fork Twelvepole Creek near Dunlow (streamgage 03206600) and Coal River at Tornado (streamgage 03200500). The Hurricane Creek streamgage has a maximum correlation of Spearman's rho 0.85 with East Fork Twelvepole Creek near Dunlow; Mud River near Milton (streamgage 03204500) is roughly halfway between these two streams. Mud River near Milton has been regulated since 1980, and the streamgage would not be a good candidate for reactivation. A streamgage on a different stream in this area would increase spatial resolution.

South Fork Hughes River below MacFarlane (03155220) is the second most isolated streamgage in the network; its nearest neighbor, among presently unregulated streamgages, is Middle Island Creek at Little (03114500). Their centroids are 30 miles apart, and Spearman's rho is 0.9445. If West Fork Little Kanawha River at Rocksdale is reactivated, it would become the nearest neighbor for the South Fork Hughes River streamgage with basin centroids 24 miles apart. The area northwest of West Fork Little Kanawha River at Rocksdale and between South Fork Hughes River below MacFarlane and Hurricane Creek at Hurricane (03201405) has a limited number of historic streamgages. A new streamgage about 20 miles southwest of South Fork Hughes River near MacFarlane and a new streamgage about 20 miles north or northeast of Hurricane Creek at Hurricane would be useful additions to fill spatial gaps in the streamgaging network. These areas were previously identified (Runner and others, 1989; Straub, 1998) as being in need of additional streamgages on small streams for regional analysis, particularly for low flows.

The correlation maps for 1970 to 1979 frequently show more detailed, and in some cases different, patterns than the maps for the other periods (fig. 30, appendix 7). These correlation maps could prove to be valuable in future regional regression analyses of streamflow characteristics or for designing networks of partial-record sampling or measurement sites.

Limitations of the Study

Correlations of daily flows for summer are much weaker than for the rest of the year, and accurate estimates of flow for ungaged sites using index streamgages are unlikely. Direct measurement of streamflow, including by reference to a stage-discharge rating, is likely to be necessary to determine flow accurately on an ungaged stream during summer in West Virginia.

Map correlation provides little if any insight into managing regulated streams. The effects of basin alterations, other than dams and diversions, on map correlations may be great. As an example, summary correlation maps for active streamgages show a zone of decreased correlation in southern West Virginia (figs. 18, 22, 24, 25) that centers around Johns Knob Branch near Elkhorn (03212640), a small stream receiving a large interbasin transfer through an underground coal mine (Kozar and others, 2013). As another example, correlation maps displayed throughout this report show a decreased zone of correlation in the eastern tip of West Virginia (figs. 20, 22, 23, 25, 32–34); this zone results from weak correlations for small streams in that area, including March Run at Grimes, MD (01617800), and Tuscarora Creek above Martinsburg, WV (01617000), that drain an area of karst (table 10). Other special conditions likely exist in which streams within an area of a certain predicted correlation do not conform to regional expectations. Because these conditions exist in many areas where streams have not been gaged, correlation maps cannot incorporate them, and accurate flow estimates are likely to be made in such areas only if users account for these conditions.

The present analysis is intended to identify spatial gaps or redundancies in the streamgaging network but only for the specific use of estimating streamflow in real time. Correlation of daily flows, and its spatial distribution, provides information relevant to the selection of regionally representative index streamgages, but it does not provide all information relevant to designing a streamgaging network that meets the other needs of the streamgaging program. Other purposes of the streamgaging network are, to varying degrees, independent of this use. This study has not considered correlation of extreme high- and low-flow values, which may not conform to the correlation of daily values and are the most important flow characteristics for many regulatory, design, and planning purposes. Other approaches exist to evaluate the streamgaging network for these purposes (Kiang and others, 2013). Although index streamgages on relatively large streams appear to provide accurate estimates of flow in real time for small, ungaged streams, the need remains for streamgages on small (drainage area <20 mi^2) streams in order to determine low-flow characteristics identified by Runner and others (1989). The present study does not address the use of streamgages for operation of dams, intakes, or other facilities, and it provides little, if any, information to address regional flood characteristics. Highly correlated streamgages may meet important operational or other needs for the USGS and its partner agencies and, therefore, do not necessarily become lower priorities for inclusion in the streamgaging network.

Summary and Conclusions

To provide information needed to manage water withdrawals from ungaged streams, the U.S. Geological Survey (USGS), in cooperation with the West Virginia Department of Environmental Protection, has evaluated correlations of daily flow among active and discontinued streamgages and the spatial distribution of those correlations. Correlations of daily flows among unregulated streamgages were determined using Spearman's rho. Correlation coefficients between pairs of streamgages were determined for 82 years of record and compared to the average number of days when flow at one streamgage of the pair (the estimator streamgage) exceeded one of three selected flow duration values, the 75 percent (D75), 60 percent (D60), and 50 percent (D50; the index flow), but the other streamgage of the pair (the estimated streamgage) did not exceed the D75. Regression equations were developed to relate Spearman's rho values and number of days of incorrect estimates using each of the three flow durations. For selected threshold values of rho of 0.95, 0.90, and 0.85, the respective rates of incorrect estimation of the number of days flow exceeded the annual D75, predicted from the regression equations, were 3.9, 4.9, and 5.9 percent when using the D75 as the index flow; 0.4, 1.2, and 1.9 percent when using the D60 as the index flow; and 0.02, 0.5, and 1.0 percent when using the D50 as the index flow.

Relations between correlation and distance between basin centroids differed between the Ohio River Basin and the Atlantic Slope River Basins. For the Atlantic Slope River Basins, the relation between distance and correlation was weaker and more variable than for the Ohio River Basin. In the Ohio River Basin, the highest correlation that might be expected between streamgages with basin centroids 50 miles apart, determined by a regression of the 99th quantile, was a Spearman's rho of 0.9128. In the Ohio River Basin, one-half of streamgages with basin centroids 50 miles apart have Spearman's rho values of 0.8472 or more, and 75 percent of streamgages with basin centroids 50 miles apart have Spearman's rho values of 0.8140 or more. For the Ohio River Basin, the distance between centroids at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.95 is 9 miles. The distance at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.90 is 25 miles, and the distance at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.85 is 48 miles. For the Atlantic Slope River Basins, the distance between centroids at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.95 is 1 mile. The distance at which 50 percent of streamgages would exceed a Spearman's rho of 0.90 is 13 miles, and the distance at which 50 percent of streamgage pairs would exceed a Spearman's rho of 0.85 is 41 miles. For pairs of streamgages in which one of the pair is in the Ohio River Basin and the other is in the Atlantic Slope River Basins, the relation between correlation and distance is weaker than for streamgages within either major basin, and the 50th quantile regression equation predicts a correlation of 0.84 at a distance of zero.

In the Appalachian Plateaus province outside the Allegheny Mountains, zones of strongest correlation to streamgages are generally round and approximately centered at the basin centroid. In the Allegheny Mountains, zones of strongest correlation are related to patterns in elevation and annual precipitation, and follow the trend of the mountain range. In the Valley and Ridge province, zones of strongest correlation follow valleys. Correlation across the crest of the mountains is generally weak. Most of West Virginia (77 percent) is within map zones where Spearman's rho for daily streamflow to at least one existing unregulated streamgage is greater than 0.9, and most withdrawals from ungaged streams for hydraulic fracturing are being made in these areas. Most of the rest of West Virginia (>99 percent, cumulatively) is within zones where Spearman's rho to existing unregulated streamgages is greater than 0.85. Regulated withdrawals were made from ungaged streams in the latter areas, but assuming spatial correlation in these areas is similar to that in the rest of West Virginia, expected correlations could be increased to 0.90 or higher with several new or reactivated streamgages. Seasonal differences in the strength and extent of correlation in daily streamflow are great. The strongest correlations among streamgages occur during the fall, followed by winter, then spring, and correlations in summer are weak. One possible explanation for the weaker correlation in summer may be the differences in precipitation and runoff associated with convective storms. Because convective storms generally are frequent and localized to small geographical areas, nearby basins often are not affected by the same storms. Field observations are likely to be necessary to confirm which streams rise in response to localized storms. A comparison of correlation patterns during previously identified climatic periods showed that the strongest correlations were found during 1963–69, a period of drought, and the weakest during 1970–79, a wet period. The apparent effect of frequent rain during 1970–79 overshadowed gaging network density, which was at its historic maximum in West Virginia. The extent of areas with high correlation to at least one streamgage was less during 1970–79 than during 1963–69. Correlations for the 1992–2011 period were slightly weaker than those for the 1963–1969 period.

Inclusion of some streamgages in areas where flow is known to be altered or regionally unrepresentative produced low correlations, and in turn, local zones of low correlation on the correlation maps. Because not all such areas include streams that have been gaged, correlation maps do not account for them. Highly correlated streamgages may meet different operational or other needs for the USGS and its partner agencies and do not automatically become lower priorities for inclusion in the streamgaging network.

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Table 1. Description of unregulated streamgages in and near West Virginia, 1930–2011, and their coordinates, drainage areas, sources of basin centroid, regulation status, and length of record.

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
01560000	Dunning Creek at Belden, PA	Falcone and others, 2011	40.181198	-78.583934	40.071747	-78.492517	172	26,298	Yes	Yes	No	Included in state low-flow report
01562000	Raystown Branch Juniata River at Saxton, PA	Falcone and others, 2011	40.070910	-78.468063	40.215912	-78.265290	756	36,525	Yes	Yes	Yes	Included in state low-flow report
01564500	Aughwick Creek near Three Springs, PA	Digitized from StreamStats	40.099814	-78.011847	40.212581	-77.925276	205	26,785	Yes	Yes	No	Included in state low-flow report
01571184	Mountain Creek near Pine Grove Furnace, PA	NHDPlus v.2	40.003887	-77.358429	40.030925	-77.308595	13.8	2,160	Yes	Yes	No	Included in state low-flow report
01573849	Bermudian Creek at Oxford Road near Heidlersburg, PA	NHDPlus v.2	40.007339	-77.191045	39.980222	-77.154611	10.2	2,528	Yes	Yes	No	Included in state low-flow report
01586210	Beaver Run near Finksburg, MD	Falcone and others, 2011	39.523059	-76.948299	39.489444	-76.902944	14	10,592	Yes	Yes	No	Included in state low-flow study
01586610	Morgan Run near Louisville, MD	Falcone and others, 2011	39.489474	-77.014373	39.451889	-76.955306	28	10,592	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01589180	Gwynns Falls at Glyndon, MD	NHDPlus v.2	39.471648	-76.823468	39.471694	-76.816889	0.32	4,748	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01591000	Patuxent River near Unity, MD	Falcone and others, 2011	39.290600	-77.133340	39.238250	-77.055722	34.8	24,544	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01591400	Cattail Creek near Glenwood, MD	Falcone and others, 2011	39.307023	-77.063964	39.255972	-77.051056	22.9	12,170	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01591700	Hawlings River near Sandy Spring, MD	Falcone and others, 2011	39.195507	-77.078764	39.174667	-77.021583	27	12,169	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01594950	McMillan Fork near Fort Pendleton, MD	NHDPlus v.2	39.283466	-79.411653	39.276694	-79.390306	2.3	9,131	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01595000	North Branch Potomac River at Steyer, MD	Paybins, 2008	39.260159	-79.393890	39.301889	-79.306889	73.1	20,180	Yes	Yes	No	Included in state low-flow study
01595300	Abram Creek at Oakmont, WV	Paybins, 2008	39.296856	-79.190231	39.366766	-79.178924	42.6	9,544	Yes	No	No	This station has recently been reactivated. Regulation and diversion status needs to be researched. No regulation known as of 1980.
01596500	Savage River near Barton, MD	Paybins, 2008	39.632324	-79.057953	39.570056	-79.101944	49.1	23,023	Yes	Yes	No	Included in state low-flow study
01599000	Georges Creek at Franklin, MD	Paybins, 2008	39.578297	-78.984535	39.493917	-79.044694	72.4	30,391	Yes	Yes	Yes	Included in state low-flow study
01599500	New Creek near Keyser, WV	Paybins, 2008	39.332420	-79.081383	39.409818	-79.001139	46.5	6,362	Yes	No	No	Several dams of unknown size in the basin since about 1965
01601000	Wills Creek below Hyndman, PA	Falcone and others, 2011	39.862537	-78.803416	39.812029	-78.716407	146	9,395	Yes	Yes	No	Included in state low-flow report

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
01601500	Wills Creek near Cumberland, MD	Paybins, 2008	39.803059	-78.812569	39.669611	-78.788028	247	30,390	Yes	Yes	Yes	Included in state low-flow study
01604500	Patterson Creek near Headsville, WV	Paybins, 2008	39.287163	-79.003319	39.443149	-78.821965	221	27,059	Yes	Yes	No	Since 1963, the flow from 115 mi² upstream from the station is partially controlled, but not diverted, by several floodwater detention reservoirs with the total combined detention capacity of 19,887 acre-ft.
01605500	South Branch Potomac River at Franklin, WV	Paybins, 2008	38.524574	-79.459030	38.635672	-79.337820	179	23,894	Yes	Yes	No	No known regulation. Small diversion which bypasses station from spring upstream for municipal supply for Franklin
01605600	Friends Run near Franklin, WV	NHDPlus v.2	38.665414	-79.420573	38.656505	-79.391711	4.39	3,053	Yes	No	No	Regulation status unknown
01606000	North Fork South Branch Potomac River at Cabins, WV	Paybins, 2008	38.759941	-79.461708	38.984555	-79.233651	310	13,912	Yes	Yes	No	No significant regulations or diversions are known
01606500	South Branch Potomac River near Petersburg, WV	Paybins, 2008	38.699230	-79.417931	38.991221	-79.175871	651	30,778	Yes	Yes	Yes	No significant regulations or diversions are known
01607500	South Fork South Branch Potomac River at Brandywine, WV	Paybins, 2008	38.505013	-79.290314	38.631507	-79.243650	103	25,238	Yes	Yes	No	Beginning in 1973, the flow from 41.3 mi² upstream from station has been partially controlled, but not diverted, by several floodwater-detention reservoirs with a total combined detention capacity of 8,882 acre-ft.
01608000	South Fork South Branch Potomac River near Moorefield, WV	Paybins, 2008	38.682751	-79.165726	39.012331	-78.956139	277	29,723	Yes	Yes	Yes	Beginning in 1973, the flow from 92.7 mi² upstream from station has been partially controlled, but not diverted, by several floodwater-detention reservoirs with a total combined detention capacity of 19,870 acre-ft.
01608050	Fort Run near Moorefield, WV	NHDPlus v.2	39.065289	-78.880651	39.065663	-78.913359	4.85	3,054	Yes	No	No	Regulation status unknown
01608400	Buffalo Creek near Romney, WV	NHDPlus v.2	39.363190	-78.701626	39.371764	-78.730572	4.33	2,983	Yes	No	No	Regulation status unknown
01608500	South Branch Potomac River near Springfield, WV	Paybins, 2008	38.849442	-79.213730	39.447039	-78.654182	1,461	32,687	Yes	Yes	Yes	No significant regulations or diversions are known
01609000	Town Creek near Oldtown, MD	Paybins, 2008	39.743542	-78.533928	39.553222	-78.555000	148	10,948	Yes	Yes	No	Included in state low-flow study
01609800	Little Cacapon River near Levels, WV	Paybins, 2008	39.373303	-78.617073	39.498705	-78.488622	108	4,018	Yes	No	No	No regulation known.
01610155	Sideling Hill Creek near Bellegrove, MD	Paybins, 2008	39.780735	-78.348908	39.649528	-78.344139	102	8,311	Yes	Yes	No	Included in state low-flow study

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01610200	Lost River at Mccauley near Baker, WV	NHDPlus v.2	38.948600	-78.842272	39.055108	-78.725017	155	3,045	Yes	No	No	No regulation known as of 1980
01610300	Cacapon River above Wardensville, WV	NHDPlus v.2	38.964712	-78.818400	39.078996	-78.619458	181	734	Yes	No	No	No regulation known
01610400	Waites Run near Wardensville, WV	Paybins, 2008	39.006382	-78.595383	39.042722	-78.598333	12.6	3,901	Yes	Yes	No	No significant regulations or diversions are known.
01610500	Cacapon River at Yellow Spring, WV	Paybins, 2008	39.003021	-78.731674	39.182326	-78.506676	306	4,475	Yes	No	No	No regulation known
01611500	Cacapon River near Great Cacapon, WV	Paybins, 2008	39.158409	-78.627884	39.582316	-78.309731	675	32,432	Yes	Yes	Yes	No significant regulations or diversions are known.
01613050	Tonoloway Creek near Needmore, PA	Falcone and others, 2011	39.923586	-78.167758	39.898421	-78.132229	10.7	16,777	Yes	Yes	No	Included in state low-flow report
01613095	Tonoloway Creek near Hancock, MD	Digitized from StreamStats	39.829383	-78.192076	39.706361	-78.152750	111	2,191	Yes	Yes	No	Occasional regulation of low flows from unknown source upstream
01613525	Licking Creek at Pectonville, MD	Digitized from StreamStats	39.887855	-78.041521	39.676278	-78.042528	193	2,405	Yes	Yes	No	No regulation mentioned
01613900	Hogue Creek near Hayfield, VA	Paybins, 2008	39.192070	-78.329003	39.214548	-78.288059	15.9	16,604	Yes	Yes	No	Included in state low-flow study
01614000	Back Creek near Jones Springs, WV	Paybins, 2008	39.320866	-78.240837	39.512042	-78.037222	235	17,615	Yes	Yes	No	No significant regulations or diversions are known.
01614500	Conococheague Creek at Fairview, MD	Falcone and others, 2011	39.916900	-77.737401	39.716389	-77.824778	494	30,437	Yes	Yes	Yes	Included in state low-flow study
01615000	Opequon Creek near Berryville, VA	Paybins, 2008	39.128247	-78.164738	39.174722	-78.078333	58.2	23,030	Yes	Yes	No	Included in state low-flow study
01616100	Dry Marsh Run near Berryville, VA	Krstolic, 2006	39.173655	-78.035224	39.192592	-78.068631	11	3,327	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01616425	Hopewell Run at Leetown, WV	NHDPlus v.2	39.338000	-77.922000	39.354639	-77.933611	8.95	1,096	Yes	No	No	Project gage for GW karst study
01616500	Opequon Creek near Martinsburg, WV	Paybins, 2008	39.256069	-78.073250	39.423710	-77.938608	273	23,799	Yes	Yes	No	Some diurnal fluctuation at low flow caused by upstream mills in Virginia and since July 18, 1988, by wastewater treatment plant, 1,000 ft upstream from Opequon Creek near Berryville, VA (01615000); drainage area 57.4 mi². The stream drains an area underlain by karst, and underground diversion is possible.
01617000	Tuscarora Creek above Martinsburg, WV	Paybins, 2008	39.457954	-78.029198	39.469543	-77.971387	11.3	11,129	Yes	Yes	No	The stream drains an area underlain by karst, and underground diversion is possible.
01617800	Marsh Run at Grimes, MD	Paybins, 2008	39.564976	-77.756706	39.514556	-77.777222	18.9	17,532	Yes	Yes	No	Included in state low-flow study

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01618100	Rockymarsh Run at Scrabble, WV	Previously unpublished	39.423000	-77.855000	39.483083	-77.831833	15.9	1,649	Yes	Yes	No	The stream drains an area underlain by karst, and underground diversion is possible.
01619000	Antietam Creek near Waynesboro, PA	Falcone and others, 2011	39.783501	-77.543909	39.716250	-77.606639	93.5	9,377	Yes	Yes	No	Small fluctuations in flow
01619500	Antietam Creek near Sharpsburg, MD	Paybins, 2008	39.669006	-77.615562	39.449778	-77.730194	281	32,730	Yes	Yes	Yes	Included in state low-flow study
01620500	North River near Stokesville, VA	Paybins, 2008	38.390289	-79.278467	38.335000	-79.239167	17.3	23,741	Yes	Yes	No	Included in state low-flow study
01621050	Muddy Creek at Mount Clinton, VA	Krstolic, 2006	38.524548	-78.950150	38.486790	-78.960307	14.3	6,745	Yes	Yes	No	Occasional diversion
01622000	North River near Burketown, VA	Paybins, 2008	38.440235	-79.078620	38.340405	-78.913639	376	30,235	Yes	Yes	Yes	Included in state low-flow study
01626000	South River near Waynesboro, VA	Krstolic, 2006	37.982321	-79.034884	38.057636	-78.908079	127	21,549	Yes	Yes	No	Minor diversion, WWTPs, flood-control dams
01626850	South River near Dooms, VA	Krstolic, 2006	37.993467	-79.014177	38.088746	-78.876968	148	10,531	Yes	Yes	No	Minor diversion, WWTPs, flood-control dams
01627500	South River at Harriston, VA	Krstolic, 2006	38.038823	-78.959188	38.218742	-78.836692	212	25,429	Yes	Yes	No	Minor diversion, WWTPs, flood-control dams
01628500	South Fork Shenandoah River near Lynnwood, VA	Krstolic, 2006	38.251318	-79.038467	38.322628	-78.754746	1,079	29,585	Yes	Yes	Yes	Some irrigation
01632000	North Fork Shenandoah River at Cootes Store, VA	Paybins, 2008	38.701133	-78.961384	38.637063	-78.852803	210	31,594	Yes	Yes	Yes	Included in state low-flow study
01632082	Linville Creek at Broadway, VA	Krstolic, 2006	38.539742	-78.866080	38.606786	-78.803357	45.7	9,549	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01632900	Smith Creek near New Market, VA	Paybins, 2008	38.543297	-78.727704	38.693450	-78.642794	93.6	18,688	Yes	Yes	No	Included in state low-flow study
01633000	North Fork Shenandoah River at Mount Jackson, VA	Paybins, 2008	38.652507	-78.842736	38.745670	-78.638904	508	24,837	Yes	Yes	No	Included in state low-flow study
01634000	North Fork Shenandoah River near Strasburg, VA	Paybins, 2008	38.729827	-78.755376	38.976776	-78.336115	770	31,594	Yes	Yes	Yes	Included in state low-flow study
01634500	Cedar Creek near Winchester, VA	Paybins, 2008	39.069125	-78.449588	39.081218	-78.329449	102	27,028	Yes	Yes	No	Included in state low-flow study
01635500	Passage Creek near Buckton, VA	Krstolic, 2006	38.826419	-78.441656	38.958166	-78.266669	86.5	29,037	Yes	Yes	Yes	Minor diversion
01636316	Spout Run at Rt 621 near Millwood, VA	Krstolic, 2006	39.090296	-78.061837	39.067025	-78.003753	21.4	3,327	Yes	Yes	No	No known regulation or diversions

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01636464	Bullskin Run below Kabletown, WV	NHDPlus v.2	39.242000	-77.911000	39.211583	-77.834861	21.8	1,644	Yes	Yes	No	The stream drains an area underlain by karst, and underground diversion is possible.
01636500	Shenandoah River at Millville, WV	Paybins, 2008	38.598648	-78.690041	39.282046	-77.789161	3,041	35,851	Yes	Yes	Yes	Operation of Potomac Light and Power hydro-electric plant 0.5 mi above gage and other plants upstream regulates flow at gage. No known diversions
01636690	Piney Run near Lovettsville, VA	Krstolic, 2006	39.268971	-77.732552	39.310833	-77.718500	13.5	3,652	Yes	Yes	No	No known regulation or diversions
01637500	Catoctin Creek near Middletown, MD	Paybins, 2008	39.527718	-77.553124	39.427250	-77.556167	66.9	23,437	Yes	Yes	No	Included in state low-flow study
01638350	South Fork Catoctin Creek at Rt 698 near Waterford, VA	Krstolic, 2006	39.163358	-77.680128	39.191111	-77.615444	31.6	3,744	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01638420	North Fork Catoctin Creek at Rt 681 near Waterford, VA	Krstolic, 2006	39.201709	-77.725176	39.205000	-77.623889	23.1	3,725	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01638480	Catoctin Creek at Taylorstown, VA	Paybins, 2008	39.200151	-77.674577	39.255102	-77.576378	89.5	14,672	Yes	Yes	No	Included in state low-flow study
01639000	Monocacy River at Bridgeport, MD	Falcone and others, 2011	39.812492	-77.246805	39.678833	-77.234500	173	25,355	Yes	Yes	No	Included in state low-flow study
01639500	Big Pipe Creek at Bruceville, MD	Falcone and others, 2011	39.645731	-77.051875	39.612361	-77.237444	102	23,376	Yes	Yes	No	Occasional diversion for irrigation upstream from station
01642190	Monocacy River at Monocacy Boulevard at Frederick, MD	NHDPlus v.2	39.666814	-77.256197	39.443435	-77.382485	703	2,922	Yes	Yes	No	No regulation mentioned
01643395	Soper Branch at Hyattstown, MD	NHDPlus v.2	39.260097	-77.296188	39.275306	-77.303667	1.17	2,805	Yes	Yes	No	No regulation mentioned
01643500	Bennett Creek at Park Mills, MD	Falcone and others, 2011	39.295155	-77.299261	39.294139	-77.407083	62.8	20,213	Yes	Yes	No	No regulation mentioned
01643590	Limestone Branch near Leesburg, VA	Krstolic, 2006	39.158799	-77.570533	39.167611	-77.535917	7.88	3,691	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01643700	Goose Creek near Middleburg, VA	Paybins, 2008	38.949695	-77.923227	38.986498	-77.796661	122	14,551	Yes	Yes	No	Included in state low-flow study
01643805	North Fork Goose Creek at Rt 729 near Lincoln, VA	Krstolic, 2006	39.115821	-77.724066	39.072306	-77.683944	38.1	3,726	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01643880	Beaverdam Creek at Rt 734 near Mountville, VA	Krstolic, 2006	39.062955	-77.800834	39.037722	-77.722250	47.2	3,727	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01644000	Goose Creek near Leesburg, VA	Paybins, 2008	38.992777	-77.803872	39.019553	-77.577492	332	31,004	Yes	Yes	Yes	Included in state low-flow study

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
01644280	Broad Run near Leesburg, VA	Krstolic, 2006	38.982364	-77.482307	39.046417	-77.432389	76.1	3,652	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01644371	Little Seneca Creek Tributary near Clarksburg, MD	NHDPlus v.2	39.239306	-77.257871	39.231495	-77.255817	0.43	2,691	Yes	Yes	No	No regulation mentioned
01644372	Little Seneca Creek Tributary at Brink, MD	Digitized from StreamStats	39.222884	-77.249150	39.222884	-77.249150	0.37	2,674	Yes	Yes	No	No regulation mentioned
01644375	Little Seneca Creek Tributary near Germantown, MD	NHDPlus v.2	39.198073	-77.258625	39.198995	-77.274984	1.35	2,655	Yes	Yes	No	No regulation mentioned
01644380	Cabin Branch near Boyds, MD	Digitized from StreamStats	39.206611	-77.288583	39.206611	-77.288583	0.79	2,678	Yes	Yes	No	No regulation mentioned
01644390	Ten Mile Creek near Boyds, MD	Digitized from StreamStats	39.232476	-77.307631	39.216000	-77.316417	4.48	365	Yes	Yes	No	No regulation mentioned
01645000	Seneca Creek at Dawsonville, MD	Falcone and others, 2011	39.193226	-77.251065	39.128083	-77.335778	101	29,590	Yes	Yes	Yes	Small diversion at times for irrigation upstream from station
01645704	Difficult Run above Fox Lake near Fairfax, VA	NHDPlus v.2	38.868311	-77.345807	38.884695	-77.332429	5.49	1,471	Yes	Yes	No	No known regulation or diversions
01645762	South Fork Little Difficult Run above mouth near Vienna, VA	NHDPlus v.2	38.895024	-77.356782	38.908889	-77.338263	2.71	1,472	Yes	Yes	No	No known regulation or diversions
01646000	Difficult Run near Great Falls, VA	Krstolic, 2006	38.930455	-77.307489	38.975943	-77.245814	57.8	27,942	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01646305	Dead Run at Whann Avenue near McLean, VA	Krstolic, 2006	38.959777	-77.175674	38.959777	-77.175674	2.05	1,360	Yes	Yes	No	No known regulation or diversions
01647850	Turkey Branch near Rockville, MD	NHDPlus v.2	39.081333	-77.073899	39.068472	-77.081750	2.74	1,778	Yes	Yes	No	No regulation mentioned
01649150	Paint Branch Tributary near Colesville, MD	NHDPlus v.2	39.097146	-76.995155	39.088497	-76.989282	1.04	1,786	Yes	Yes	No	No regulation mentioned
01649190	Paint Branch near College Park, MD	NHDPlus v.2	39.081570	-76.976535	39.033139	-76.964278	13.1	1,461	Yes	Yes	No	No regulation mentioned
01649500	Northeast Branch Anacostia River at Riverdale, MD	Falcone and others, 2011	39.034081	-76.915980	38.960250	-76.925972	72.8	26,724	Yes	Yes	No	Some regulation at low flow by sand and gravel plants upstream from station
01650500	Northwest Branch Anacostia River near Colesville, MD	Falcone and others, 2011	39.108492	-77.033395	39.065667	-77.029333	21	26,971	Yes	Yes	No	Diversions at low flow since 1962 for irrigation of golf courses upstream from station

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
01650800	Sligo Creek near Takoma Park, MD	NHDPlus v.2	39.018118	-77.029717	38.986222	-77.004861	6.45	1,095	Yes	Yes	No	No regulation mentioned
01651000	Northwest Branch Anacostia River near Hyattsville, MD	Falcone and others, 2011	39.050913	-77.016208	38.952333	-76.966056	49.4	26,755	Yes	Yes	No	Small diversion since 1962 for irrigation of golf courses upstream
01652500	Fourmile Run at Alexandria, VA	Krstolic, 2006	38.869252	-77.127563	38.843333	-77.085861	12.6	13,466	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01654000	Accotink Creek near Annandale, VA	Krstolic, 2006	38.857384	-77.258934	38.812891	-77.228316	23.9	23,376	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01656000	Cedar Run near Catlett, VA	Krstolic, 2006	38.684879	-77.738444	38.636787	-77.624990	93.4	21,294	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01656903	Flatlick Branch above Frog Branch at Chantilly, VA	NHDPlus v.2	38.891780	-77.402567	38.882390	-77.431905	4.2	1,471	Yes	Yes	No	No known regulation or diversions
01658500	South Fork Quantico Creek near Independent Hill, VA	Krstolic, 2006	38.611224	-77.446809	38.587343	-77.428596	7.62	22,068	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01660400	Aquia Creek near Garrisonville, VA	Krstolic, 2006	38.501975	-77.519158	38.490401	-77.433594	35	13,891	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01662800	Battle Run near Laurel Mills, VA	Krstolic, 2006	38.710485	-78.094175	38.655676	-78.073887	25.8	18,698	Yes	Yes	No	At times, unknown amount of diversion for irrigation upstream from gage.
01663500	Hazel River at Rixeyville, VA	Krstolic, 2006	38.628814	-78.179617	38.591789	-77.964996	285	21,988	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
01664000	Rappahannock River at Remington, VA	Krstolic, 2006	38.676125	-78.063641	38.530680	-77.813605	619	25,202	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02011400	Jackson River near Bacova, VA	Paybins, 2008	38.209909	-79.717866	38.042347	-79.881444	157	13,519	Yes	Yes	No	Included in state low-flow study
02011460	Back Creek near Sunearise, VA	Paybins, 2008	38.337082	-79.722212	38.245401	-79.768663	60.9	13,606	Yes	Yes	No	Included in state low-flow study
02013000	Dunlap Creek near Covington, VA	Paybins, 2008	37.750626	-80.184406	37.802902	-80.047004	162	30,315	Yes	Yes	Yes	Included in state low-flow study
02014000	Potts Creek near Covington, VA	Paybins, 2008	37.598555	-80.216527	37.729014	-80.042280	153	27,028	Yes	Yes	No	Included in state low-flow study
02015700	Bullpasture River at Williamsville, VA	Krstolic, 2006	38.321784	-79.530791	38.195403	-79.570323	110	18,688	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02016000	Cowpasture River near Clifton Forge, VA	Krstolic, 2006	38.121362	-79.601277	37.791796	-79.759492	461	31,411	Yes	Yes	Yes	Low flow affected by springs and by occasional regulation from unknown source
02017500	Johns Creek at New Castle, VA	Krstolic, 2006	37.459830	-80.318556	37.506240	-80.106715	105	31,046	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.

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02018000	Craig Creek at Parr, VA	Krstolic, 2006	37.483987	-80.184645	37.665962	-79.911439	329	31,594	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02020500	Calfpasture River above Mill Creek at Goshen, VA	Krstolic, 2006	38.205137	-79.386088	37.987906	-79.493653	141	25,933	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02022500	Kerrs Creek near Lexington, VA	Krstolic, 2006	37.864468	-79.523099	37.825687	-79.443094	35.1	30,681	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02024915	Pedlar River at Forest Road near Buena Vista, VA	Krstolic, 2006	37.756391	-79.252481	37.697500	-79.278333	27.1	3,249	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02028500	Rockfish River near Greenfield, VA	Krstolic, 2006	37.931425	-78.864057	37.869585	-78.823354	94.8	25,020	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02031000	Mechums River near White Hall, VA	Krstolic, 2006	38.041939	-78.716174	38.102636	-78.592794	95.3	14,975	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02032640	North Fork Rivanna River near Earlysville, VA	Krstolic, 2006	38.263471	-78.507923	38.163467	-78.424732	108	6,574	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02053800	South Fork Roanoke River near Shawsville, VA	Krstolic, 2006	37.107192	-80.254175	37.140132	-80.266433	109	18,627	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02054500	Roanoke River at Lafayette, VA	Krstolic, 2006	37.179219	-80.277286	37.236522	-80.209209	254	24,837	Yes	Yes	No	Occasional diurnal fluctuation caused by meat-processing plant
02054530	Roanoke River at Glenvar, VA	Krstolic, 2006	37.184942	-80.266710	37.267912	-80.139486	281	7,233	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02055100	Tinker Creek near Daleville, VA	Krstolic, 2006	37.439162	-79.930941	37.417633	-79.935319	11.7	20,241	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02056650	Back Creek near Dundee, VA	Krstolic, 2006	37.191573	-80.002667	37.227639	-79.868092	55.8	13,606	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02056900	Blackwater River near Rocky Mount, VA	Krstolic, 2006	37.060502	-80.009442	37.045141	-79.844199	115	12,783	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02059485	Goose Creek at Rt 747 near Bunker Hill, VA	Krstolic, 2006	37.351282	-79.680760	37.266389	-79.587778	125	1,753	Yes	Yes	No	No known regulation or diversions.
02061000	Big Otter River near Bedford, VA	Krstolic, 2006	37.429933	-79.511172	37.364030	-79.419197	114	7,963	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
02071530	Smith River at Smith River Church near Woolwine, VA	Krstolic, 2006	36.762085	-80.307970	36.778468	-80.249218	26.3	6,209	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03039200	Clear Run near Buckstown, PA	NHDPlus v.2	40.040279	-78.807752	40.047024	-78.832522	3.68	5,208	Yes	No	No	Used in low-flow report, unregulated for POR
03049000	Buffalo Creek near Freeport, PA	Falcone and others, 2011	40.853484	-79.694790	40.715898	-79.699494	137	25,932	Yes	Yes	No	Included in state low-flow report

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03049800	Little Pine Creek near Etna, PA	Falcone and others, 2011	40.547132	-79.919093	40.520346	-79.938108	5.78	17,897	Yes	Yes	No	Included in state low-flow report
03049807	Pine Creek at Grant Avenue at Etna, PA	NHDPlus v.2	40.596896	-79.992978	40.503139	-79.948444	57.3	1,936	Yes	Yes	No	Included in state low-flow report
03050000	Tygart Valley River near Dailey, WV	Paybins, 2008	38.635960	-79.991997	38.809275	-79.881734	185	30,918	Yes	Yes	No	No significant regulations or diversions are known
03050500	Tygart Valley River near Elkins, WV	Paybins, 2008	38.704800	-79.946259	38.923717	-79.878959	271	21,915	Yes	No	No	Some regulation is affected by manipulation of the gates in the upper and lower flood control diversion dams, by the city of Elkins. The diversion channel empties into the main channel about 0.3 mi above the gage, and the lower flood control dam is about 0.6 mi above the gage.
03050800	Roaring Creek at Norton, WV	NHDPlus v.2	38.880388	-79.972055	38.934827	-79.949796	29.2	1,828	Yes	No	No	Regulation status unknown
03050900	Grassy Run at Norton, WV	NHDPlus v.2	38.921392	-79.975062	38.936216	-79.960908	2.86	1,828	Yes	No	No	Regulation status unknown
03051000	Tygart Valley River at Belington, WV	Paybins, 2008	38.795708	-79.932289	39.029269	-79.935908	406	38,470	Yes	Yes	Yes	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03051500	Middle Fork River at Midvale, WV	Paybins, 2008	38.809135	-80.067688	38.938991	-80.090079	122	10,015	Yes	No	No	No regulation known
03052000	Middle Fork River at Audra, WV	Paybins, 2008	38.839050	-80.065697	39.039545	-80.068135	148	22,508	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03052500	Sand Run near Buckhannon, WV	Paybins, 2008	38.935112	-80.148972	38.963989	-80.152581	14.3	24,107	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03053500	Buckhannon River at Hall, WV	Paybins, 2008	38.857010	-80.207855	39.051210	-80.114525	277	35,599	Yes	Yes	Yes	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03054500	Tygart Valley River at Philippi, WV	Paybins, 2008	38.843185	-80.046639	39.150375	-80.038691	914	26,481	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03056250	Three Fork Creek near Grafton, WV	Paybins, 2008	39.424625	-79.864883	39.336481	-79.993409	96.8	10,226	Yes	Yes	No	No significant regulations or diversions are known
03056500	Tygart Valley River at Fetterman, WV	Paybins, 2008	38.972946	-80.005272	39.350091	-80.041466	1,304	11,658	Yes	No	No	Regulation status unknown
03057300	West Fork River at Walkersville, WV	Paybins, 2008	38.845512	-80.420601	38.868709	-80.457866	28.8	2,991	Yes	No	No	Records affected by unquantified backwater from Stonewall Jackson Lake
03057500	Skin Creek near Brownsville, WV	Paybins, 2008	38.943283	-80.397163	38.975096	-80.444256	25.7	5,479	Yes	No	No	In backwater from Stonewall Jackson Dam since 1990
03058006	West Fork River at Bendale,WV	NHDPlus v.2	38.910926	-80.438573	39.014817	-80.477313	101	2,191	Yes	No	No	Floodwater reservoirs noted in 1980

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03058500	West Fork River at Butcherville, WV	Paybins, 2008	38.954849	-80.435631	39.090648	-80.467592	181	31,131	No	No	No	Flow partially regulated since 1973 by Stonecoal Reservoir. Flow regulated since January 1990 by Stonewall Jackson Lake.
03059000	West Fork River at Clarksburg, WV	Paybins, 2008	39.054180	-80.428246	39.270923	-80.355368	384	22,127	No	No	No	Floodwater reservoirs noted in 1980. Flow partially regulated since 1973 by Stonecoal Reservoir. Flow regulated since January 1990 by Stonewall Jackson Lake.
03059500	Elk Creek at Quiet Dell, WV	Paybins, 2008	39.150913	-80.212608	39.227869	-80.297033	84.6	9,862	Yes	No	No	No regulation known
03060100	Salem Fork Subwatershed 9 near Salem, WV	Previously unpublished	39.270921	-80.570653	39.270921	-80.570653	0.92	2,349	Yes	No	No	Regulation status unknown
03060500	Salem Fork at Salem, WV	Paybins, 2008	39.281456	-80.569222	39.286199	-80.542874	8.32	6,849	Yes	No	No	Regulation status unknown
03061000	West Fork River at Enterprise, WV	Paybins, 2008	39.163303	-80.373962	39.422308	-80.275919	759	32,241	No	No	No	Flow regulated continuously by operation of Stonecoal Lake and Stonewall Jackson Dam above Weston, WV.
03061410	Laurel Run at Curtisville, WV	NHDPlus v.2	39.528037	-80.448619	39.520640	-80.438699	1.11	1,096	Yes	No	No	No regulation known as of 1980.
03061435	Hibbs Run near Mannington, WV	NHDPlus v.2	39.559070	-80.384436	39.543139	-80.390086	1.42	730	Yes	No	No	Regulation status unknown
03061495	Davy Run at Katy, WV	NHDPlus v.2	39.527414	-80.206774	39.510639	-80.213970	1.76	730	Yes	No	No	Regulation status unknown
03061500	Buffalo Creek at Barrackville, WV	Paybins, 2008	39.551655	-80.352760	39.503973	-80.172024	116	33,165	Yes	Yes	Yes	Flow from 5.20 mi² is partially controlled, but not diverted, by three floodwater-detention reservoirs. Some additional regulation at low flow from mine pumpage above station.
03062213	Stewart Run at Crown, WV	NHDPlus v.2	39.610680	-80.106860	39.582027	-80.104517	2.43	730	Yes	No	No	Area is heavily mined.
03062215	Indian Creek at Crown, WV	NHDPlus v.2	39.612063	-80.123896	39.576749	-80.097017	11.8	1,096	Yes	No	No	Heavily mined. Mine pumping noted in 1980.
03062400	Cobun Creek at Morgantown, WV	Paybins, 2008	39.561173	-79.922058	39.608138	-79.955064	11	12,601	Yes	No	No	No regulation noted in 1980. Area is mined.
03062500	Deckers Creek at Morgantown, WV	Paybins, 2008	39.560005	-79.846481	39.629248	-79.952563	63.2	11,904	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03063600	Horsecamp Run at Harman, WV	NHDPlus v.2	38.904913	-79.482591	38.914277	-79.508664	6.57	2,999	Yes	No	No	No regulation known
03065000	Dry Fork at Hendricks, WV	Paybins, 2008	38.894959	-79.568512	39.072329	-79.622837	349	25,916	Yes	Yes	No	No significant regulations or diversions are known.
03065200	Blackwater River at Cortland, WV	NHDPlus v.2	39.032000	-79.447000	39.064275	-79.413382	18.5	820	Yes	No	No	No known regulation
03065400	Blackwater River near Davis, WV	Paybins, 2008	39.082172	-79.406372	39.140108	-79.419772	54.7	6,276	Yes	Yes	No	No significant regulations or diversions are known.

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03066000	Blackwater River at Davis, WV	Paybins, 2008	39.111710	-79.402962	39.127052	-79.468385	85.9	33,025	Yes	Yes	Yes	No significant regulations or diversions are known.
03066630	Tub Run near Douglas, WV	NHDPlus v.2	39.123754	-79.550283	39.114830	-79.549778	1.17	1,420	Yes	No	No	Regulation status unknown
03066720	Big Run near Douglas, WV	NHDPlus v.2	39.130724	-79.572411	39.112329	-79.572557	1.3	789	Yes	No	No	Regulation status unknown
03066730	West Fork Big Run near Douglas, WV	NHDPlus v.2	39.118653	-79.585436	39.115385	-79.579502	1.07	788	Yes	No	No	Regulation status unknown
03067510	Shavers Fork near Cheat Bridge, WV	NHDPlus v.2	38.521900	-79.925800	38.617058	-79.869785	60.2	4,383	Yes	Yes	No	No significant regulations or diversions are known.
03068500	Shavers Fork at Flint, WV	NHDPlus v.2	38.625472	-79.872144	38.850110	-79.730339	124	2,922	Yes	No	No	No regulation known
03068600	Shavers Fork above Bowden, WV	NHDPlus v.2	38.649350	-79.857536	38.902887	-79.694505	138	1,919	Yes	No	No	No regulation known
03068604	Taylor Run near Alpena, WV	NHDPlus v.2	38.929084	-79.665939	38.923442	-79.669782	1.06	731	Yes	No	No	No regulation noted in 1980
03068607	Stalnaker Run near Bowden, WV	NHDPlus v.2	38.928092	-79.693818	38.917331	-79.686172	1.55	731	Yes	No	No	No regulation known
03068610	Taylor Run at Bowden, WV	Paybins, 2008	38.920120	-79.680534	38.907609	-79.696727	5.06	3,390	Yes	No	No	No regulation known
03068800	Shavers Fork below Bowden, WV	Paybins, 2008	38.673855	-79.844170	38.913163	-79.770342	151	8,432	Yes	Yes	No	No significant regulations or diversions are known.
03069000	Shavers Fork at Parsons, WV	Paybins, 2008	38.784405	-79.807625	39.096217	-79.676729	213	25,202	Yes	No	No	No regulation known
03069500	Cheat River near Parsons, WV	Paybins, 2008	38.907661	-79.619865	39.122884	-79.681174	722	36,433	Yes	Yes	Yes	No significant regulations or diversions are known.
03069870	Cheat River at Hwy 50 near Rowlesburg, WV	Paybins, 2008	38.971531	-79.627419	39.319822	-79.656727	912	4,748	Yes	No	No	No regulation known
03069880	Buffalo Creek near Rowlesburg, WV	Paybins, 2008	39.271683	-79.751167	39.288712	-79.704231	12.2	3,653	Yes	No	No	No regulation known
03070000	Cheat River at Rowlesburg, WV	Paybins, 2008	38.981422	-79.630562	39.346209	-79.665337	939	26,664	Yes	No	No	No regulation known
03070260	Cheat River at Albright, WV	NHDPlus v.2	39.027200	-79.632400	39.494810	-79.644497	1,044	1,096	Yes	Yes	No	No significant regulations or diversions are known.
03070310	Conner Run near Valley Point, WV	NHDPlus v.2	39.576010	-79.671271	39.571751	-79.677274	0.54	617	Yes	No	No	Regulation status unknown
03070350	Cheat River near Mt. Nebo, WV	NHDPlus v.2	39.065000	-79.633000	39.594527	-79.748666	1,132	730	Yes	No	No	No regulation known
03070500	Big Sandy Creek at Rockville, WV	Paybins, 2008	39.701851	-79.617920	39.621750	-79.704556	200	36,645	Yes	Yes	Yes	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.

Table 1. Description of unregulated streamgages in and near West Virginia, 1930–2011, and their coordinates, drainage areas, sources of basin centroid, regulation status, and length of record.—Continued

[dd, decimal degrees; mi², square miles; ft³/s, cubic feet per second; ADR, Annual Water-Data Report; GW, groundwater; MTR, mountaintop removal; NWIS-Web, National Water Information System, web interface; POR, period of record; WWTP, wastewater-treatment plant]

Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi^2)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03071000	Cheat River near Pisgah, WV	Paybins, 2008	39.170315	-79.632362	39.607026	-79.777556	1,354	11,323	Yes	No	No	No regulation known
03072000	Dunkard Creek at Shannopin, PA	Paybins, 2008	39.720791	-80.218666	39.759245	-79.970615	229	25,840	Yes	Yes	No	Included in state low-flow report
03072590	Georges Creek at Smithfield	Paybins, 2008	39.823514	-79.742318	39.795632	-79.796162	16.3	5,546	Yes	No	No	Used in low-flow report, unregulated for POR
03072840	Tenmile Creek near Clarksville, PA	NHDPlus v.2	40.059679	-80.191354	39.997574	-80.041721	133	3,956	No	No	No	Unregulated before 1979
03073000	South Fork Tenmile Creek at Jefferson, PA	Falcone and others, 2011	39.911853	-80.246938	39.923131	-80.072558	180	23,741	Yes	Yes	No	Included in state low-flow report
03074300	Lick Run at Hopwood, PA	NHDPlus v.2	39.852743	-79.673825	39.867854	-79.694211	3.8	4,449	No	No	No	Unregulated before 1978
03074500	Redstone Creek at Waltersburg, PA	Falcone and others, 2011	39.917254	-79.712059	39.980076	-79.764209	73.7	25,202	Yes	Yes	No	Included in state low-flow report
03075500	Youghiogheny River near Oakland, MD	Paybins, 2008	39.370544	-79.450012	39.421583	-79.423639	134	25,603	Yes	Yes	No	Town of Oakland diverted an average of 0.4 ft3/s for water supply. The diversion is returned upstream.
03075650	Hayes Run near Cranesville, WV	Previously unpublished	39.532034	-79.487545	39.532034	-79.487545	0.93	774	Yes	No	No	Regulation status unknown
03075670	Muddy Creek near Cranesville, WV	NHDPlus v.2	39.539936	-79.485237	39.524812	-79.481434	5.09	784	Yes	No	No	Regulation status unknown
03075680	Cupp Run near Cranesville, WV	NHDPlus v.2	39.510616	-79.517618	39.512590	-79.501157	1.42	738	Yes	No	No	Regulation status unknown
03075905	Cherry Creek at State Park Road near McHenry, MD	NHDPlus v.2	39.560713	-79.287636	39.538000	-79.315778	13.1	1,461	Yes	Yes	No	No regulation mentioned
03076600	Bear Creek at Friendsville, MD	Paybins, 2008	39.630791	-79.321701	39.656139	-79.394111	48.9	17,166	Yes	Yes	No	Included in state low-flow study
03078000	Casselman River at Grantsville, MD	Falcone and others, 2011	39.644759	-79.196821	39.702194	-79.136389	62.5	23,444	Yes	Yes	No	Included in state low-flow study
03079000	Casselman River at Markleton, PA	Falcone and others, 2011	39.824175	-79.092890	39.859917	-79.228833	382	33,237	Yes	Yes	Yes	Included in state low-flow report
03080000	Laurel Hill Creek at Ursina, PA	Falcone and others, 2011	39.976320	-79.268842	39.820355	-79.321423	121	33,968	Yes	Yes	Yes	Included in state low-flow report
03082200	Poplar Run near Normalville, PA	NHDPlus v.2	40.044648	-79.454088	40.016463	-79.425591	9.27	6,303	No	No	No	Unregulated before 1978
03084800	Thompson Run at Turtle Creek, PA	NHDPlus v.2	40.448162	-79.808642	40.405347	-79.827826	18	2,486	Yes	Yes	No	Included in state low-flow report
03085213	Sawmill Run at Duquesne Heights near Pittsburgh, PA	Digitized from StreamStats	40.437320	-80.025312	40.432847	-80.029498	18.1	2,709	Yes	Yes	No	Included in state low-flow report

Table 1. Description of unregulated streamgages in and near West Virginia, 1930–2011, and their coordinates, drainage areas, sources of basin centroid, regulation status, and length of record.—Continued

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03085500	Chartiers Creek at Carnegie, PA	Paybins, 2008	40.282501	-80.194672	40.400625	-80.096444	257	31,046	Yes	Yes	No	Included in state low-flow report
03093000	Eagle Creek at Phalanx Station OH	Falcone and others, 2011	41.271423	-81.077076	41.261167	-80.954257	97.6	30,072	Yes	Yes	Yes	Included in state low-flow report
03103000	Pymatuning Creek near Orangeville, PA	NHDPlus v.2	41.457109	-80.597376	41.311166	-80.477570	169	17,378	Yes	No	No	Used in low-flow report, unregulated for POR
03104760	Harthegig Run near Greenfield, PA	NHDPlus v.2	41.196395	-80.343315	41.186169	-80.327010	2.26	4,581	No	No	No	Unregulated before 1981
03106000	Connoquenessing Creek near Zelienople, PA	Falcone and others, 2011	40.824116	-79.980080	40.817009	-80.242284	356	33,603	Yes	Yes	Yes	Included in state low-flow report
03106500	Slippery Rock Creek at Wurtemburg, PA	Falcone and others, 2011	41.072393	-80.031427	40.883952	-80.233673	398	36,525	Yes	Yes	Yes	Included in state low-flow report
03108000	Raccoon Creek at Moffatts Mill, PA	Paybins, 2008	40.478622	-80.360283	40.627844	-80.337563	178	25,567	Yes	Yes	No	Included in state low-flow report
03109500	Little Beaver Creek near East Liverpool OH	Paybins, 2008	40.800694	-80.640823	40.675897	-80.540624	496	35,064	Yes	Yes	Yes	Included in state low-flow report
03110000	Yellow Creek near Hammondsville OH	Paybins, 2008	40.508850	-80.884468	40.537842	-80.725078	147	25,901	Yes	Yes	No	Included in state low-flow report
03110830	Kings Creek at Weirton, WV	Paybins, 2008	40.462639	-80.505928	40.435623	-80.592572	48.9	3,938	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03111500	Short Creek near Dillonvale OH	Paybins, 2008	40.245331	-80.885414	40.193404	-80.734248	123	25,567	Yes	Yes	No	Included in state low-flow report
03111548	Wheeling Creek below Blaine OH	Paybins, 2008	40.127495	-80.947533	40.067016	-80.808420	97.7	10,169	Yes	Yes	No	Included in state low-flow report
03112000	Wheeling Creek at Elm Grove, WV	Paybins, 2008	39.975300	-80.505753	40.044518	-80.660912	281	26,298	Yes	Yes	No	The flow from 205 mi² upstream from station is partially controlled, but not diverted, by seven floodwater detention reservoirs with a total combined detention capacity of 24,148 acre-ft. Cummulative detention as construction progressed 1975 to 1995
03113700	Little Grave Creek near Glendale, WV	Paybins, 2008	39.970539	-80.683098	39.961186	-80.700915	4.95	2,935	Yes	No	No	No regulation known
03113990	Captina Creek at S.R. 148 at Armstrongs Mills OH	NHDPlus v.2	39.929987	-81.076072	39.906740	-80.935929	127	3,044	Yes	Yes	No	Included in state low-flow report
03114500	Middle Island Creek at Little, WV	Paybins, 2008	39.372665	-80.758003	39.475076	-80.997054	458	26,261	Yes	Yes	No	No significant regulations or diversions are known.

Table 1. Description of unregulated streamgages in and near West Virginia, 1930–2011, and their coordinates, drainage areas, sources of basin centroid, regulation status, and length of record.—Continued

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03114650	Buffalo Run near Little, WV	Paybins, 2008	39.508930	-81.018684	39.487020	-81.007332	4.19	3,177	Yes	No	No	No regulation known
03115400	Little Muskingum River at Bloomfield OH	Paybins, 2008	39.669979	-81.136856	39.563129	-81.203724	210	14,263	Yes	Yes	No	Included in state low-flow report
03117500	Sandy Creek at Waynesburg OH	Falcone and others, 2011	40.719200	-81.089600	40.672561	-81.259831	253	26,602	Yes	Yes	No	Included in state low-flow report
03118500	Nimishillen Creek at North Industry OH	Falcone and others, 2011	40.851978	-81.329550	40.740556	-81.365833	175	32,872	Yes	Yes	Yes	Included in state low-flow report
03121850	Huff Run at Mineral City OH	NHDPlus v.2	40.614584	-81.279989	40.597285	-81.359001	12.3	5,113	Yes	Yes	No	Included in state low-flow report
03141870	Leatherwood Creek near Kipling OH	NHDPlus v.2	39.982896	-81.334732	39.990072	-81.495676	69.5	4,260	Yes	Yes	No	Included in state low-flow report
03149500	Salt Creek near Chandlersville OH	NHDPlus v.2	39.990400	-81.852100	39.908681	-81.860411	75.7	8,369	Yes	Yes	No	Included in state low-flow report
03151400	Little Kanawha River near Wildcat, WV	Paybins, 2008	38.757851	-80.372566	38.743434	-80.525367	112	13,440	Yes	Yes	No	No significant regulations or diversions are known.
03151500	Little Kanawha River near Burnsville, WV	Paybins, 2008	38.768654	-80.417336	38.823709	-80.592871	155	13,149	No	No	No	Flow regulated since 1979 by Burnsville Dam
03151600	Little Kanawha River at Burnsville, WV	NHDPlus v.2	38.784764	-80.489852	38.865095	-80.676208	248	1,627	No	No	No	Flow partially regulated by five flood-water detention reservoirs affecting 49.5 mi² and regulated since March 1979 by Burnsville Reservoir at mile 124.2.
03152000	Little Kanawha River at Glenville, WV	Paybins, 2008	38.837483	-80.559944	38.932972	-80.838222	387	27,881	No	No	No	Flow partially regulated since 1968 by five floodwater detention reservoirs affecting 49.5 mi² and since 1979 by Burnsville Lake
03152200	Buck Run near Leopold, WV	Paybins, 2008	39.135765	-80.701004	39.123978	-80.690378	2.91	2,922	Yes	No	No	No regulation known
03152500	Leading Creek near Glenville, WV	Paybins, 2008	39.063488	-80.728577	38.962589	-80.866493	144	5,205	Yes	No	No	No regulation known
03153000	Steer Creek near Grantsville, WV	Paybins, 2008	38.763767	-80.919487	38.862589	-81.034832	166	13,886	Yes	No	No	No regulation known
03153500	Little Kanawha River at Grantsville, WV	Paybins, 2008	38.873230	-80.733452	38.922031	-81.097612	913	18,262	No	No	No	Flow partially regulated since 1968 by five floodwater detention reservoirs affecting 49.5 mi² and since 1979 by Burnsville Lake
03154000	West Fork Little Kanawha River at Rocksdale, WV	Paybins, 2008	38.735046	-81.138825	38.844254	-81.222617	205	14,974	Yes	No	No	No significant regulations or diversions are known.
03154250	Tanner Run at Spencer, WV	Paybins, 2008	38.798985	-81.389603	38.803143	-81.365954	2.82	3,105	Yes	No	No	No regulation known
03154500	Reedy Creek near Reedy, WV	Paybins, 2008	38.858906	-81.439026	38.961193	-81.390120	79.4	9,862	Yes	No	No	No regulation known

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03155000	Little Kanawha River at Palestine, WV	Paybins, 2008	38.864563	-80.945732	39.058969	-81.389564	1,516	26,664	No	No	No	Prior to 1968, flow partially regulated by old dams 3, 4, and 5 that leak at variable rates. Flow partially regulated since 1968 by five floodwater-detention reservoirs affecting 49.5 mi². Flow regulated since March 1979 by Burnsville Reservoir at mile 124.2.
03155220	South Fork Hughes River below Macfarlan, WV	NHDPlus v.2	39.082300	-81.173800	39.078969	-81.212337	229	6,972	Yes	Yes	No	No significant regulations or diversions are known.
03155410	North Bend Run near Cairo,WV	Previously unpublished	39.222856	-81.116779	39.222856	-81.116779	0.14	839	Yes	No	No	No regulation known
03155500	Hughes River at Cisco, WV	Paybins, 2008	39.172749	-81.025681	39.118690	-81.277339	453	21,549	Yes	No	No	Unregulated when gage was discontinued in 1994. Location in backwater from Hughes River Dam since 2002
03155520	Robinson Run near Petroleum,WV	Previously unpublished	39.229244	-81.224003	39.229244	-81.224003	0.07	839	Yes	No	No	No regulation known
03157000	Clear Creek near Rockbridge OH	Falcone and others, 2011	39.637095	-82.703784	39.588398	-82.578495	89	26,298	Yes	Yes	No	Included in state low-flow report
03158200	Monday Creek at Doanville OH	NHDPlus v.2	39.563489	-82.247264	39.435348	-82.191537	114	5,251	Yes	Yes	No	Included in state low-flow report
03159540	Shade River near Chester OH	Paybins, 2008	39.157574	-82.009644	39.063689	-81.881802	156	16,922	Yes	Yes	No	Included in state low-flow report
03164000	New River near Galax, VA	Krstolic, 2006	36.502605	-81.365686	36.647350	-80.978969	1,141	29,950	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03165000	Chestnut Creek at Galax, VA	Krstolic, 2006	36.606901	-80.881001	36.645961	-80.919244	39.4	24,471	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03167000	Reed Creek at Grahams Forge, VA	Krstolic, 2006	36.955170	-81.126672	36.939010	-80.887300	258	33,786	Yes	Yes	Yes	Occasional diurnal fluctuation at low flow caused by mills upstream
03170000	Little River at Graysontown, VA	Krstolic, 2006	36.960396	-80.360561	37.037626	-80.556724	309	30,315	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03173000	Walker Creek at Bane, VA	Paybins, 2008	37.157882	-80.950009	37.268178	-80.709513	299	26,846	Yes	Yes	No	Included in state low-flow study
03175500	Wolf Creek near Narrows, VA	Paybins, 2008	37.184083	-81.188812	37.305677	-80.849799	223	29,474	Yes	Yes	No	Included in state low-flow study
03177500	Indian Creek at Indian Mills, WV	Paybins, 2008	37.534454	-80.633171	37.532065	-80.819247	189	3,379	Yes	No	No	No regulation known
03177710	Bluestone River at Falls Mills, VA	Krstolic, 2006	37.228674	-81.321602	37.271506	-81.304823	44.3	8,618	Yes	Yes	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03178000	Bluestone River near Spanishburg, WV	NHDPlus v.2	37.309659	-81.258747	37.433451	-81.110926	199	3,652	Yes	No	No	No regulation known
03178500	Camp Creek near Camp Creek, WV	Paybins, 2008	37.539063	-81.159218	37.504284	-81.127595	32	9,219	Yes	No	No	No regulation known

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03179000	Bluestone River near Pipestem, WV	Paybins, 2008	37.390644	-81.195892	37.544008	-81.010368	395	22,711	Yes	Yes	No	No significant regulations or diversions are known.
03179500	Bluestone River at Lilly, WV	Paybins, 2008	37.413399	-81.176521	37.584841	-80.965089	438	9,709	Yes	No	No	No regulation known
03180300	East Fork Greenbrier River at Frank, WV	NHDPlus v.2	38.578315	-79.703470	38.542894	-79.806447	67.1	2,407	Yes	No	No	No regulation known
03180500	Greenbrier River at Durbin, WV	Paybins, 2008	38.606445	-79.741928	38.543727	-79.833115	133	25,020	Yes	No	No	Before 1994, some diversion for industrial use at tannery at Frank, although practically all the diverted flow was returned to the stream at the tannery.
03181200	Indian Draft near Marlinton, WV	NHDPlus v.2	38.299158	-80.074579	38.280119	-80.075065	3.06	3,398	Yes	No	No	No regulation known
03182000	Knapp Creek at Marlinton, WV	Paybins, 2008	38.194389	-79.948731	38.211232	-80.074787	108	4,748	Yes	No	No	No regulation known
03182500	Greenbrier River at Buckeye, WV	Paybins, 2008	38.387516	-79.884110	38.185953	-80.130623	540	30,316	Yes	Yes	Yes	No significant regulations or diversions are known.
03182650	Spring Creek at Spring Creek, WV	Previously unpublished	37.956787	-80.352297	37.956787	-80.352297	120	731	Yes	No	No	Regulation status unknown. Karst area. No drainage area reported from NWIS.
03182700	Anthony Creek near Anthony, WV	Paybins, 2008	37.974937	-80.127380	37.907621	-80.290627	144	4,018	Yes	No	No	No regulation known
03182950	Howard Creek at Caldwell, WV	NHDPlus v.2	37.781265	-80.296654	37.781788	-80.387295	84.4	2,557	Yes	No	No	No regulation known
03183000	Second Creek near Second Creek, WV	Paybins, 2008	37.617100	-80.400070	37.684845	-80.456737	80.8	10,957	Yes	No	No	No regulation known
03183500	Greenbrier River at Alderson, WV	Paybins, 2008	38.098797	-80.143120	37.724287	-80.641468	1,364	42,795	Yes	Yes	Yes	No significant regulations or diversions are known.
03184000	Greenbrier River at Hilldale, WV	Paybins, 2008	38.043968	-80.223053	37.640120	-80.805083	1,619	27,870	Yes	Yes	No	No significant regulations or diversions are known.
03184200	Big Creek near Bellepoint, WV	Paybins, 2008	37.699188	-80.805023	37.674564	-80.814251	8.27	3,075	Yes	No	No	No regulation known
03185000	Piney Creek at Raleigh, WV	Paybins, 2008	37.701202	-81.199143	37.760671	-81.162321	52.7	14,950	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03185500	New River at Caperton	Paybins, 2008	37.304138	-80.792557	38.022334	-81.028988	6826	10,896	No	No	No	Unregulated before 1939
03186500	Williams River at Dyer, WV	Paybins, 2008	38.326881	-80.280907	38.378999	-80.483974	128	29,965	Yes	Yes	Yes	No significant regulations or diversions are known.
03187000	Gauley River at Camden on Gauley, WV	Paybins, 2008	38.361675	-80.333633	38.365943	-80.600923	236	19,631	Yes	No	No	No significant regulations or diversions are known.

Table 1. Description of unregulated streamgages in and near West Virginia, 1930–2011, and their coordinates, drainage areas, sources of basin centroid, regulation status, and length of record.—Continued

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03187300	North Fork Cranberry River near Hillsboro, WV	Paybins, 2008	38.261929	-80.277649	38.258172	-80.323965	9.78	5,113	Yes	No	No	No regulation known
03187500	Cranberry River near Richwood, WV	Paybins, 2008	38.265854	-80.361038	38.295390	-80.526475	80.4	19,755	Yes	Yes	No	No significant regulations or diversions are known.
03189000	Cherry River at Fenwick, WV	Paybins, 2008	38.174084	-80.484024	38.229281	-80.583143	150	15,712	Yes	No	No	No regulation known
03189100	Gauley River near Craigsville, WV	Paybins, 2008	38.287506	-80.410309	38.290945	-80.640924	529	16,436	Yes	Yes	No	No significant regulations or diversions are known.
03189500	Gauley River near Summersville, WV	Paybins, 2008	38.297543	-80.481178	38.270943	-80.819264	680	16,344	No	No	No	Unregulated before 1965
03189650	Collison Creek near Nallen, WV	Paybins, 2008	38.171013	-80.846497	38.176500	-80.868430	2.78	4,018	Yes	No	No	No regulation known
03189890	Meadow River at McRoss, WV	NHDPlus v.2	37.968150	-80.649031	37.993728	-80.747868	163	1,096	Yes	No	No	No regulation known
03190000	Meadow River at Nallen, WV	Paybins, 2008	37.984402	-80.720085	38.112613	-80.876207	287	18,474	Yes	No	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03190400	Meadow River near Mt. Lookout, WV	Paybins, 2008	38.014011	-80.754295	38.189832	-80.946766	365	16,101	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03191500	Peters Creek near Lockwood, WV	Paybins, 2008	38.290871	-80.935158	38.262607	-81.023158	40.2	14,828	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03192000	Gauley River above Belva, WV	Paybins, 2008	38.201698	-80.639442	38.233440	-81.180942	1,317	30,662	No	No	No	Regulated by Summersville Dam since May 1965.
03193000	Kanawha River at Kanawha Falls, WV	Paybins, 2008	37.471077	-80.776985	38.138163	-81.214275	8,371	22,462	No	No	No	Regulation from Claytor reservoir since 1939 and from Bluestone Dam since 1949, and Summersville Dam since 1965.
03193778	Little Creek near Chelyan, WV	NHDPlus v.2	38.176559	-81.525194	38.182603	-81.512339	1.44	867	Yes	No	No	Regulation status unknown
03193830	Gilmer Run near Marlinton, WV	Paybins, 2008	38.313438	-80.094467	38.320118	-80.097567	1.8	3,398	Yes	No	No	No regulation known
03194500	Elk River below Back Fork at Webster Springs, WV	NHDPlus v.2	38.487930	-80.190622	38.480664	-80.420638	242	1,918	Yes	No	No	No regulation known
03194700	Elk River below Webster Springs, WV	Paybins, 2008	38.489712	-80.217758	38.597326	-80.490364	266	18,628	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03195000	Elk River at Centralia, WV	Paybins, 2008	38.495190	-80.232414	38.616770	-80.555367	281	10,592	Yes	No	No	No regulation known

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03195100	Right Fork Holly River at Guardian, WV	Paybins, 2008	38.565521	-80.407204	38.635381	-80.465919	51.9	2,405	Yes	No	No	No regulation known
03195250	Left Fork Holly River near Replete, WV	Paybins, 2008	38.646351	-80.339279	38.688714	-80.432307	46.5	2,405	Yes	No	No	No regulation known
03195500	Elk River at Sutton, WV	Paybins, 2008	38.545692	-80.356041	38.663156	-80.709541	542	19,724	No	No	No	Flow regulated since October 1960 by Sutton Lake
03195600	Granny Creek at Sutton, WV	Paybins, 2008	38.693977	-80.684532	38.676766	-80.712875	6.39	3,775	Yes	No	No	No regulation known
03196500	Birch River at Herold, WV	NHDPlus v.2	38.512580	-80.699053	38.574823	-80.800933	124	3,157	Yes	No	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03196750	Buffalo Creek at Clay, WV	NHDPlus v.2	38.433782	-80.938035	38.454546	-81.066774	114	595	Yes	No	No	No regulation known. Basin is heavily mined.
03196800	Elk River at Clay, WV	Falcone and others, 2011	38.537207	-80.580622	38.460657	-81.087609	992	7,305	No	No	No	Flow regulated since October 1960 by Sutton Reservoir
03197000	Elk River at Queen Shoals, WV	Paybins, 2008	38.521927	-80.658417	38.470932	-81.284006	1,145	30,681	No	No	No	Flow regulated since October 1960 by Sutton Lake. Flows were affected by dam construction during the 1959–60 water years and were not used for any statistical calculations.
03197790	Little Sandy Creek near Elkview,WV	NHDPlus v.2	38.512090	-81.467641	38.455930	-81.500123	43.6	913	Yes	No	No	No regulation known
03198020	Trace Fork at Ruth, WV	NHDPlus v.2	38.287693	-81.728938	38.307319	-81.727069	2.73	1,553	Yes	No	No	Unregulated
03198022	Trace Fork downstream Dryden Hollow at Ruth, WV	NHDPlus v.2	38.295894	-81.733409	38.315374	-81.728181	4.72	1,553	Yes	No	No	Regulation status unknown
03198350	Clear Fork at Whitesville, WV	Paybins, 2008	37.923298	-81.381531	37.966219	-81.524278	62.8	4,748	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03198450	Drawdy Creek near Peytona, WV	Paybins, 2008	38.103214	-81.714844	38.124824	-81.692342	7.75	3,287	Yes	No	No	No regulation known. Basin is heavily mined.
03198500	Big Coal River at Ashford, WV	Paybins, 2008	37.943481	-81.493591	38.179822	-81.711511	391	33,112	Yes	Yes	Yes	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03198550	Big Coal River near Alum Creek,	NHDPlus v.2	37.976122	-81.522427	38.250097	-81.798181	445	2,830	Yes	No	No	No regulation known. Basin is heavily mined.
03198690	Spruce Fork at Sharples, WV	NHDPlus v.2	37.870000	-81.812000	37.924167	-81.828333	44.1	731	Yes	No	No	No regulation known. Basin is heavily mined.
03199000	Little Coal River at Danville, WV	Paybins, 2008	37.920067	-81.734444	38.079823	-81.836235	269	19,846	Yes	No	No	No regulation known. Basin is heavily mined.

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi^2)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03199300	Rock Creek near Danville, WV	Paybins, 2008	38.090248	-81.776558	38.100100	-81.829846	12.2	2,124	Yes	No	No	No regulation known. Basin is heavily mined.
03199400	Little Coal River at Julian, WV	Paybins, 2008	37.946350	-81.749428	38.154821	-81.852348	318	3,653	Yes	No	No	No regulation known. Basin is heavily mined.
03199700	Coal River at Alum Creek, WV	NHDPlus v.2	37.983699	-81.638851	38.286763	-81.806516	837	2,192	Yes	No	No	No regulation known. Basin is heavily mined.
03200500	Coal River at Tornado, WV	Paybins, 2008	37.991364	-81.643951	38.338983	-81.841518	862	20,920	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03201000	Pocatalico River at Sissonville, WV	Paybins, 2008	38.628845	-81.496521	38.526204	-81.631238	238	19,718	Yes	No	No	No regulation known
03201405	Hurricane Creek at Hurricane, WV	Paybins, 2008	38.416397	-81.978943	38.445367	-82.006803	26.8	5,114	Yes	Yes	No	No significant regulations or diversions are known.
03201410	Poplar Fork at Teays, WV	Paybins, 2008	38.436604	-81.922829	38.450646	-81.931523	8.47	4,266	Yes	No	No	No regulation known
03201902	Raccoon Creek near Bolins Mills OH	NHDPlus v.2	39.343594	-82.365440	39.230556	-82.285833	205	3,577	Yes	Yes	No	Included in state low-flow report
03201980	Little Raccoon Creek near Ewington OH	NHDPlus v.2	39.132297	-82.507334	39.010630	-82.452102	99.7	5,047	Yes	Yes	No	Included in state low-flow report
03202000	Raccoon Creek at Adamsville OH	Paybins, 2008	39.179279	-82.402451	38.875556	-82.356111	585	32,141	Yes	Yes	No	Included in state low-flow report
03202240	Allen Creek at Allen Junction, WV	NHDPlus v.2	37.635755	-81.342084	37.592614	-81.346491	8.43	789	Yes	No	No	No regulation known
03202245	Marsh Fork at Maben, WV	Paybins, 2008	37.660961	-81.420830	37.638725	-81.393714	4.85	1,063	Yes	No	No	No regulation known. Basin is heavily mined.
03202255	Still Run at Itmann, WV	NHDPlus v.2	37.610223	-81.415429	37.580947	-81.428159	7.12	790	Yes	No	No	Regulation status unknown
03202260	Black Fork above Black Fork Falls near Mullens, WV	NHDPlus v.2	37.633721	-81.436250	37.619002	-81.448993	2.68	792	Yes	No	No	No regulation known
03202262	Black Fork at Mouth near Mullens, WV	NHDPlus v.2	37.633301	-81.436594	37.625113	-81.453159	2.76	792	Yes	No	No	No regulation known
03202310	Bearhole Fork at Pineville, WV	NHDPlus v.2	37.608810	-81.493125	37.587891	-81.519827	6.27	771	Yes	No	No	No regulation known. Apparently unmined during POR.
03202400	Guyandotte River near Baileysville, WV	Paybins, 2008	37.584251	-81.380341	37.604000	-81.645110	306	16,163	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03202480	Brier Creek at Fanrock, WV	Paybins, 2008	37.536732	-81.643974	37.563445	-81.652332	7.34	2,991	Yes	No	No	No regulation known. Basin was apparently not heavily mined during POR.
03202490	Indian Creek at Fanrock, WV	NHDPlus v.2	37.524693	-81.575545	37.567056	-81.652054	41.3	2,652	Yes	No	No	No regulation known. Basin was apparently not heavily mined during POR.
03202695	Milam Fork at McGraws, WV	NHDPlus v.2	37.682514	-81.450170	37.680113	-81.473994	6.64	788	Yes	No	No	No regulation known. Basin is heavily mined.

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03202750	Clear Fork at Clear Fork, WV	Paybins, 2008	37.700378	-81.553146	37.623166	-81.707334	126	13,975	Yes	Yes	No	Gage site is at the upper limit of maximum pool elevation, 1,155 ft for R. D. Bailey Lake. Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03202900	Guyandotte River near Justice, WV	NHDPlus v.2	37.608882	-81.462268	37.607054	-81.790115	512	2,192	Yes	No	No	No regulation known. Basin is heavily mined.
03203000	Guyandotte River at Man, WV	Paybins, 2008	37.630974	-81.568901	37.740385	-81.876786	758	12,326	No	No	No	Flow regulated upstream since February 1980 by R.D. Bailey Dam at mile 112.
03203600	Guyandotte River at Logan, WV	Paybins, 2008	37.646629	-81.599373	37.842326	-81.975957	833	18,263	No	No	No	Flow regulated since February 1980 by R.D. Bailey Lake at mile 111.6, drainage area 535 mi², as well as active pumping and passive drainage from coal mines.
03203670	Whitman Creek at Whitman, WV	NHDPlus v.2	37.786149	-82.047807	37.807882	-82.028182	10.9	3,083	Yes	No	No	Regulation status unknown
03204000	Guyandotte River at Branchland, WV	Paybins, 2008	37.748753	-81.753143	38.220923	-82.202642	1224	25,020	No	No	No	Flow regulated since February 1980 by R.D. Bailey Dam, as well as active pumping and passive drainage from coal mines.
03204205	Unnamed Tributary To Ballard Fork near Mud, WV	Previously unpublished	38.071000	-81.914000	38.069167	-81.920000	0.19	1,425	Yes	No	No	Treatment site in MTR study
03204210	Spring Branch near Mud, WV	Previously unpublished	38.061000	-81.927000	38.067778	-81.937778	0.53	1,425	Yes	No	No	Unregulated
03204215	Ballard Fork near Mud, WV	NHDPlus v.2	38.068000	-81.924000	38.068889	-81.942222	2.12	1,425	Yes	No	No	Partial treatment site in MTR study
03204220	Mud River at Mud, WV	NHDPlus v.2	38.068000	-81.945000	38.094444	-81.978333	17	681	Yes	No	No	Basin was heavily mined throughout POR.
03204500	Mud River near Milton, WV	Paybins, 2008	38.241940	-82.023117	38.388422	-82.113196	256	15,555	Yes	No	No	Unregulated before 1995.
03205470	Symmes Creek at Aid, OH	NHDPlus v.2	38.780323	-82.502653	38.596191	-82.495157	302	3,986	Yes	Yes	No	Included in state low-flow report
03206500	Fourpole Creek at Huntington, WV	NHDPlus v.2	38.382210	-82.419088	38.404249	-82.479044	21.5	3,136	Yes	No	No	No regulation known
03206600	East Fork Twelvepole Creek near Dunlow, WV	Paybins, 2008	37.953064	-82.242584	38.017316	-82.295977	38.5	17,532	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03206800	East Fork Twelvepole C near E Lynn, WV	Paybins, 2008	38.035709	-82.287094	38.154255	-82.384594	139	1,918	Yes	No	No	Unregulated before 1972
03206980	West Fork Twelvepole Creek above Wayne at Echo, WV	NHDPlus v.2	38.006233	-82.366765	38.181198	-82.475709	108	691	Yes	No	No	Regulation status unknown
03207000	Twelvepole Creek at Wayne, WV	Paybins, 2008	38.045918	-82.334656	38.218141	-82.448486	291	9,496	Yes	No	No	Unregulated before 1972

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03207800	Levisa Fork at Big Rock, VA	Paybins, 2008	37.250591	-81.999910	37.353720	-82.195694	297	16,071	Yes	Yes	No	Included in state low-flow study
03207915	Elkfoot Branch Levisa Fork near High, KY	NHDPlus v.2	37.398544	-82.281495	37.397885	-82.284031	0.7	1,461	Yes	No	No	Used in low-flow report
03207962	Dicks Fork at Phyllis, KY	Paybins, 2008	37.458391	-82.337720	37.449271	-82.337644	0.82	3,299	No	No	No	Unregulated before 1984
03208500	Russell Fork at Haysi, VA	Paybins, 2008	37.104766	-82.252642	37.207054	-82.295699	286	31,122	Yes	Yes	Yes	Included in state low-flow study
03208950	Cranes Nest River near Clintwood, VA	Paybins, 2008	37.053314	-82.503258	37.123995	-82.438761	66.5	17,532	Yes	Yes	No	Included in state low-flow study
03209440	Shelby Creek at Dorton, KY	NHDPlus v.2	37.257969	-82.564409	37.277328	-82.578766	12.6	1,840	Yes	No	No	Used in low-flow report
03210000	Johns Creek near Meta, KY	Paybins, 2008	37.518166	-82.344116	37.567044	-82.457927	56.3	25,385	Yes	Yes	No	Included in state low-flow report
03212000	Paint Creek at Staffordsville, KY	Paybins, 2008	37.872796	-82.979935	37.834815	-82.870719	103	9,314	No	No	No	Unregulated before 1975
03212558	Puncheoncamp Branch at Leckie, WV	NHDPlus v.2	37.351408	-81.396898	37.343727	-81.411492	1.36	784	Yes	No	No	Regulation status unknown
03212567	Freeman Branch near Skygusty, WV	Previously unpublished	37.274560	-81.487328	37.274560	-81.487328	0.3	766	Yes	No	No	Regulation status unknown
03212580	Left Fork Sandlick Creek at Elbert, WV	Previously unpublished	37.335670	-81.577329	37.335670	-81.577329	1.78	793	Yes	No	No	Regulation status unknown
03212585	Right Fork Sandlick Creek near Gary, WV	NHDPlus v.2	37.340984	-81.578291	37.347614	-81.566773	1.21	792	Yes	No	No	Regulation status unknown
03212600	Tug Fork at Welch, WV	NHDPlus v.2	37.340998	-81.494955	37.417058	-81.590107	85.9	988	Yes	No	No	Basin was heavily mined throughout POR.
03212640	Johns Knob Branch at Elkhorn, WV	NHDPlus v.2	37.389000	-81.385000	37.385072	-81.397028	0.815	603	Yes	No	No	Gage for special study, receives large interbasin transfer
03212700	Elkhorn Creek at Maitland, WV	NHDPlus v.2	37.414928	-81.425270	37.429836	-81.552050	69.9	703	Yes	No	No	Regulation status unknown
03212703	Elkhorn Creek Tributary at Welch, WV	Previously unpublished	37.429558	-81.567051	37.429558	-81.567051	0.63	794	Yes	No	No	Regulation status unknown
03212750	Tug Fork downstream of Elkhorn Creek at Welch, WV	Paybins, 2008	37.380306	-81.474060	37.441224	-81.599830	174	9,011	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.

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Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03212980	Dry Fork at Beartown, WV	Paybins, 2008	37.270306	-81.664856	37.395390	-81.802614	209	8,998	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03212985	Dry Fork at Avondale, WV	NHDPlus v.2	37.279064	-81.671545	37.425667	-81.789558	225	986	Yes	No	No	Basin was heavily mined throughout POR.
03213000	Tug Fork at Litwar, WV	Paybins, 2008	37.350166	-81.608643	37.485667	-81.843727	504	19,846	Yes	No	No	Basin was heavily mined throughout POR.
03213495	Crane Creek near Panther, WV	NHDPlus v.2	37.418998	-81.852493	37.424556	-81.860673	0.54	735	Yes	No	No	Regulation status unknown
03213500	Panther Creek near Panther, WV	Paybins, 2008	37.387280	-81.877876	37.445556	-81.871111	31	17,934	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03213620	Tug Fork at Vulcan, W. Va.	NHDPlus v.2	37.391581	-81.739813	37.551773	-82.124298	778	3,158	Yes	No	No	Basin was heavily mined throughout POR.
03213700	Tug Fork at Williamson, WV	Paybins, 2008	37.422783	-81.816849	37.673157	-82.280141	936	16,437	Yes	Yes	No	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03213800	Pigeon Creek near Lenore, WV	NHDPlus v.2	37.720607	-82.141415	37.787044	-82.262085	93.9	1,077	Yes	No	No	Regulation status unknown
03214000	Tug Fork near Kermit, WV	Paybins, 2008	37.487011	-81.907341	37.817597	-82.388757	1,188	18,689	Yes	No	No[1]	Basin was heavily mined throughout POR.
03214500	Tug Fork at Kermit, WV	Paybins, 2008	37.505245	-81.947159	37.837319	-82.408758	1,280	13,049	Yes	Yes	No[1]	Flows may be affected by passive drainage or active pumping from coal mines. The extent of any flow alteration is unknown.
03214900	Tug Fork at Glenhayes, WV	Paybins, 2008	37.560638	-82.029366	38.005647	-82.514597	1,507	3,121	Yes	No	No	Basin was heavily mined throughout POR.
03215500	Blaine Creek at Yatesville, KY	Paybins, 2008	38.030388	-82.829533	38.144531	-82.684603	217	14,793	No	No	No	Unregulated before 1975
03216400	Little Sandy River at Leon, KY	NHDPlus v.2	38.160196	-83.108666	38.286470	-82.977392	255	6,575	No	No	No	Unregulated before 1967
03216540	East Fork Little Sandy River near Fallsburg, KY	Paybins, 2008	38.223260	-82.769114	38.233695	-82.708772	12.2	6,976	Yes	No	No	Used in low-flow report
03217000	Tygarts Creek near Greenup, KY	Falcone and others, 2011	38.393310	-83.139458	38.564245	-82.952116	242	25,989	Yes	Yes	No	Included in state low-flow report
03237255	Kinniconick Creek below Trace Creek at Tannery, KY	NHDPlus v.2	38.540469	-83.226433	38.545278	-83.221389	214	3,950	Yes	Yes	No	Included in state low-flow report
03248300	Licking River below Mason Fork near Salyersville, KY	NHDPlus v.2	37.614713	-82.987039	37.730648	-83.057948	107	3,075	Yes	Yes	No	Included in state low-flow report
03249000	Licking River at Yale, KY	NHDPlus v.2	37.849448	-83.211012	38.048694	-83.491574	714	1,461	Yes	No	No	Used in low-flow report, unregulated for POR

Table 1. Description of unregulated streamgages in and near West Virginia, 1930–2011, and their coordinates, drainage areas, sources of basin centroid, regulation status, and length of record.—Continued

[dd, decimal degrees; mi², square miles; ft³/s, cubic feet per second; ADR, Annual Water-Data Report; GW, groundwater; MTR, mountaintop removal; NWIS-Web, National Water Information System, web interface; POR, period of record; WWTP, wastewater-treatment plant]

Streamgage number	Streamgage name	Source of basin centroid	Centroid latitude (dd)	Centroid longitude (dd)	Streamgage latitude (dd)	Streamgage longitude (dd)	Drainage area (mi²)	Days of streamflow record	Was complete period of record unregulated?	Was the site active and unregulated on 9/30/11?	Included in analyses of nearly continuous record?	Regulation status or source used to justify an assumption of regulation status
03250100	North Fork Triplett Creek near Morehead, KY	Falcone and others, 2011	38.293467	-83.437845	38.199248	-83.480464	84.7	9,170	Yes	No	No	Included in state low-flow report
03277300	North Fork Kentucky River at Whitesburg, KY	NHDPlus v.2	37.169690	-82.736430	37.117598	-82.824604	66.4	4,748	Yes	Yes	No	Included in state low-flow report
03488000	North Fork Holston River near Saltville, VA	Krstolic, 2006	36.971806	-81.528034	36.896781	-81.746229	221	33,817	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03524000	Clinch River at Cleveland, VA	Krstolic, 2006	37.043419	-81.819529	36.944830	-82.154857	533	33,237	Yes	Yes	Yes	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.
03524500	Guest River at Coeburn, VA	Krstolic, 2006	36.963688	-82.555362	36.929269	-82.456262	87.2	4,748	Yes	No	No	ADR or NWIS-Web does not mention regulation for this site, while regulated sites have detailed remarks.

[1]Records from Tug Fork near Kermit, WV, (03214000) and Tug Fork at Kermit, WV, (03214500) were combined for some analyses using a procedure described by Wiley (2006).

Table 5. Number of days exceeding the annual 75-percent flow duration for 15 selected streamgages in West Virginia, 1930–2011, and their average as a proportion.

[Average is for full years only. NO, not operated during that water year; PR, operated for part of the year. Flow duration values from Wiley, 2006]

Water year	Streamgage															Average
	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1930	243	242	254	248	233	228	NO	233	213	274	235	239	229	PR	228	238
1931	232	236	208	169	226	225	NO	228	229	245	261	244	268	184	172	223
1932	223	224	199	166	225	214	PR	229	237	273	225	233	263	243	228	227
1933	326	317	321	351	297	291	274	309	301	255	305	311	299	241	213	294
1934	223	218	193	184	248	245	197	255	226	213	216	214	238	218	183	218
1935	329	321	275	330	294	288	246	315	306	295	325	327	316	298	293	304
1936	267	266	260	305	249	229	212	233	246	242	257	251	199	203	214	242
1937	294	294	278	321	273	278	251	278	287	307	306	288	287	271	250	284
1938	329	327	297	329	309	306	261	310	302	318	323	325	278	312	325	310
1939	291	284	266	274	257	232	225	267	281	253	272	272	238	236	274	261
1940	254	265	295	295	249	254	245	273	259	266	254	242	226	209	214	253
1941	294	301	300	300	263	273	268	295	290	295	280	273	244	203	175	270
1942	266	256	223	218	301	302	296	296	298	307	284	278	274	268	231	273
1943	311	311	265	319	312	324	323	295	307	279	319	318	305	280	279	303
1944	195	189	206	170	230	236	219	210	222	236	215	209	221	190	175	208
1945	319	310	297	337	313	310	288	322	330	316	293	279	294	259	274	303
1946	273	280	303	313	277	273	264	278	275	272	271	265	258	239	256	273
1947	233	213	244	209	250	266	280	233	247	271	229	231	260	235	225	242
1948	310	314	246	307	282	297	288	278	279	300	329	331	309	247	240	290
1949	362	359	349	365	274	266	254	290	294	246	332	331	306	243	243	301
1950	317	305	303	323	322	324	270	303	310	303	316	329	341	331	328	315
1951	312	315	305	323	279	283	267	279	287	286	295	294	292	297	315	295
1952	253	257	266	303	225	237	246	214	226	237	232	243	229	277	279	248
1953	230	235	231	269	220	212	193	214	218	185	220	223	211	237	239	222
1954	208	209	191	190	258	262	217	258	267	221	263	260	261	215	215	233
1955	301	309	324	318	274	262	273	278	281	277	272	267	250	280	237	280
1956	248	253	220	202	290	311	305	286	281	326	257	245	268	209	220	261
1957	257	240	229	263	247	263	235	251	257	241	282	297	274	222	261	255
1958	283	287	278	305	310	321	318	293	299	308	318	329	299	301	321	305
1959	177	178	180	177	232	258	271	214	232	243	205	204	231	188	201	213
1960	283	280	322	320	270	270	251	279	292	253	287	288	293	267	273	282
1961	235	232	224	198	301	313	282	278	300	274	284	272	295	263	266	268
1962	268	270	240	278	253	259	255	252	268	222	255	262	253	285	281	260
1963	246	241	239	205	277	304	238	298	297	265	238	236	280	270	261	260
1964	208	205	217	190	218	207	189	220	232	222	196	194	213	180	197	206
1965	214	220	225	211	209	200	198	209	211	207	223	226	221	240	262	218
1966	159	158	149	127	188	167	162	191	195	218	251	208	270	160	189	186
1967	312	321	331	287	290	267	196	314	304	230	308	303	276	321	329	293
1968	254	250	281	284	258	247	253	245	248	263	273	288	268	297	294	267
1969	262	267	219	255	266	280	247	257	253	260	284	286	293	312	232	265
1970	230	264	289	312	269	276	245	289	273	270	230	234	279	227	225	261
1971	288	297	312	325	291	285	311	285	287	313	288	294	293	307	327	300
1972	343	339	349	366	312	296	316	306	306	285	316	325	312	346	366	326
1973	311	329	362	355	318	294	307	309	301	282	297	329	308	323	337	317
1974	340	337	315	303	297	304	329	316	307	319	303	319	299	339	339	318
1975	322	318	326	309	280	276	340	300	301	324	293	307	283	315	333	308
1976	308	298	308	292	253	262	318	275	255	324	284	300	281	273	299	289
1977	248	227	247	226	308	303	348	263	263	302	289	292	315	307	361	287
1978	318	319	345	327	322	326	353	312	302	347	326	320	309	319	346	326
1979	304	311	334	303	307	300	342	308	300	299	304	301	310	308	311	309

Table 5. Number of days exceeding the annual 75-percent flow duration for 15 selected streamgages in West Virginia, 1930–2011, and their average as a proportion.—Continued

[Average is for full years only. NO, not operated during that water year; PR, operated for part of the year. Flow duration values from Wiley, 2006]

Water year	Streamgage															Average
	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1980	329	334	325	314	336	319	363	335	322	327	300	308	309	358	361	329
1981	235	257	225	157	294	301	288	288	264	297	238	232	276	285	291	262
1982	293	288	264	259	307	311	284	309	305	284	295	287	294	286	282	290
1983	257	253	232	253	281	280	244	267	263	254	280	278	280	287	298	267
1984	309	324	320	334	292	287	309	287	288	295	304	300	293	306	300	303
1985	308	312	275	263	280	280	283	308	287	303	288	298	278	287	293	290
1986	279	283	253	237	286	277	242	292	308	266	289	272	315	308	310	281
1987	282	269	259	253	279	273	294	281	291	300	266	263	301	295	282	279
1988	246	248	250	254	247	242	219	260	258	260	229	221	236	225	177	238
1989	313	307	294	240	326	322	339	345	337	322	323	318	331	326	319	317
1990	305	305	322	315	323	329	350	317	311	339	307	308	304	319	332	319
1991	255	255	261	294	247	235	243	232	258	242	251	253	241	268	294	255
1992	274	262	287	243	277	317	254	257	270	290	265	261	277	316	301	277
1993	220	211	274	302	204	216	242	209	204	242	230	222	232	282	264	237
1994	307	312	307	319	319	321	321	319	316	292	297	293	309	343	337	314
1995	264	271	271	290	227	210	251	249	232	240	226	227	223	240	251	245
1996	342	342	NO	358	320	311	334	342	336	311	335	335	320	336	334	333
1997	297	303	302	329	293	297	311	292	294	286	288	292	283	338	332	302
1998	276	291	291	304	286	281	256	285	285	275	271	276	264	289	274	280
1999	161	177	177	179	186	179	165	169	184	184	173	168	173	193	201	178
2000	306	331	328	338	315	323	278	321	326	278	328	323	344	323	309	318
2001	277	288	301	263	283	287	332	306	284	268	287	285	248	303	267	285
2002	190	181	182	91	225	224	246	225	219	238	222	215	222	238	237	210
2003	356	357	357	353	341	343	343	347	331	336	342	355	332	354	346	346
2004	334	338	354	349	324	341	359	331	328	340	324	318	289	366	366	337
2005	336	335	314	331	276	276	284	291	287	278	314	325	294	341	347	309
2006	280	297	293	317	285	286	287	291	292	269	266	263	298	317	319	291
2007	278	288	291	295	308	292	299	327	321	276	304	290	305	294	314	299
2008	277	291	261	225	276	266	299	290	281	290	255	244	249	293	272	271
2009	236	233	263	214	248	252	253	261	250	248	242	254	247	317	307	255
2010	248	243	238	233	289	288	263	255	264	270	269	264	281	353	339	273
2011	245	261	238	275	294	315	310	320	307	303	253	225	267	311	312	282
Annual summary, water years 1930–2011:																
Maximum	362	359	362	366	341	343	363	347	337	347	342	355	344	366	366	346
25th percentile	310	312	307	319	301	303	309	306	301	300	304	307	299	315	319	303
Median	278	284	275	294	279	280	271	285	285	275	284	278	280	286	279	280
75th percentile	246	243	239	233	249	254	245	255	255	248	251	244	249	240	237	255
Minimum	159	158	149	91	186	167	162	169	184	184	173	168	173	160	172	178

Table 6. Number of days exceeding the relevant seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, by season, water years 1930–2011, and their average as a proportion.

[Average is for full years only. NO, not operated during that season; PR, operated for part of the season; fall, October 1–December 31; winter, January 1–March 31; spring, April 1–June 30; summer, July 1–September 30. Flow duration values from Wiley, 2006]

Water year	Season	Streamgage															Average
		01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1930	Fall	91	91	91	92	88	89	NO	91	88	91	91	92	88	NO	91	90
	Winter	65	66	58	72	67	65	NO	66	56	72	58	55	87	NO	62	65
	Spring	30	30	33	24	39	35	NO	33	32	67	36	31	33	PR	28	35
	Summer	0	2	9	7	2	4	NO	7	3	27	2	0	10	3	3	6
1931	Fall	11	8	10	4	10	6	NO	17	14	11	12	10	22	0	11	10
	Winter	37	33	5	4	52	52	NO	56	51	44	46	38	62	36	22	38
	Spring	86	85	71	70	82	79	NO	80	85	74	87	84	87	67	64	79
	Summer	90	92	80	79	88	92	NO	74	92	92	92	92	92	65	55	84
1932	Fall	32	26	17	2	44	42	NO	55	59	89	42	40	66	39	29	42
	Winter	63	59	45	39	70	68	NO	71	68	67	75	74	79	74	70	66
	Spring	66	64	65	64	55	54	NO	55	56	53	57	64	61	80	67	62
	Summer	44	40	22	26	52	58	PR	50	54	56	56	59	71	53	37	48
1933	Fall	80	78	81	82	77	71	57	72	76	58	80	79	78	82	51	73
	Winter	79	79	83	90	81	79	70	70	79	80	83	83	86	81	77	80
	Spring	70	72	76	77	78	72	76	73	75	73	69	71	72	59	67	72
	Summer	92	91	92	92	92	92	73	92	91	77	86	89	91	45	28	82
1934	Fall	75	79	78	63	61	72	57	76	65	56	46	44	56	41	23	59
	Winter	45	43	32	28	71	56	48	58	55	54	43	42	48	40	38	47
	Spring	45	42	55	53	62	55	30	43	48	37	45	40	49	47	43	46
	Summer	38	34	48	62	50	56	33	73	64	48	32	53	66	60	66	52
1935	Fall	76	71	54	85	64	65	45	73	71	64	74	82	76	74	85	71
	Winter	86	81	69	89	81	75	65	71	75	79	85	86	80	59	80	77
	Spring	78	78	73	81	73	79	78	79	80	73	78	78	85	84	88	79
	Summer	92	92	82	91	90	81	60	92	86	89	92	92	86	70	61	84
1936	Fall	91	87	63	90	72	70	58	72	71	55	68	66	58	59	57	69
	Winter	83	89	90	89	69	75	80	71	70	71	88	77	81	59	72	78
	Spring	57	49	60	67	56	34	42	37	37	46	53	44	33	25	40	45
	Summer	63	56	40	81	54	45	27	56	60	74	67	66	25	29	35	52
1937	Fall	78	77	55	90	76	67	46	71	74	77	84	85	78	51	52	71
	Winter	90	90	90	90	80	77	67	77	81	78	87	88	83	84	86	83
	Spring	69	72	63	91	78	86	90	85	83	74	72	65	58	58	54	73
	Summer	80	85	88	92	76	79	53	61	69	82	83	85	88	77	63	77
1938	Fall	90	92	92	92	89	89	80	82	81	88	90	89	84	77	88	87
	Winter	75	71	39	84	75	72	82	68	74	74	63	68	75	71	69	71
	Spring	75	73	69	63	77	80	60	85	81	67	68	72	66	71	77	72
	Summer	82	81	61	88	69	66	35	81	74	81	78	88	77	83	83	75
1939	Fall	57	58	44	65	55	51	31	53	56	49	55	58	59	56	59	54
	Winter	74	74	67	67	60	68	67	69	68	67	70	67	68	69	71	68
	Spring	72	70	68	59	65	44	63	54	68	62	66	63	47	44	52	60
	Summer	82	82	81	80	63	53	54	80	68	54	72	73	56	38	57	66
1940	Fall	71	76	74	72	45	40	42	67	53	62	44	23	17	0	5	46
	Winter	51	49	56	51	47	48	51	54	54	57	37	34	49	19	16	45
	Spring	86	86	85	91	91	91	82	80	89	89	90	85	85	79	59	85
	Summer	92	92	82	92	66	61	69	76	70	65	90	92	84	80	84	80
1941	Fall	92	92	92	92	76	75	63	86	79	66	73	70	60	31	19	71
	Winter	47	49	64	71	49	52	40	49	49	62	57	56	50	24	14	49
	Spring	39	38	38	36	43	49	49	46	50	56	42	38	41	40	33	43
	Summer	72	74	71	69	65	62	73	80	76	90	73	70	65	61	48	70
1942	Fall	38	31	18	17	51	56	68	64	52	80	48	49	52	31	38	46
	Winter	41	36	25	25	47	50	56	51	50	55	57	52	56	32	25	44
	Spring	60	58	57	58	67	60	60	55	64	65	67	69	66	41	31	59
	Summer	89	87	79	86	92	92	91	92	92	91	84	92	92	92	84	89
1943	Fall	92	92	88	92	92	92	92	92	92	91	92	92	91	92	92	92
	Winter	88	88	90	90	79	81	77	86	82	79	81	77	80	85	76	83
	Spring	77	77	72	87	63	69	77	68	64	72	72	72	64	66	60	71
	Summer	71	72	40	68	77	77	74	69	73	68	73	71	76	23	28	64

Table 6. Number of days exceeding the relevant seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, by season, water years 1930–2011, and their average as a proportion.—Continued

[Average is for full years only. NO, not operated during that season; PR, operated for part of the season; fall, October 1–December 31; winter, January 1–March 31; spring, April 1–June 30; summer, July 1–September 30. Flow duration values from Wiley, 2006]

Water year	Season	Streamgage															Average
		01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1944	Fall	27	26	46	25	56	56	53	33	38	55	50	52	62	17	19	41
	Winter	50	47	55	40	66	65	51	67	66	61	55	55	60	57	50	56
	Spring	73	70	65	67	85	90	72	86	83	80	69	68	64	61	67	73
	Summer	56	52	24	39	32	28	51	40	41	58	46	28	4	18	12	35
1945	Fall	92	92	75	92	87	91	91	92	92	90	77	63	63	50	55	80
	Winter	77	81	86	78	77	77	75	67	80	73	70	72	71	77	73	76
	Spring	72	66	65	55	84	79	72	81	86	78	79	79	81	84	87	77
	Summer	91	89	92	89	84	87	64	92	86	87	87	90	85	71	68	84
1946	Fall	89	92	92	92	77	80	77	78	79	92	75	75	70	78	71	81
	Winter	83	82	88	90	72	70	67	71	76	68	81	81	77	79	88	78
	Spring	77	77	79	82	81	84	82	73	74	76	70	70	70	63	75	76
	Summer	44	45	59	74	44	21	46	44	39	20	42	39	32	17	41	40
1947	Fall	16	17	38	32	33	37	53	23	28	33	23	20	41	21	37	30
	Winter	45	42	43	44	56	62	68	60	50	55	54	55	51	52	58	53
	Spring	73	72	52	48	74	71	72	70	75	70	81	66	79	65	44	67
	Summer	79	72	73	57	88	89	87	72	88	92	90	88	79	79	70	80
1948	Fall	63	61	48	73	55	53	66	59	55	61	69	77	61	57	59	61
	Winter	53	53	53	47	63	65	62	63	63	62	56	55	59	55	51	57
	Spring	70	72	63	79	76	81	71	84	83	84	80	74	82	55	57	74
	Summer	92	92	80	92	92	92	76	83	90	87	92	92	92	61	61	85
1949	Fall	92	92	88	92	92	77	65	88	89	84	92	92	92	61	56	83
	Winter	90	90	90	90	86	86	88	81	90	90	88	87	85	87	84	87
	Spring	76	76	76	79	51	53	50	55	56	50	73	70	66	66	60	64
	Summer	92	92	92	92	83	88	70	77	86	50	92	90	90	60	57	81
1950	Fall	92	92	92	92	78	83	59	70	71	61	78	79	92	80	80	80
	Winter	86	83	73	64	88	90	85	88	90	90	82	88	90	89	80	84
	Spring	79	82	79	79	91	91	75	85	88	91	87	91	91	91	91	86
	Summer	87	86	73	90	92	90	90	76	89	91	92	92	92	92	92	88
1951	Fall	92	92	92	92	85	85	89	89	87	90	92	92	90	92	92	90
	Winter	87	87	90	90	85	87	88	82	85	86	85	85	84	76	72	85
	Spring	90	89	86	89	86	83	77	79	78	76	77	90	87	89	84	84
	Summer	85	87	75	76	55	55	37	44	52	56	68	70	62	65	83	65
1952	Fall	62	61	61	45	58	60	41	48	48	45	51	55	59	61	69	55
	Winter	85	86	90	91	71	71	65	76	77	80	82	84	79	83	90	81
	Spring	69	71	71	85	66	69	67	68	69	70	65	65	67	67	71	69
	Summer	72	79	89	92	39	39	66	25	37	63	57	66	34	71	60	59
1953	Fall	43	44	57	88	28	28	44	35	31	35	35	35	29	41	43	41
	Winter	83	83	90	90	79	80	80	82	81	81	81	83	81	83	79	82
	Spring	72	70	72	80	67	64	54	68	70	54	73	71	70	82	87	70
	Summer	36	34	51	64	38	43	21	26	30	0	17	22	25	46	52	34
1954	Fall	20	18	39	35	22	25	14	29	28	5	26	25	27	17	10	23
	Winter	52	49	41	46	64	64	41	66	67	57	57	56	65	38	36	53
	Spring	76	74	72	73	69	65	72	74	81	71	81	79	80	64	68	73
	Summer	71	73	48	27	91	92	82	84	89	79	92	90	85	70	69	76
1955	Fall	82	78	78	78	91	91	89	88	91	91	87	83	78	85	73	84
	Winter	74	75	70	73	70	76	78	71	71	72	75	71	72	85	79	74
	Spring	68	71	83	68	50	53	70	60	57	55	59	55	56	69	58	62
	Summer	88	83	87	90	40	44	57	57	59	60	46	44	30	42	43	58
1956	Fall	57	60	74	82	53	55	66	54	47	74	46	34	41	33	38	54
	Winter	62	61	59	53	63	63	63	63	63	63	62	61	64	62	62	62
	Spring	79	77	62	30	85	83	91	91	89	84	85	81	85	76	76	78
	Summer	92	92	92	64	92	92	92	92	92	92	92	92	90	77	91	89
1957	Fall	82	85	78	84	85	84	92	85	81	92	84	92	87	76	90	85
	Winter	77	75	71	68	75	72	69	80	79	84	77	79	82	76	77	76
	Spring	67	66	64	77	54	69	44	52	63	48	64	64	58	34	49	58
	Summer	37	33	12	24	20	27	11	32	31	22	59	61	70	22	53	34

Table 6. Number of days exceeding the relevant seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, by season, water years 1930–2011, and their average as a proportion.—Continued

[Average is for full years only. NO, not operated during that season; PR, operated for part of the season; fall, October 1–December 31; winter, January 1–March 31; spring, April 1–June 30; summer, July 1–September 30. Flow duration values from Wiley, 2006]

Water year	Season	Streamgage															Average
		01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1958	Fall	75	85	66	66	78	80	70	78	78	77	86	92	81	74	84	78
	Winter	62	70	67	77	55	66	57	55	49	55	60	72	56	69	68	63
	Spring	60	59	67	81	75	78	66	64	68	68	63	61	66	83	84	70
	Summer	79	83	83	92	86	89	92	91	85	92	91	92	85	85	92	88
1959	Fall	19	8	21	26	61	68	92	58	54	84	54	53	60	65	92	54
	Winter	34	25	19	13	64	60	69	69	73	77	55	50	68	57	63	53
	Spring	70	71	73	63	72	73	56	59	65	59	72	72	68	63	64	67
	Summer	30	30	53	58	43	54	56	25	42	24	47	43	47	19	31	40
1960	Fall	81	86	92	92	69	69	65	73	74	70	81	82	74	72	87	78
	Winter	73	78	85	78	72	73	69	51	55	55	64	69	52	76	85	69
	Spring	73	73	89	86	62	64	62	67	67	54	68	70	76	49	53	68
	Summer	79	69	89	92	83	88	82	79	83	64	76	78	86	66	70	79
1961	Fall	45	42	20	14	75	74	48	75	73	43	63	68	73	67	78	57
	Winter	46	48	55	44	70	66	65	58	58	67	55	55	59	62	61	58
	Spring	88	84	89	82	86	84	91	86	89	89	83	81	80	77	79	85
	Summer	73	84	77	78	90	92	92	84	83	92	92	92	92	69	76	84
1962	Fall	76	75	45	71	81	91	92	59	79	74	78	81	78	80	81	76
	Winter	82	75	54	76	84	83	83	79	82	72	79	86	75	90	85	79
	Spring	77	80	79	86	56	50	50	74	67	44	46	50	58	64	67	63
	Summer	40	47	53	54	33	55	29	50	49	15	33	51	38	61	82	46
1963	Fall	72	71	66	53	81	92	70	70	75	75	68	67	69	71	91	73
	Winter	44	47	42	50	63	68	65	66	54	62	53	53	71	76	88	60
	Spring	56	56	54	39	63	65	55	71	64	70	57	49	70	63	45	58
	Summer	46	35	16	10	70	77	66	92	83	48	59	57	80	65	43	56
1964	Fall	50	48	45	34	50	54	23	55	54	41	49	47	57	43	39	46
	Winter	74	85	87	84	67	71	67	68	62	75	67	69	68	72	69	72
	Spring	47	49	56	51	50	42	51	51	52	61	41	40	44	36	46	48
	Summer	32	16	18	7	52	46	48	34	57	48	24	28	34	8	30	32
1965	Fall	65	72	68	54	54	53	43	63	62	47	54	59	53	69	76	59
	Winter	89	90	87	87	71	68	72	89	74	71	71	72	66	72	80	77
	Spring	50	52	53	51	43	44	49	41	42	48	56	59	47	46	60	49
	Summer	21	22	10	14	32	38	23	13	31	30	39	35	44	57	50	31
1966	Fall	13	7	0	1	24	15	61	34	40	68	92	87	89	9	20	37
	Winter	37	35	21	25	36	34	33	48	49	48	46	40	48	19	20	36
	Spring	45	43	46	44	56	55	54	51	51	56	64	53	54	50	46	51
	Summer	23	22	25	19	56	47	12	37	52	16	51	40	65	47	76	39
1967	Fall	92	92	92	92	92	85	50	92	92	56	92	92	92	92	92	86
	Winter	86	86	81	88	71	62	46	69	74	64	87	84	75	81	88	76
	Spring	71	69	77	49	69	67	65	72	68	66	73	74	69	72	77	69
	Summer	60	69	92	82	65	62	37	81	70	57	69	72	62	64	78	68
1968	Fall	90	90	92	92	92	84	66	75	87	79	92	92	82	78	85	85
	Winter	50	68	61	79	54	54	39	45	46	43	48	49	43	60	60	53
	Spring	60	49	63	47	65	71	75	58	56	73	80	79	71	76	89	67
	Summer	34	23	53	64	42	50	90	53	34	33	20	51	49	89	83	51
1969	Fall	56	55	61	57	61	60	54	59	61	56	59	65	76	86	60	62
	Winter	32	27	18	36	43	43	34	43	43	41	40	43	40	41	32	37
	Spring	47	39	30	17	54	60	58	52	51	54	57	54	54	64	56	50
	Summer	85	86	68	83	92	92	72	87	88	83	85	88	92	92	46	83
1970	Fall	71	87	60	92	69	89	47	74	73	59	67	74	75	64	29	69
	Winter	76	84	83	90	74	70	65	77	73	67	71	71	69	74	60	74
	Spring	45	45	63	55	52	49	73	46	45	63	47	47	61	51	56	53
	Summer	64	79	68	68	92	90	80	89	89	86	73	67	89	59	70	78
1971	Fall	71	68	70	65	76	73	77	72	72	77	70	69	72	67	79	72
	Winter	87	87	90	90	86	84	75	85	85	87	87	86	84	85	81	85
	Spring	77	76	88	90	63	59	68	69	62	64	66	76	64	84	91	73
	Summer	86	92	92	92	88	78	92	66	78	92	85	81	85	92	92	86

Table 6. Number of days exceeding the relevant seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, by season, water years 1930–2011, and their average as a proportion.—Continued

[Average is for full years only. NO, not operated during that season; PR, operated for part of the season; fall, October 1–December 31; winter, January 1–March 31; spring, April 1–June 30; summer, July 1–September 30. Flow duration values from Wiley, 2006]

Water year	Season	Streamgage															Average
		01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1972	Fall	92	92	92	92	82	80	90	87	80	82	88	92	81	92	92	88
	Winter	85	85	89	61	85	86	89	74	79	86	79	82	76	89	90	82
	Spring	83	80	91	85	76	75	68	76	76	69	76	79	75	82	89	79
	Summer	92	92	92	92	85	81	91	78	82	64	83	92	83	92	92	86
1973	Fall	92	92	92	92	92	92	78	89	90	63	92	92	92	92	92	89
	Winter	90	90	90	90	66	71	78	66	71	75	80	75	73	73	74	77
	Spring	81	83	88	91	83	72	84	87	83	84	85	91	84	86	90	85
	Summer	90	92	92	92	87	73	92	81	72	82	74	87	89	90	89	85
1974	Fall	92	92	92	92	82	78	90	91	85	82	80	83	85	83	92	87
	Winter	90	90	90	90	87	87	84	90	90	86	89	88	89	90	90	89
	Spring	88	88	91	89	88	88	86	77	87	85	86	91	89	86	91	87
	Summer	92	92	92	92	89	90	88	92	90	90	90	92	89	92	92	91
1975	Fall	77	77	60	76	77	74	92	67	67	85	77	77	75	92	92	78
	Winter	90	90	88	87	81	80	90	86	84	87	86	87	80	81	86	86
	Spring	78	80	83	80	82	86	88	76	80	85	80	82	81	86	89	82
	Summer	92	92	92	92	81	75	86	83	88	82	82	90	78	88	92	86
1976	Fall	92	92	92	92	79	75	92	92	83	92	92	92	84	92	92	89
	Winter	83	80	89	91	75	76	80	74	74	81	74	71	71	81	82	79
	Spring	38	31	36	56	36	48	69	42	32	73	40	38	40	24	40	43
	Summer	53	57	86	57	58	62	91	64	62	85	62	57	73	76	68	67
1977	Fall	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
	Winter	38	35	40	26	47	45	48	43	42	47	46	40	45	41	43	42
	Spring	31	26	33	30	51	47	64	45	48	59	37	30	59	48	70	45
	Summer	22	21	30	3	91	92	92	82	89	91	92	90	92	90	92	71
1978	Fall	87	84	87	68	92	92	92	92	91	92	92	92	92	92	92	89
	Winter	47	48	83	90	44	43	55	32	34	40	44	45	41	65	80	53
	Spring	72	69	82	84	82	81	78	83	79	82	76	69	72	74	76	77
	Summer	88	92	92	92	87	90	92	90	81	92	75	71	70	89	92	86
1979	Fall	42	43	92	64	50	53	87	49	45	74	40	35	40	48	78	56
	Winter	75	82	79	90	69	70	79	73	73	69	73	75	74	78	84	76
	Spring	85	87	82	91	75	74	79	78	77	72	87	91	91	91	91	83
	Summer	92	92	92	92	92	92	92	92	92	91	92	92	92	92	92	92
1980	Fall	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
	Winter	68	75	79	91	59	58	57	54	54	47	61	63	62	73	81	65
	Spring	80	81	80	78	82	83	86	86	81	84	74	74	77	67	66	79
	Summer	86	86	92	69	92	91	92	92	87	92	84	88	87	92	92	88
1981	Fall	55	68	66	32	67	67	70	56	59	67	44	44	66	85	92	63
	Winter	32	27	25	14	62	58	64	51	51	64	40	37	42	58	51	45
	Spring	85	87	85	35	91	90	91	91	91	91	88	85	84	86	91	85
	Summer	70	73	72	54	83	81	92	83	82	85	72	73	79	73	92	78
1982	Fall	66	66	67	29	73	77	72	84	77	70	67	66	78	61	88	69
	Winter	70	70	67	67	77	74	66	80	83	78	80	82	82	73	73	75
	Spring	73	73	69	80	62	57	57	66	64	50	67	75	70	76	78	68
	Summer	77	75	63	82	92	92	92	91	89	84	80	76	82	92	92	84
1983	Fall	88	86	63	77	90	84	80	87	88	63	86	86	83	92	92	83
	Winter	63	57	51	57	55	53	55	55	58	58	66	69	56	59	68	59
	Spring	77	78	78	91	81	76	74	73	77	85	82	83	82	85	78	80
	Summer	32	35	43	58	62	66	70	21	33	78	40	42	43	66	72	51
1984	Fall	74	79	85	84	72	70	77	72	74	73	74	71	73	79	86	76
	Winter	71	80	86	91	65	59	69	68	60	65	70	71	56	68	60	69
	Spring	63	60	64	71	55	58	69	62	53	69	58	58	55	64	71	62
	Summer	87	92	82	92	86	89	92	79	82	92	92	92	88	87	75	87
1985	Fall	92	92	86	91	83	86	83	74	78	78	92	92	85	89	86	86
	Winter	59	76	61	73	66	69	70	67	70	58	68	74	55	78	74	68
	Spring	79	74	63	48	77	82	71	79	79	86	73	73	70	84	74	74
	Summer	73	73	70	49	69	63	64	71	71	80	74	75	65	64	75	69

Table 6. Number of days exceeding the relevant seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, by season, water years 1930–2011, and their average as a proportion.—Continued

[Average is for full years only. NO, not operated during that season; PR, operated for part of the season; fall, October 1–December 31; winter, January 1–March 31; spring, April 1–June 30; summer, July 1–September 30. Flow duration values from Wiley, 2006]

Water year	Season	Streamgage															Average
		01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
1986	Fall	76	72	71	71	72	71	64	76	74	67	72	70	69	66	81	71
	Winter	62	71	68	63	49	62	65	56	53	59	51	58	45	63	59	59
	Spring	46	59	48	42	58	50	49	61	59	44	55	48	64	74	64	55
	Summer	83	76	55	19	86	92	72	80	89	77	83	80	92	92	92	78
1987	Fall	79	62	57	48	92	92	92	86	92	92	84	81	92	92	92	82
	Winter	77	76	79	76	48	52	38	68	58	42	74	76	61	59	70	64
	Spring	72	70	68	78	71	61	72	72	73	68	70	70	78	76	85	72
	Summer	62	54	32	55	53	54	88	47	48	71	47	45	53	53	66	55
1988	Fall	88	89	67	92	69	69	58	74	75	70	70	63	70	67	41	71
	Winter	55	53	58	69	61	64	67	60	58	71	57	52	57	30	11	55
	Spring	67	65	74	58	63	62	59	64	65	63	58	58	61	60	47	62
	Summer	35	60	88	32	38	36	47	35	40	52	24	27	31	47	36	42
1989	Fall	61	57	35	14	73	71	76	77	74	81	64	68	71	70	74	64
	Winter	59	54	49	29	72	70	84	76	78	82	70	77	70	72	72	68
	Spring	89	84	80	82	90	91	89	91	91	86	84	81	89	91	91	87
	Summer	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
1990	Fall	92	92	92	92	92	91	92	89	83	92	92	92	83	92	92	91
	Winter	89	77	63	90	86	85	79	71	87	68	88	90	85	87	90	82
	Spring	76	73	70	75	81	88	89	78	79	79	73	75	78	77	86	78
	Summer	78	90	89	81	89	90	92	82	92	92	92	92	87	85	89	88
1991	Fall	82	82	81	83	86	89	92	84	86	92	82	83	86	85	91	86
	Winter	85	90	90	90	86	88	90	83	86	89	84	89	86	90	90	88
	Spring	42	46	47	57	43	42	48	44	44	49	48	55	46	53	76	49
	Summer	49	56	53	68	63	58	19	47	75	19	68	41	58	66	86	55
1992	Fall	38	37	46	31	50	55	41	40	46	40	43	40	51	55	55	45
	Winter	65	58	51	50	82	76	74	84	79	75	63	66	76	69	62	69
	Spring	84	86	77	81	70	71	48	69	68	61	84	88	82	85	90	76
	Summer	91	79	92	87	91	92	92	90	85	92	91	84	88	92	92	89
1993	Fall	56	51	71	80	53	58	65	53	52	65	59	55	59	92	81	63
	Winter	65	71	78	90	63	66	72	53	57	69	63	67	66	61	54	66
	Spring	60	60	62	81	54	53	55	59	55	51	59	64	62	80	77	62
	Summer	25	29	84	92	23	26	52	33	27	50	27	22	27	87	78	45
1994	Fall	77	69	71	91	86	89	92	85	86	92	87	85	76	92	90	85
	Winter	89	86	89	90	78	79	88	77	74	77	81	87	78	89	90	83
	Spring	61	61	59	73	63	70	61	64	63	63	53	53	68	67	73	63
	Summer	91	92	92	92	88	90	92	92	90	92	76	81	83	92	92	89
1995	Fall	48	58	79	92	45	29	67	51	50	61	43	43	44	91	92	60
	Winter	71	72	79	81	70	73	72	68	70	60	67	70	66	81	76	72
	Spring	76	70	66	65	75	73	86	74	72	71	77	82	66	91	91	76
	Summer	72	77	62	89	37	36	68	65	45	29	46	49	31	71	82	57
1996	Fall	80	82	NO	92	60	61	81	73	72	57	79	83	76	87	92	77
	Winter	90	89	NO	91	77	80	79	86	82	77	81	81	82	89	83	83
	Spring	91	91	NO	91	74	79	85	82	82	81	87	89	79	83	88	84
	Summer	92	92	NO	92	92	92	92	92	92	92	92	92	87	92	92	92
1997	Fall	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
	Winter	80	80	86	90	71	71	85	72	70	73	75	79	66	89	90	78
	Spring	78	82	77	91	73	86	87	80	76	79	76	77	72	91	91	81
	Summer	86	68	92	92	59	60	89	81	66	74	57	52	60	92	91	75
1998	Fall	91	76	78	89	65	63	66	75	73	69	67	69	67	73	70	73
	Winter	88	90	90	90	88	88	86	85	89	88	89	86	87	85	69	87
	Spring	72	91	87	91	72	72	74	79	75	77	69	81	72	89	91	79
	Summer	71	68	83	92	81	79	77	70	69	75	76	55	51	74	85	74
1999	Fall	10	10	68	46	49	33	16	14	30	33	29	23	26	55	76	35
	Winter	62	62	40	58	72	75	65	77	77	80	68	66	81	73	60	68
	Spring	44	46	40	31	48	47	51	48	48	51	52	56	49	41	57	47
	Summer	23	31	40	26	0	10	31	16	15	40	16	18	19	39	52	25

Table 6. Number of days exceeding the relevant seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, by season, water years 1930–2011, and their average as a proportion.—Continued

[Average is for full years only. NO, not operated during that season; PR, operated for part of the season; fall, October 1–December 31; winter, January 1–March 31; spring, April 1–June 30; summer, July 1–September 30. Flow duration values from Wiley, 2006]

Water year	Season	Streamgage															Average
		01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000	
2000	Fall	92	92	92	92	62	61	41	86	84	52	88	87	86	71	79	78
	Winter	46	45	41	61	55	51	49	59	62	49	56	49	61	39	36	51
	Spring	57	66	63	64	71	77	83	64	70	85	76	74	82	75	63	71
	Summer	92	92	87	92	92	92	92	90	92	92	92	92	92	92	92	92
2001	Fall	68	79	75	79	71	75	92	76	68	61	82	81	65	92	90	77
	Winter	67	70	67	30	66	61	72	72	65	66	60	59	60	54	48	61
	Spring	63	69	66	73	69	67	63	65	66	68	59	61	68	68	80	67
	Summer	87	90	92	68	76	86	92	86	76	87	77	86	65	92	92	83
2002	Fall	16	19	16	2	23	26	56	23	23	43	22	20	23	65	80	30
	Winter	19	14	11	4	32	34	54	52	51	59	31	31	52	31	23	33
	Spring	73	74	74	38	78	76	78	74	76	79	67	64	72	73	83	72
	Summer	50	47	49	7	65	56	68	68	62	65	67	70	60	77	76	59
2003	Fall	87	90	88	85	85	82	81	85	86	77	89	87	84	91	91	86
	Winter	73	60	66	80	64	63	55	69	63	61	64	67	65	71	70	66
	Spring	91	91	91	91	88	90	91	90	89	86	90	91	89	91	91	90
	Summer	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
2004	Fall	92	92	92	92	92	92	92	92	92	92	92	92	90	92	92	92
	Winter	73	85	91	91	71	74	82	78	73	79	70	74	68	82	81	78
	Spring	88	89	90	90	86	89	86	89	88	86	82	84	81	91	91	87
	Summer	90	88	92	91	88	92	92	87	85	92	92	92	58	92	92	88
2005	Fall	92	92	92	92	87	88	92	92	88	87	92	92	92	92	92	91
	Winter	80	78	90	90	79	85	89	69	71	76	72	75	74	89	90	80
	Spring	73	74	75	77	65	66	69	69	66	75	66	63	59	74	72	70
	Summer	77	78	83	74	64	51	83	61	66	55	73	73	69	92	92	73
2006	Fall	78	80	79	86	71	76	76	71	71	72	64	66	69	78	92	75
	Winter	64	58	62	70	56	61	52	73	70	64	59	58	65	54	25	59
	Spring	63	63	50	38	78	77	78	73	74	64	63	58	73	63	66	65
	Summer	73	83	73	84	70	73	91	83	83	74	81	80	86	92	92	81
2007	Fall	92	92	87	92	92	92	92	91	92	86	92	92	92	92	92	91
	Winter	65	63	58	90	79	76	81	77	70	72	63	66	67	77	58	71
	Spring	72	69	53	68	56	54	52	59	62	51	75	71	68	57	67	62
	Summer	58	71	78	78	79	73	92	90	82	83	71	60	79	69	79	76
2008	Fall	68	68	64	32	72	69	92	69	69	56	68	68	68	71	71	67
	Winter	83	82	63	46	84	84	89	82	82	82	83	81	76	56	48	75
	Spring	82	84	83	71	76	77	89	91	89	87	72	71	67	83	67	79
	Summer	66	76	75	53	53	48	92	66	59	91	48	43	35	87	68	64
2009	Fall	45	47	80	52	43	40	52	52	44	45	44	39	46	61	59	50
	Winter	49	37	26	13	59	52	56	73	66	58	48	51	64	69	62	52
	Spring	83	85	89	89	73	78	81	81	74	89	82	85	78	87	91	83
	Summer	66	67	62	50	68	82	85	65	63	78	82	84	72	92	92	74
2010	Fall	79	76	69	64	88	92	78	88	87	89	91	92	92	92	92	85
	Winter	74	81	82	90	62	78	78	44	47	64	55	65	48	83	83	69
	Spring	50	51	65	56	81	71	81	73	69	74	54	70	64	91	91	69
	Summer	29	21	16	20	63	57	57	29	48	33	51	40	57	92	92	47
2011	Fall	71	71	68	83	89	87	62	70	84	59	87	78	88	88	92	78
	Winter	56	54	44	40	72	76	77	66	66	71	57	54	62	64	51	61
	Spring	75	77	78	91	65	71	76	82	73	78	65	67	69	71	87	75
	Summer	60	65	79	75	84	86	92	92	89	92	43	40	55	92	92	76

Table 7. Maximum number of days between flows exceeding the annual 75-percent flow duration at 15 selected streamgages in West Virginia, water years 1930–2011.

[NO, not operated during that water year]

Water year	Streamgages														
	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000
1930	103	102	93	76	97	109	NO	69	97	43	103	105	63	125	88
1931	171	192	162	112	164	178	NO	130	158	109	170	173	107	222	134
1932	73	73	78	98	42	40	41	32	40	41	56	58	27	60	64
1933	79	80	84	28	45	58	74	12	45	73	46	64	32	38	96
1934	62	52	37	47	28	37	45	21	21	44	70	71	30	64	82
1935	21	27	46	15	23	23	29	20	22	27	20	17	17	22	21
1936	46	47	53	11	39	39	41	27	48	26	35	33	75	51	51
1937	62	63	69	15	50	49	57	43	64	29	36	41	45	38	40
1938	25	26	48	10	32	37	64	24	31	18	26	24	25	34	19
1939	42	44	111	47	43	54	113	42	42	51	43	46	41	60	39
1940	28	36	34	24	69	81	69	21	23	77	31	113	68	167	169
1941	18	25	18	22	32	29	30	15	24	29	31	33	35	78	78
1942	56	93	102	97	46	48	31	17	29	25	52	51	32	79	82
1943	25	43	62	33	21	20	21	26	24	34	24	23	23	79	72
1944	65	84	82	121	54	68	37	59	57	59	67	90	97	113	161
1945	13	22	26	8	12	11	22	13	12	20	23	110	110	62	102
1946	58	52	49	48	58	79	37	53	69	70	60	65	44	81	60
1947	83	77	47	55	83	104	62	78	94	95	85	92	69	107	133
1948	47	53	55	52	54	46	31	46	40	36	26	23	48	51	30
1949	3	6	9	0	17	19	23	17	13	42	20	20	19	48	54
1950	33	25	33	20	11	23	39	28	13	72	23	22	5	12	11
1951	20	27	35	28	42	42	62	41	33	67	61	59	15	37	13
1952	45	44	43	61	52	53	109	56	53	113	92	91	46	44	33
1953	76	76	49	25	89	102	54	89	89	120	87	81	89	67	60
1954	119	120	102	50	117	114	128	102	102	194	149	149	146	139	99
1955	41	41	41	44	37	36	35	32	34	30	25	35	46	50	38
1956	63	57	62	54	80	51	43	45	48	12	69	82	57	98	89
1957	62	85	89	87	62	80	99	63	63	92	32	31	32	63	26
1958	68	91	95	93	68	86	30	68	69	98	12	12	19	21	21
1959	67	121	52	54	53	28	29	46	33	75	52	50	43	55	36
1960	26	33	15	11	76	51	52	18	15	44	25	52	17	78	31
1961	42	42	92	96	30	24	33	14	31	39	19	38	24	33	32
1962	67	69	57	48	71	64	71	63	63	85	73	54	43	38	35
1963	72	100	86	97	22	15	39	15	16	44	81	65	23	43	32
1964	75	120	124	134	59	52	82	53	53	63	91	91	59	77	83
1965	66	66	43	80	62	74	50	79	62	46	60	60	40	30	30
1966	82	92	130	198	36	123	69	86	39	64	40	57	32	83	87
1967	27	24	10	17	26	31	54	25	25	29	24	24	27	26	27
1968	77	92	66	19	30	30	26	27	30	37	93	41	37	16	18
1969	96	112	38	35	36	35	62	35	24	40	111	60	23	14	35
1970	34	32	53	33	17	18	74	19	15	71	36	35	25	43	55
1971	50	54	57	57	21	24	16	29	19	16	55	56	21	30	20
1972	22	23	13	0	23	35	32	30	14	41	32	29	27	11	0
1973	17	25	1	5	18	30	37	21	23	47	38	20	17	17	15
1974	12	12	13	17	35	20	15	15	16	12	16	14	22	21	16
1975	27	28	27	27	26	18	14	23	25	19	30	27	30	22	16
1976	52	37	28	45	56	50	38	61	56	38	55	51	31	22	12
1977	89	91	73	132	14	21	7	24	26	16	14	16	20	13	3
1978	26	17	15	159	26	13	4	20	20	7	27	26	28	16	16
1979	83	64	17	64	52	39	17	37	39	21	82	84	76	73	63

Table 7. Maximum number of days between flows exceeding the annual 75-percent flow duration at 15 selected streamgages in West Virginia, water years 1930–2011.—Continued

[NO, not operated during that water year]

Water year	Streamgages														
	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000
1980	31	30	33	37	9	16	1	17	8	17	33	17	23	8	5
1981	56	55	58	63	27	29	25	29	27	30	59	59	26	22	21
1982	36	43	48	47	31	14	35	9	15	31	46	44	20	38	46
1983	67	84	76	52	28	29	66	49	65	33	64	62	49	30	31
1984	87	104	54	65	48	50	80	62	78	36	84	83	62	41	43
1985	31	29	30	34	51	51	64	29	33	14	21	30	35	34	46
1986	50	49	51	107	70	70	79	43	48	32	41	52	55	68	34
1987	47	58	73	149	47	39	37	50	54	37	61	60	37	43	37
1988	74	43	34	64	40	40	39	38	38	39	43	60	31	56	57
1989	38	38	61	118	21	21	13	13	16	13	25	23	17	23	23
1990	28	26	13	11	21	19	10	17	23	7	12	13	15	25	10
1991	48	48	40	39	35	39	86	32	32	99	51	53	29	24	16
1992	101	102	33	102	33	27	138	76	34	151	60	60	25	48	51
1993	52	102	29	20	102	58	58	62	80	31	93	77	52	31	44
1994	29	29	29	28	18	19	11	13	19	17	27	24	22	10	11
1995	70	70	42	46	52	84	41	43	52	47	79	77	54	59	32
1996	46	47	NO	5	79	67	11	12	49	61	58	79	17	10	15
1997	21	20	22	15	33	29	14	20	20	45	35	35	19	18	33
1998	22	22	37	35	29	29	72	30	20	32	25	62	24	44	59
1999	116	116	95	94	118	119	117	59	93	44	82	109	98	41	74
2000	18	8	11	7	122	123	149	25	10	32	25	13	8	44	40
2001	31	29	29	39	21	20	13	23	21	18	28	27	47	26	30
2002	98	97	56	204	72	58	37	60	73	31	99	97	116	66	71
2003	9	8	8	12	8	11	11	8	8	11	13	9	11	11	11
2004	24	18	12	16	16	6	3	16	8	9	20	29	58	0	0
2005	27	25	44	25	31	27	65	28	28	28	28	26	27	19	12
2006	35	34	52	32	52	35	71	49	49	50	55	35	34	44	18
2007	53	36	33	30	21	18	15	13	13	21	18	24	17	40	33
2008	41	61	58	56	43	45	23	36	54	25	57	74	58	38	42
2009	45	44	36	79	89	100	42	34	98	60	101	131	101	61	64
2010	53	77	76	110	34	34	51	53	27	52	40	52	30	11	14
2011	55	54	49	30	14	10	21	14	11	18	60	59	58	26	26
Annual summary, water years 1930–2011:															
Maximum	171	192	162	204	164	178	149	130	158	194	170	173	146	222	169
25th percentile	68	79	66	78	58	58	64	52	54	60	66	70	54	62	60
Median	48	48	48	46	38	38	39	30	33	38	43	52	32	41	35
75th percentile	28	29	30	23	26	23	23	20	20	25	26	27	23	22	19
Minimum	3	6	1	0	8	6	1	8	8	7	12	9	5	0	0

Table 8. Maximum number of days between flows exceeding the seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, water years, 1930–2011.

[NO, not operated during that water year]

Water year	Streamgages														
	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000
1930	110	90	74	48	68	63	NO	45	69	39	75	109	33	66	91
1931	177	159	77	105	135	132	NO	106	130	105	141	177	94	134	88
1932	53	66	71	52	36	36	37	23	21	36	49	52	19	41	62
1933	31	46	76	26	42	52	70	13	16	63	14	30	12	31	65
1934	45	46	50	62	20	19	36	28	28	36	47	47	28	44	81
1935	15	17	25	9	22	22	28	19	21	23	18	11	16	18	19
1936	28	30	38	13	23	33	30	25	25	36	23	26	34	61	48
1937	29	33	40	1	39	37	47	41	41	8	13	21	33	36	36
1938	14	15	27	15	14	26	52	12	10	14	13	12	15	19	21
1939	30	21	43	30	38	42	101	31	36	36	36	34	33	41	30
1940	25	39	21	21	50	48	43	20	23	26	24	35	51	174	108
1941	31	29	33	32	27	28	29	22	21	26	20	21	32	33	40
1942	44	45	79	86	40	40	24	21	22	13	43	44	26	48	49
1943	21	20	33	19	21	18	18	21	19	19	19	20	19	69	59
1944	50	46	48	48	48	48	38	54	52	44	52	49	42	102	74
1945	11	15	12	12	8	9	11	11	7	11	12	19	55	54	23
1946	42	38	28	15	39	40	34	39	41	65	40	52	41	43	29
1947	67	63	37	34	64	65	59	64	66	90	65	78	66	68	54
1948	40	44	47	42	40	39	25	40	32	29	29	28	35	32	21
1949	14	15	15	12	27	26	27	18	15	17	15	16	18	22	34
1950	9	6	14	15	10	7	29	14	13	33	6	7	0	8	8
1951	7	4	7	9	14	13	29	21	19	21	11	11	11	15	14
1952	22	21	38	32	23	43	76	52	50	58	42	42	42	37	21
1953	38	37	27	16	61	60	46	87	86	129	54	52	59	54	38
1954	77	74	41	44	111	110	81	98	98	203	107	80	116	93	93
1955	16	19	21	44	33	32	24	19	19	19	21	21	34	37	35
1956	29	30	48	64	47	47	28	28	28	28	36	67	53	82	45
1957	40	49	69	62	61	61	51	48	56	39	24	23	15	50	25
1958	16	32	18	17	67	67	20	21	62	12	15	17	15	18	13
1959	39	45	45	41	28	24	26	27	27	30	29	32	28	28	23
1960	14	13	5	13	49	47	49	40	34	34	21	26	37	41	25
1961	44	24	47	73	18	18	21	24	24	20	23	23	21	17	17
1962	45	24	49	24	40	37	20	20	20	49	43	39	38	20	12
1963	49	36	35	47	13	9	16	15	16	22	20	43	19	14	23
1964	45	58	60	72	50	46	72	37	37	59	62	64	32	67	51
1965	57	42	46	37	54	46	49	60	52	45	37	36	40	40	24
1966	51	61	166	123	29	49	76	45	29	46	29	34	28	119	69
1967	21	16	11	28	15	26	36	10	23	29	15	10	22	22	10
1968	49	54	19	23	29	27	32	27	28	28	45	27	29	29	30
1969	68	74	59	46	31	32	39	34	33	37	63	37	36	19	27
1970	35	21	26	23	15	16	28	20	27	33	38	24	17	40	53
1971	21	22	21	39	17	19	15	10	18	10	20	46	20	20	7
1972	8	11	2	20	12	12	16	15	12	21	13	12	12	9	1
1973	7	6	2	0	10	12	11	10	11	23	7	11	10	17	16
1974	3	3	0	1	10	11	5	5	7	10	12	9	7	9	0
1975	15	15	17	11	15	15	6	15	15	8	16	15	16	9	4
1976	31	31	28	26	27	25	12	15	28	9	30	32	17	39	28
1977	48	65	58	143	43	43	42	42	42	42	46	48	42	42	28
1978	28	22	7	19	36	37	31	41	39	35	34	33	32	17	15
1979	51	46	11	23	30	28	12	28	32	19	60	75	60	30	6

Table 8. Maximum number of days between flows exceeding the seasonal 75-percent flow duration at 15 selected streamgages in West Virginia, water years, 1930–2011.—Continued

[NO, not operated during that water year]

Water year	Streamgages														
	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000
1980	14	14	9	18	18	18	22	25	21	29	20	16	17	18	25
1981	32	34	42	45	25	26	22	25	26	25	33	33	26	24	32
1982	29	26	29	35	19	24	20	20	20	32	33	31	14	14	12
1983	47	45	34	33	21	24	22	21	20	19	45	44	45	22	19
1984	60	58	28	20	33	45	22	29	31	25	59	65	58	22	16
1985	19	19	27	21	19	27	15	20	19	23	16	15	27	19	16
1986	21	39	41	42	36	46	37	32	33	32	36	37	47	21	23
1987	25	30	58	60	35	33	23	36	36	21	35	38	26	17	17
1988	35	23	17	25	46	47	50	40	39	39	46	52	30	31	53
1989	23	24	39	62	19	20	11	13	14	11	22	19	17	19	16
1990	13	13	26	16	5	5	11	13	9	15	18	16	9	6	4
1991	47	45	44	21	50	39	44	36	39	31	44	39	43	14	11
1992	91	89	38	58	23	22	39	61	29	67	44	48	24	23	23
1993	34	37	18	12	44	34	17	33	34	21	34	59	34	18	17
1994	17	30	32	8	23	17	20	23	19	23	26	38	18	10	10
1995	34	33	22	7	45	61	15	32	35	41	49	45	41	18	7
1996	7	6	NO	0	73	60	6	10	10	55	16	9	7	4	6
1997	13	10	9	0	20	15	4	15	15	14	15	14	16	1	1
1998	17	16	14	2	27	29	24	11	19	20	24	22	24	13	22
1999	89	89	52	65	123	45	47	57	32	34	51	60	76	46	34
2000	28	43	47	14	127	36	37	21	22	30	20	27	21	41	29
2001	19	19	19	39	17	19	15	19	19	16	19	18	20	18	22
2002	58	59	86	99	70	56	24	56	70	19	60	71	72	31	46
2003	9	18	13	10	14	15	20	16	15	19	20	19	18	14	14
2004	17	6	1	1	6	10	3	7	7	5	21	15	10	9	10
2005	18	17	15	14	24	25	22	25	24	22	25	28	27	17	17
2006	22	33	38	37	45	32	21	46	45	16	27	33	27	14	26
2007	23	27	38	19	22	21	38	14	17	24	23	22	17	26	23
2008	37	24	24	34	37	41	2	23	23	23	33	33	54	22	23
2009	43	40	35	70	83	87	24	31	33	45	64	66	97	25	14
2010	34	32	53	31	18	17	23	22	29	23	29	31	19	7	7
2011	26	28	34	34	16	11	18	24	24	18	30	52	18	14	20
Annual summary, water years 1930–2011:															
Maximum	177	159	166	143	135	132	101	106	130	203	141	177	116	174	108
25th percentile	45	45	47	45	45	46	38	39	36	37	44	47	41	41	36
Median	30	30	33	26	29	32	25	24	26	26	29	33	27	23	23
75th percentile	17	19	18	15	19	19	18	18	19	19	20	19	17	17	14
Minimum	3	3	0	0	5	5	2	5	7	5	6	7	0	1	0

Table 13. Average number of days when flow at one streamgage of a pair exceeded the indicated flow-duration interval, but flow at the other streamgage did not exceed the 75-percent flow duration, and Spearman's rho correlation coefficients for daily flow at 15 selected streamgages in West Virginia, 1930–2011.

[D75, flow equalled or exceeded on 75 percent of days; D60, flow equalled or exceeded 60 percent of days; D50, flow equalled or exceeded on 50 percent of days. Flow duration values from Wiley, 2006.]

Station:	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000
Exceeding D75															
01606500		7.7	19.5	22.8	21.6	25.8	29.6	21.1	20.0	27.0	14.5	15.8	25.0	24.3	27.0
01608500	9.2		17.3	21.0	23.8	27.8	31.7	23.3	23.0	29.0	18.4	17.5	28.1	26.1	28.2
01611500	17.9	14.2		19.4	28.5	31.8	32.9	27.0	28.0	30.2	24.6	23.3	32.5	28.0	29.3
01636500	21.7	18.5	19.8		34.3	37.1	39.9	33.7	33.8	37.6	28.5	26.7	37.0	32.3	32.4
03051000	22.3	23.0	31.1	36.1		11.1	25.2	16.9	11.4	22.4	17.2	21.3	18.2	25.1	28.9
03053500	26.5	27.1	34.6	38.9	11.2		25.6	19.5	16.1	22.7	21.0	24.3	20.1	27.1	31.9
03061500	26.9	27.5	31.6	36.9	21.6	21.7		22.8	23.3	16.5	25.1	26.6	26.4	25.4	29.1
03066000	23.5	24.4	31.2	37.3	18.7	21.3	28.3		11.4	23.0	22.0	26.3	22.8	30.1	33.8
03069500	22.0	23.5	31.7	36.9	12.7	17.3	28.3	10.8		23.7	18.4	23.5	19.0	28.6	32.1
03070500	27.6	28.1	32.8	39.2	22.3	22.5	18.7	21.0	22.3		24.9	28.0	25.7	29.7	34.2
03182500	15.2	17.6	27.0	30.3	17.2	20.9	28.2	20.2	17.1	25.0		11.0	17.1	24.7	28.2
03183500	15.6	15.8	24.8	27.5	20.4	23.4	28.9	23.6	21.4	27.2	10.1		20.6	22.7	25.6
03186500	25.1	26.8	34.6	38.2	17.7	19.5	28.6	20.4	17.2	25.3	16.5	20.9		26.6	31.6
03198500	26.7	27.1	32.3	35.9	26.9	28.8	31.1	30.1	28.9	31.6	26.4	25.4	28.9		15.1
03214000	29.2	28.9	33.2	35.7	30.4	33.3	34.9	33.4	32.3	35.8	29.7	28.0	33.6	14.9	
Exceeding D60															
01606500		1.2	4.6	9.0	6.1	9.4	11.9	5.9	4.8	10.2	1.9	3.1	7.4	8.7	11.1
01608500	0.1		2.3	6.0	7.1	10.4	12.9	7.2	6.3	11.2	2.7	2.9	9.3	9.4	11.3
01611500	3.4	1.7		4.4	10.7	13.8	14.2	10.1	10.3	12.4	7.1	6.6	13.3	11.6	13.3
01636500	5.4	3.2	4.2		16.1	18.5	20.1	15.5	15.5	18.6	10.0	8.6	16.8	14.6	15.4
03051000	7.4	9.2	15.2	20.4		2.0	10.1	3.6	1.3	8.6	4.5	7.9	5.0	10.5	13.3
03053500	10.4	11.8	18.0	22.9	0.9		9.5	5.2	2.5	8.8	6.7	9.9	6.1	11.3	15.0
03061500	11.4	12.4	15.7	20.3	5.9	5.9		6.8	7.0	3.5	9.4	11.1	9.6	11.1	13.6
03066000	9.3	11.1	15.8	22.5	5.3	7.7	11.7		0.9	9.5	9.1	12.8	8.7	15.0	18.1
03069500	7.8	10.2	15.7	21.7	2.5	5.5	12.1	1.5		9.5	6.5	10.6	6.9	13.7	16.8
03070500	11.8	12.9	16.3	23.0	6.8	6.7	4.3	5.4	5.6		9.8	12.6	9.5	13.4	17.5
03182500	2.4	4.1	9.8	14.6	3.6	5.9	11.3	5.5	2.9	9.5		1.9	2.6	8.8	12.2
03183500	2.6	3.2	8.5	12.3	4.6	7.3	11.6	7.3	4.5	10.6	0.4		3.3	6.7	9.1
03186500	10.9	12.8	18.5	23.4	5.6	7.0	13.4	7.2	4.3	12.2	4.8	8.3		11.5	15.9
03198500	9.9	10.3	14.4	18.5	9.1	10.3	12.8	11.9	10.7	12.9	9.0	8.2	9.5		2.7
03214000	11.2	11.4	14.4	17.5	11.8	13.9	15.4	15.2	14.5	16.6	10.8	9.3	13.9	2.4	

Table 13. Average number of days when flow at one streamgage of a pair exceeded the indicated flow-duration interval, but flow at the other streamgage did not exceed the 75-percent flow duration, and Spearman's rho correlation coefficients for daily flow at 15 selected streamgages in West Virginia, 1930–2011.—Continued

[D75, flow equalled or exceeded on 75 percent of days; D60, flow equalled or exceeded 60 percent of days; D50, flow equalled or exceeded on 50 percent of days. Flow duration values from Wiley, 2006.]

Station:	01606500	01608500	01611500	01636500	03051000	03053500	03061500	03066000	03069500	03070500	03182500	03183500	03186500	03198500	03214000
Exceeding D50															
01606500		0.4	2.1	4.6	2.4	4.4	6.2	1.8	0.9	5.5	0.6	1.3	2.5	4.5	5.9
01608500	0.0		0.8	2.8	2.8	4.8	6.7	2.5	1.8	6.0	1.0	1.2	3.5	4.8	6.1
01611500	1.2	0.4		1.3	5.0	7.3	7.5	4.7	4.6	6.5	2.9	2.9	6.5	6.5	7.6
01636500	1.8	0.8	1.5		8.8	10.6	12.2	8.1	8.5	11.1	4.5	3.9	9.0	8.9	9.7
03051000	3.6	5.4	9.4	14.0		0.8	4.9	1.4	0.4	4.5	2.3	4.7	2.6	6.0	8.0
03053500	5.9	7.4	11.7	16.0	0.4		4.9	2.3	0.9	4.8	3.9	6.3	3.4	6.9	9.5
03061500	6.3	7.1	9.3	13.1	2.9	2.9		2.6	2.9	1.5	5.1	6.4	4.9	6.2	7.7
03066000	5.6	7.2	10.8	16.2	3.1	4.9	7.2		0.3	5.7	5.7	8.7	5.6	9.8	12.1
03069500	4.2	6.4	10.5	15.0	1.2	2.8	6.9	0.5		5.5	3.8	7.0	3.8	8.6	11.0
03070500	6.7	7.6	10.1	15.7	3.2	3.5	1.6	2.3	2.3		5.2	7.4	4.9	7.5	10.4
03182500	0.9	2.1	5.3	9.1	1.6	2.9	6.1	2.4	0.7	5.2		1.0	0.7	4.5	6.7
03183500	0.9	1.4	4.7	7.8	2.1	3.7	6.4	3.2	1.5	5.9	0.1		1.1	3.3	4.8
03186500	6.5	8.5	12.7	16.9	3.4	4.4	8.5	4.2	2.3	8.0	2.6	5.5		7.2	10.1
03198500	4.7	5.2	7.6	11.0	3.9	4.8	6.2	5.8	4.8	6.5	3.7	3.6	3.9		1.0
03214000	5.4	5.8	7.7	10.0	5.1	6.1	7.8	7.3	6.6	8.6	4.3	3.6	5.3	0.6	
Spearman's rho correlation coefficient, daily flows															
01606500		0.9696	0.8968	0.8456	0.8485	0.8039	0.7683	0.8387	0.8677	0.7866	0.9318	0.9205	0.8219	0.8098	0.7794
01608500	0.9696		0.9375	0.8904	0.8105	0.7729	0.7427	0.7980	0.8206	0.7558	0.8926	0.9038	0.7690	0.7884	0.7657
01611500	0.8968	0.9375		0.9071	0.7347	0.7021	0.7089	0.7302	0.7399	0.7181	0.8085	0.8235	0.6879	0.7400	0.7276
01636500	0.8456	0.8904	0.9071		0.6397	0.6150	0.6106	0.6267	0.6411	0.6042	0.7435	0.7744	0.6144	0.6775	0.6772
03051000	0.8485	0.8105	0.7347	0.6397		0.9575	0.8367	0.8875	0.9426	0.8545	0.8937	0.8569	0.8837	0.8111	0.7561
03053500	0.8039	0.7729	0.7021	0.6150	0.9575		0.8426	0.8520	0.8990	0.8490	0.8576	0.8276	0.8603	0.8081	0.7452
03061500	0.7683	0.7427	0.7089	0.6106	0.8367	0.8426		0.8052	0.8133	0.8993	0.7899	0.7651	0.7733	0.7771	0.7324
03066000	0.8387	0.7980	0.7302	0.6267	0.8875	0.8520	0.8052		0.9595	0.8561	0.8448	0.7950	0.8489	0.7350	0.6812
03069500	0.8677	0.8206	0.7399	0.6411	0.9426	0.8990	0.8133	0.9595		0.8605	0.8913	0.8392	0.8951	0.7637	0.7083
03070500	0.7866	0.7558	0.7181	0.6042	0.8545	0.8490	0.8993	0.8561	0.8605		0.8126	0.7759	0.8028	0.7475	0.6883
03182500	0.9318	0.8926	0.8085	0.7435	0.8937	0.8576	0.7899	0.8448	0.8913	0.8126		0.9601	0.9094	0.8267	0.7832
03183500	0.9205	0.9038	0.8235	0.7744	0.8569	0.8276	0.7651	0.7950	0.8392	0.7759	0.9601		0.8646	0.8525	0.8228
03186500	0.8219	0.7690	0.6879	0.6144	0.8837	0.8603	0.7733	0.8489	0.8951	0.8028	0.9094	0.8646		0.7923	0.7293
03198500	0.8098	0.7884	0.7400	0.6775	0.8111	0.8081	0.7771	0.7350	0.7637	0.7475	0.8267	0.8525	0.7923		0.7293
03214000	0.7794	0.7657	0.7276	0.6772	0.7561	0.7452	0.7324	0.6812	0.7083	0.6883	0.7832	0.8228	0.7293	0.9326	

Appendixes 1–8

ArcGIS geodatabases containing rasters depicting correlations between daily flows at unregulated streamgages in and near West Virginia, 1930–2011, available at: *http://dx.doi.org/10.3133/sir20145061*

Appendix 1. Flow correlation at all unregulated streamgages for full years, 1930–2011.

Appendix 2. Flow correlation at all unregulated streamgages for fall months only, 1930–2011.

Appendix 3. Flow correlation at all unregulated streamgages for winter months only, 1930–2011.

Appendix 4. Flow correlation at all unregulated streamgages for spring months only, 1930–2011.

Appendix 5. Flow correlation at all unregulated streamgages for summer months only, 1930–2011.

Appendix 6. Flow correlation at all unregulated streamgages for full years, 1963–1969.

Appendix 7. Flow correlation at all unregulated streamgages for full years, 1970–1979.

Appendix 8. Flow correlation at all unregulated streamgages for full years, 1992–2011.

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