Regional Relations in Bankfull Channel Characteristics Determined from Flow Measurements at Selected Stream-Gaging Stations in West Virginia, 1911-2002

By Terence Messinger and Jeffrey B. Wiley

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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

˚F = (1.8 x ˚C) + 32

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

˚C = (˚F - 32) / 1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88), and horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Altitude, as used in this report, refers to distance above the vertical datum.

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By Terence Messinger and Jeffrey B. Wiley

Abstract

Three bankfull channel characteristics—cross-sectional area, width, and depth—were significantly correlated with drainage area in regression equations developed for two regions in West Virginia. Channel characteristics were determined from analysis of flow measurements made at 74 U.S. Geological Survey stream-gaging stations at flows between 0.5 and 5.0 times bankfull flow between 1911 and 2002.

Graphical and regression analysis were used to delineate an "Eastern Region" and a "Western Region," which were separated by the boundary between the Appalachian Plateaus and Valley and Ridge Physiographic Provinces. Streams that drained parts of both provinces had channel characteristics typical of the Eastern Region, and were grouped with it. Standard error for the six regression equations, three for each region, ranged between 8.7 and 16 percent. Cross-sectional area and depth were greater relative to drainage area for the Western Region than they were for the Eastern Region. Regression equations were defined for streams draining between 46.5 and 1,619 square miles for the Eastern Region, and between 2.78 and 1,354 square miles for the Western Region.

Stream-gaging stations with two or more cross sections where flow had been measured at flows between 0.5 and 5.0 times the 1.5-year flow showed poor replication of channel characteristics compared to the 95-percent confidence intervals of the regression, suggesting that within-reach variability for the stream-gaging stations may be substantial. A disproportionate number of the selected stream-gaging stations were on large (drainage area greater than 100 square miles) streams in the central highlands of West Virginia, and only one stream-gaging station that met data-quality criteria was available to represent the region within about 50 miles of the Ohio River north of Parkersburg, West Virginia. Many of the cross sections were at bridges, which can change channel shape. Although the data discussed in this report may not be representative of channel characteristics on many or most streams, the regional equations in this report provide useful information for field identification of bankfull indicators.

Introduction

Programs and policies developed following passage of the Federal Clean Water Act in 1972 have successfully reduced stream pollution from industrial and other point sources, yet some of the broad goals in the Clean Water Act have not been achieved (U.S. Environmental Protection Agency, 2000). For instance, the Clean Water Act specifies support of aquatic life and protection of biological integrity as primary uses of waters of the United States. In streams of the Mid-Atlantic Highlands (a region including West Virginia and parts of Pennsylvania, Maryland, and Virginia) during 1993 and 1994, over 31 percent of stream miles were in poor condition as measured with a fish Index of Biotic Integrity, and 27 percent of stream miles were in poor condition as measured with aquatic insect indicators. Physical habitat degradation is seen as one of the most common reasons that streams fail to adequately support aquatic life. In the Mid-Atlantic Highlands in 1993 and 1994, 24 percent of the total stream length had poor riparian habitat, and 25 percent of the regional stream length had excess sedimentation (U.S. Environmental Protection Agency, 2000).

In addition to improving land-use and water-management practices in a watershed, stream-channel restoration is considered an important part of the strategy to restore many streams with degraded habitat to a condition that fully supports aquatic life. Stream-channel restoration is the practice of applying knowledge and principals of geomorphology in rebuilding damaged stream channels so that they transport sediment and remain stable. A crucial aspect of stream restoration is to design a stable size and shape for the stream, so that its channel will maintain its dimension, pattern, and profile over time without degrading or aggrading (Rosgen, 1996).

The 1.5-year recurrence flow has been identified as bankfull flow in most streams (Leopold, 1994). Bankfull flow is of geomorphic significance because it moves the greatest amount of sediment in the stream channel over time; consequently, it is sometimes referred to as the "effective discharge" (Leopold and others, 1964). Estimates of bankfull flow have ranged from the 1.1-year flow to the 30-year flow, but geomorphic features that indicate the top of the stream channel most commonly correspond with flows between the 1- and 2-year recurrence flow calculated from the annual peak series. The 1.5-year recurrence flow from the annual peak series corresponds to the 1-year recurrence flow from the partial duration series (Langbein, 1949). The 1.5-year recurrence flow was assumed to be bankfull flow for this study, and is the flow referred to as “bankfull” throughout the rest of this report; however, this usage is not meant to imply that field studies have verified the 1.5-year recurrence flow as bankfull flow in West Virginia.

Flow measurements made at U.S. Geological Survey (USGS) stream-gaging stations provide a large body of data on stream-channel characteristics at specific cross sections (Leopold and Maddock, 1953; Leopold, 1994; Rosgen, 1996). The USGS, in cooperation with the West Virginia Department of Transportation and West Virginia Conservation Agency, with cooperation facilitated by the Canaan Valley Institute, has analyzed the relation between flow and stream channel cross-sectional area, width, and average depth, and determined regional relations in these characteristics at the 1.5-year recurrence flow calculated from the annual peak series at stream-gaging stations in West Virginia. This study was intended to help investigators locate bankfull indicators in stream channels near stream-gaging stations or at reference reaches, an important part of data collection done in the design phase of stream-restoration projects. The regional equations presented in this report are not intended to be used to design stream channels without first collecting additional data. The USGS is currently (2003) collecting information on stream-channel characteristics in West Virginia to be used to develop regional curves for designing channels; information on this study is available from the West Virginia District Office of the USGS.

Purpose and scope

This report describes the relations between drainage area, flow, and bankfull stream channel characteristics at selected stream-gaging stations in West Virginia. The relation between flow and stream channel cross-sectional area, width, and average depth measured in current-meter flow measurements made between 1911 and 2002 were analyzed for stream-gaging stations on unregulated streams draining less than 2,000 mi^2. The relation between flow and stream channel area, width, and average depth were also analyzed for cross sections at stream-gaging stations where three or more current-meter flow measurements had been made at flows between 0.5 and 5.0 times the 1.5-year recurrence flow, and where these relations appeared to be stable. The regional relations between drainage area and stream channel area, width, and average depth at the 1.5-year recurrence flow were determined using the latter set of data. Equations presented in this report are to be used to help field identification of bankfull indicators.

Description of study area

Most of West Virginia is within the Appalachian Plateaus (20,000 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 Province (fig. 1). The Appalachian Plateaus consist of flat-lying sedimentary rocks that were uplifted in the Appalachian Orogeny 250 million years ago. The rocks of the Appalachian Plateaus have been eroded by water into hills and valleys. Streams in this province drain in a dendritic pattern. The maximum altitudes (nearly 5,000 ft) are in mountains in the eastern part of the Province, and the minimum altitudes (about 600 ft) are near the Ohio River in the western part of West Virginia (fig. 2). The greatest relief is in the area of greatest altitude (Messinger and Hughes, 2001).

Rocks of the Appalachian Plateaus are mostly Mississippian and Pennsylvanian, although the Dunkard Group may be of Permian age (Cardwell and others, 1968). The oldest rocks in the Province are in the east, in the region with the greatest altitude; the youngest rocks are in the west, near the Ohio River. A band of karstic limestone and dolomite, with extensive caves and other solution openings, is near the southeastern border of West Virginia with Virginia. Of Pennsylvanian rocks, the hardest rocks and highest proportions of sandstone are in the oldest rocks, in the south and east. Generally and with local exceptions, the proportions of shale, and softness and erodibility of sandstone, are greater in the younger rocks to the north and west than in the oldest Pennsylvanian rocks. Most of the commonly mined coal seams in West Virginia are Pennsylvanian.

In West Virginia, the Valley and Ridge Province consists of layers of folded and faulted sedimentary rocks that are Mississippian 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 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, most significantly the Great Valley near the eastern edge of the Province, are karstic and underlain by limestone and dolomite.

Precipitation in the Appalachian Plateaus increases with altitude, from about 40 inches per year near the Ohio River, to more than 60 inches per year in the mountains in central West Virginia (fig. 3). The Allegheny Front, a mountain range that divides the Appalachian Plateaus and Valley and Ridge in the north, but is within the Appalachian Plateaus in the south, creates an orographic divide and causes a precipitation shadow. Annual precipitation east and southeast of the precipitation shadow is between 31 and 35 inches per year. Average annual precipitation in the Valley and Ridge Province increases from west to east, to about 42 inches per year in the easternmost part of the province. Other climatic characteristics are distrib-

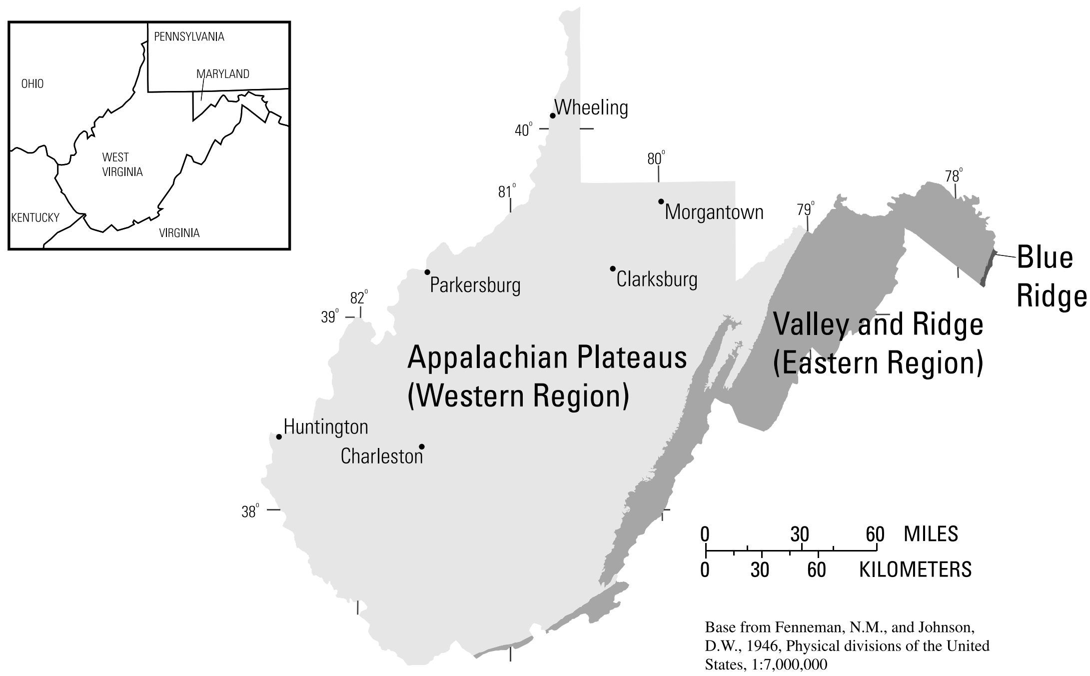

Figure 1. Physiographic provinces of West Virginia, and selected towns and cities.

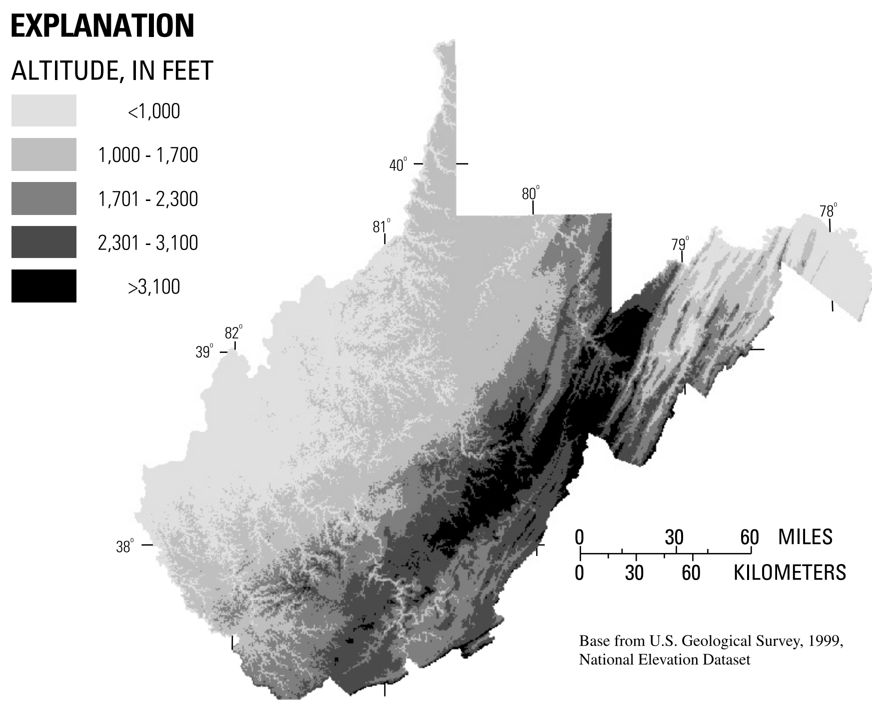

Figure 2. Altitudes in West Virginia.

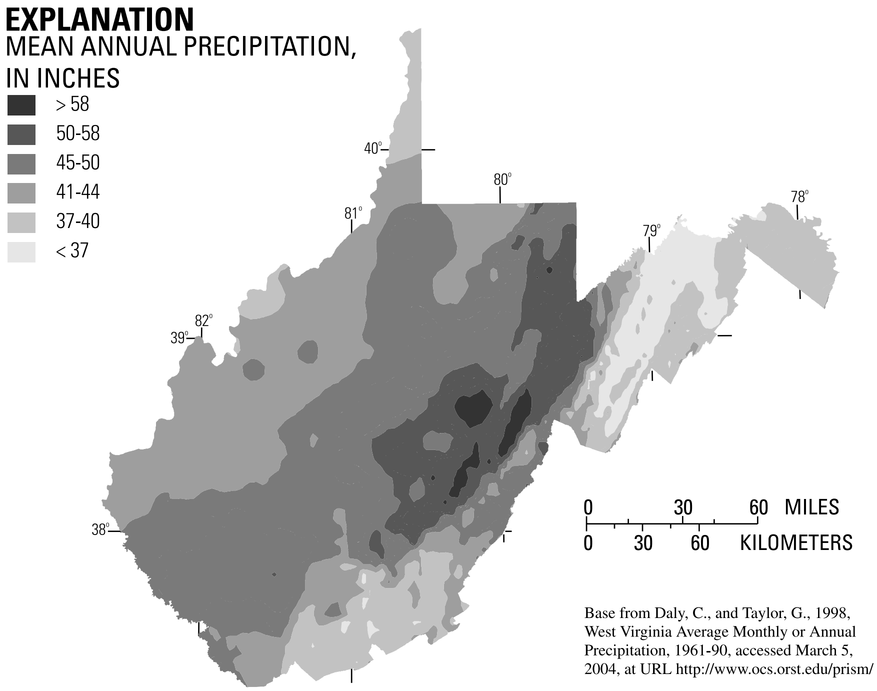

Figure 3. Mean annual precipitation in West Virginia.

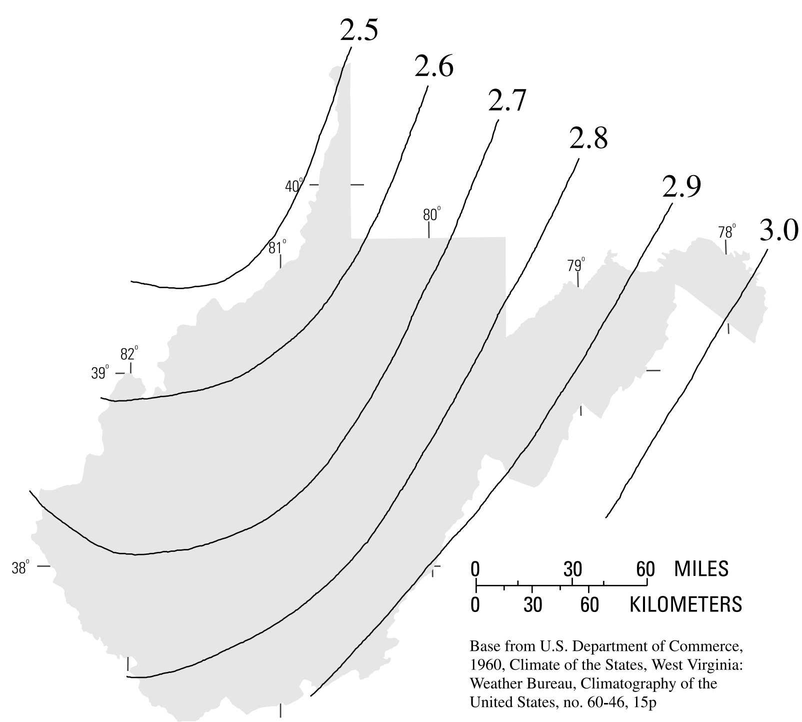

Figure 4. Two-year, 24-hour precipitation intensity, in inches, in West Virginia.

uted in patterns different than that of annual precipitation. The 2-year, 24-hour precipitation intensity increases from west to east (fig. 4). Average annual snowfall is influenced by the same orographic factors that influence average precipitation, but is even more strongly influenced by altitude.

Land uses in West Virginia that affect streamflow are determined by topography, geology, and location. Extensive commercial agriculture (more than about 25 percent of land cover) is limited to the Ohio and Kanawha River terraces, the Greenbrier, Bluestone, and Tygart Valley River Basins, and valleys in the Valley and Ridge Province. The only major urbanized areas in West Virginia are in the Charleston-Huntington area and other areas near the Ohio River, and in the Clarksburg-Morgantown area. The primary land cover in the rest of West Virginia is forest. Coal mining is economically and hydrologically important but is difficult to quantify historically or at a regional scale. The extent of underground mining is particularly difficult to quantify. Underground and surface mining, which are usually done in the same areas, have complex hydrologic effects that sometimes counteract each other.

Stream gaging network in West Virginia

The stream-gaging program of the USGS is an aggregation of networks and individual streamflow stations that originally were established for various purposes (Wahl and others, 1995). The general objective of the stream-gaging program is to provide information on flow characteristics at any point on any stream, either from measurements or estimates based on statistical relations. Streamflow data are collected for immediate decision making, future planning, or both.

Historical trends in the extent of the network

The stream-gaging program in West Virginia, as elsewhere in the United States, has expanded and contracted in response to concern about floods and droughts, changes in public water sources or standards for project design, national concern about the effect of surface mining on hydrology, and specific legislative acts (Wahl and others, 1995). Changes in the number of stream-gaging stations in West Virginia are important to this study because many of the stations used have been discontinued and many were operated for a relatively short time, so that flow frequencies calculated from these stations reflect the hydrologic conditions of the time they were operated. Consequently, statistics such as the 1.5-year flow may be skewed, when calculated from a station with a short period of record.

About 20 stream-gaging stations were operated in West Virginia between 1911, the year that the first flow measurement used in this study was made, and 1927 (fig. 5; Runner and others, 1989). In 1928, the number of stream-gaging stations approximately doubled. After this major increase, the number of stations generally increased to 94 active stations in 1947. About 95 stations made up the West Virginia network until 1964, when a network of small-stream crest gages was established to provide information for bridge design. The number of stream-gaging stations increased to 115 active stations in 1969 and remained consistent until 1977. In 1978, the number decreased slightly as several stream-gaging stations were discontinued but others were activated as part of the Coal Hydrology Program, a national program mandated by the Surface Mining Control and Reclamation Act to define hydrologic conditions in areas with surface mining. In 1983, following the end of the Coal Hydrology Program, the number of stream-gaging stations dropped from 103 to 73. The stream-gaging network was partially restored following the 1985 flood (Carpenter, 1988) to 81 stations. Except for a few years in the 1990s when two phases of the crest-gage program were active, the network has included between 80 and 90 stations.

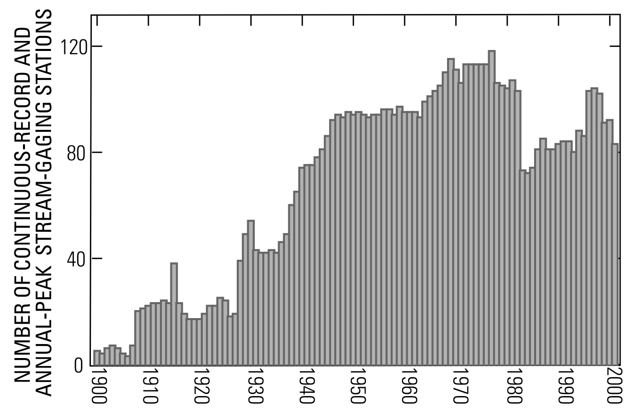

Figure 5. Number of continuous-record and annual-peak stream-gaging stations in West Virginia, 1900-2001. Data from Runner and others (1987) and U.S. Geological Survey Annual Water-Resources Data Reports (1986-2001)

Limitations of data available from the stream-gaging network

Historical stream-gaging data from West Virginia have major limitations because of geographic and size distribution of streams in the network (fig. 5; table 1). The most serious problem with the stream-gaging network is lack of stream-gaging stations on streams draining areas less than 100 square miles and especially on streams draining less than 10 square miles, but the geographic distribution of stream-gaging stations is also a major problem in interpreting the regional relations of channel characteristics and drainage area.

At most stream-gaging stations on small streams, only a few high-flow current-meter measurements were made. Small streams are generally flashy and hard to reach before high water

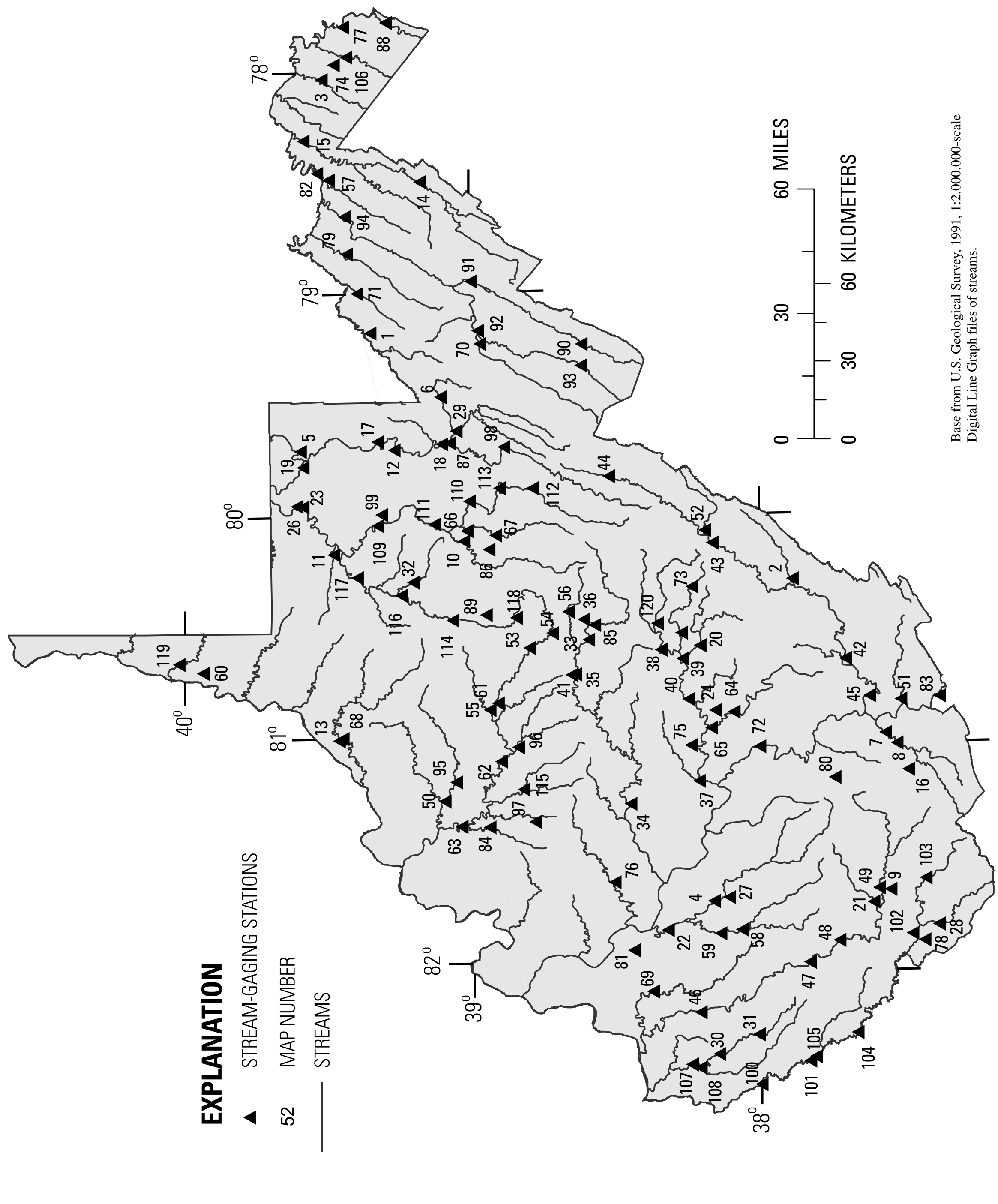

Figure 6. Selected stream-gaging stations in West Virginia.

Table 1. Map numbers and station numbers for selected stream-gaging stations in West Virginia.

Map number	Station number	Stream-gaging station	Drainage area (mi^2)
1	01595300	Abram Creek at Oakmont	42.6
2	03182700	Anthony Creek near Anthony	144
3	01614000	Back Creek near Jones Springs	235
4	03198500	Big Coal River at Ashford	391
5	03070500	Big Sandy Creek at Rockville	200
6	03066000	Blackwater River at Davis	85.9
7	03179500	Bluestone River at Lilly	438
8	03179000	Bluestone River near Pipestem	395
9	03202480	Briar Creek at Fanrock	7.34
10	03053500	Buckhannon River at Hall	277
11	03061500	Buffalo Creek at Barrackville	116
12	03069880	Buffalo Creek near Rowlesburg	12.2
13	03114650	Buffalo Run near Little	4.19
14	01610500	Cacapon River at Yellow Springs	306
15	01611500	Cacapon River near Great Cacapon	675
16	03178500	Camp Creek near Camp Creek	32
17	03070000	Cheat River at Rowlesburg	974
18	03069500	Cheat River near Parsons	722
19	03071000	Cheat River at Pisgah	1,354
20	03189000	Cherry River at Fenwick	150
21	03202750	Clear Fork at Clear Fork	126
22	03200500	Coal River at Tornado	862
23	03062400	Cobun Creek at Morgantown	11
24	03189650	Collison Creek near Nallen	2.78
25	03187500	Cranberry River near Richwood	80.4
26	03062500	Deckers Creek at Morgantown	63.2
27	03198450	Drawdy Creek near Peytona	7.75
28	03212980	Dry Fork at Beartown	209
29	03065000	Dry Fork at Hendricks	349
30	03206800	East Fork Twelvepole Creek near East Lynn	139
31	03206600	East Fork Twelvepole Creek near Dunlow	38.5
32	03059500	Elk Creek at Quiet Dell	84.6

Table 1. Map numbers and station numbers for selected stream-gaging stations in West Virginia.—Continued

Map number	Station number	Stream-gaging station	Drainage area (mi^2)
33	03195000	Elk River at Centralia	281
34	03197000	Elk River at Queen Shoals	1,145
35	03195500	Elk River at Sutton	542
36	03194700	Elk River below Webster Springs	266
37	03192000	Gauley River above Belva	1,317
38	03187000	Gauley River at Camden-on-Gauley	236
39	03189100	Gauley River near Craigsville	529
40	03189500	Gauley River near Summersville	680
41	03195600	Granny Creek at Sutton	6.98
42	03183500	Greenbrier River at Alderson	1,364
43	03182500	Greenbrier River at Buckeye	540
44	03180500	Greenbrier River at Durbin	133
45	03184000	Greenbrier River at Hilldale	1,619
46	03204000	Guyandotte River at Branchland	1,224
47	03203600	Guyandotte River at Logan	833
48	03203000	Guyandotte River at Man	758
49	03202400	Guyandotte River near Baileysville	306
50	03155500	Hughes River at Cisco	453
51	03177500	Indian Creek at Indian Mills	189
52	03182000	Knapp Creek at Marlinton	108
53	03151500	Little Kanawha River near Burnsville	155
54	03151400	Little Kanawha River near Wildcat	112
55	03152500	Leading Creek near Glenville	144
56	03195250	Left Fork Holly River near Replete	46.5
57	01609800	Little Cacapon River near Levels	108
58	03199000	Little Coal River at Danville	269
59	03199400	Little Coal River at Julian	318
60	03113700	Little Grave Creek near Glendale	4.95
61	03152000	Little Kanawha River at Glenville	387
62	03153500	Little Kanawha River at Grantsville	913
63	03155000	Little Kanawha River at Palestine	1,516
64	03190000	Meadow River at Nallen	287

Table 1. Map numbers and station numbers for selected stream-gaging stations in West Virginia.—Continued

Map number	Station number	Stream-gaging station	Drainage area (mi^2)
65	03190400	Meadow River near Mt. Lookout	365
66	03052000	Middle Fork River at Audra	148
67	03051500	Middle Fork River at Midvale	122
68	03114500	Middle Island Creek at Little	458
69	03204500	Mud River at Milton	256
70	01606000	North Fork South Branch Potomac at Cabins	335
71	01599500	New Creek at Keyser	46.5
72	03185500	New River at Caperton	6,826
73	03187300	North Fork Cranberry River near Hillsboro	9.78
74	01616500	Opequon Creek near Martinsburg	273
75	03191500	Peters Creek near Lockwood	40.2
76	03201000	Pocatalico River at Sissonville	238
77	01618000	Potomac River at Shepherdstown	5,936
78	03213500	Panther Creek near Panther	31
79	01604500	Patterson Creek near Headsville	211
80	03185000	Piney Creek at Raleigh	52.7
81	03201410	Poplar Fork at Teays	8.47
82	01610000	Potomac River at Paw Paw	3,129
83	03177000	Rich Creek near Peterstown	50.6
84	03154500	Reedy Creek near Reedy	79.4
85	03195100	Right Fork Holly River at Guardian	51.9
86	03052500	Sand Run near Buckhannon	14.3
87	03069000	Shavers Fork at Parsons	213
88	01636500	Shenandoah River at Millville	3,022
89	03057500	Skin Creek near Brownsville	25.7
90	01607500	South Fork South Branch Potomac River at Brandywine	103
91	01608000	South Fork South Branch Potomac River near Moorefield	277
92	01606500	South Branch Potomac River near Petersburg	676
93	01605500	South Branch Potomac River at Franklin	179
94	01608500	South Branch Potomac River near Springfield	1,486
95	03155200	South Fork Hughes River at Macfarlan	210
96	03153000	Steer Creek near Grantsville	162

Table 1. Map numbers and station numbers for selected stream-gaging stations in West Virginia.—Continued

Map number	Station number	Stream-gaging station	Drainage area (mi^2)
97	03154250	Tanner Run at Spencer	2.82
98	03068610	Taylor Run at Bowden	5.06
99	03056250	Three Forks Creek near Grafton	96.8
100	03214900	Tug Fork at Glenhayes	1,507
101	03214500	Tug Fork at Kermit	1,280
102	03213000	Tug Fork at Litwar	504
103	03212750	Tug Fork at Welch	174
104	03213700	Tug Fork at Williamson	936
105	03214000	Tug Fork near Kermit	1,188
106	01617000	Tuscarora Creek above Martinsburg	11.3
107	03207000	Twelvepole Creek at Wayne	291
108	03207020	Twelvepole Creek below Wayne	300
109	03056500	Tygart Valley River at Fetterman	1,304
110	03051000	Tygart Valley River at Belington	406
111	03054500	Tygart Valley River at Philippi	914
112	03050000	Tygart Valley River near Dailey	185
113	03050500	Tygart Valley River near Elkins	271
114	03058500	West Fork River at Butcherville	181
115	03154000	West Fork Little Kanawha River at Rocksdale	205
116	03059000	West Fork River at Clarksburg	384
117	03061000	West Fork River at Enterprise	759
118	03057300	West Fork River at Walkersville	28.8
119	03112000	Wheeling Creek at Elm Grove	281
120	03186500	Williams River at Dyer	128

recedes. For a small stream that peaks within an hour after a storm, which is typical for streams in West Virginia that drain less than 10 mi^2, a hydrographer would have to predict when and where a storm might hit and travel there to measure while flow is still high. Often, making these measurements is not practical within time and staffing constraints. Also, many of the stream-gaging stations on small streams have shorter periods of record than stream-gaging stations on large streams, so there have not been as many chances to measure these streams at high flows. Because of the difficulty in making high-flow current-meter measurements at gaging stations on small streams, the typical practice is to use indirect flow measurements to define the rating in the range of bankfull rather than to extend ratings from lower current-meter measurements.

Many of the rivers in West Virginia form in the mountains in central West Virginia, where altitude and precipitation are greatest. Because most stream-gaging stations in West Virginia have been operated to determine flow in major rivers (those draining more than 500 mi^2), most stations on smaller streams have been operated in the headwaters of major river basins. Few stream-gaging stations have been operated on tributaries that enter near the mouth of a major stream. As a result, few stream-gaging stations have been operated within about 50 miles of the Ohio River, particularly north of the Little Kanawha River.

Runner and others (1989) noted that one of the greatest weaknesses of the stream-gaging network in West Virginia was the lack of stream-gaging stations on minor tributaries of the Ohio River. Geology, topography, elevation, average precipitation, and precipitation intensity are substantially different in this region than in the central highlands (fig. 3, fig. 4).

Basin characteristics of gaged streams

Basin characteristics used in this study were the same as those used by Wiley and others (2002; 2000). Basin characteristics were determined by visual integration of various mapped characteristics. Land use, including coal mining, was not among the basin characteristics that were considered. This study would have been strengthened by GIS analysis and the inclusion of some additional basin characteristics, including land use and surface geology; however, outlines of the basins were not available as GIS coverages.

Acknowledgements

The Canaan Valley Institute facilitated cooperation for this project through stream restoration workshops and meetings, and creation of the West Virginia Stream Team. The West Virginia Stream Team is an association of Federal agencies, State agencies, academia, and other groups that share an interest in preserving and restoring the quality of streams in West Virginia. Members of the West Virginia Stream Team, particularly the Canaan Valley Institute, the Natural Resource Conservation Service, and West Virginia Department of Natural Resources contributed to the development of the project objectives.

Methods

The present study used flow measurements made at USGS stream-gaging stations in West Virginia between 1911 and 2002. Flow measurements during this period were made using documented methods (U.S. Geological Survey, 1901; Lyon, 1915; Corbett and others, 1943; Rantz and others, 1982). Changes in methodology between 1915 and 1943 were documented in internal agency memoranda. The greatest change in methodology between 1911 and 2002 came when automobiles and roads progressed so that hydrographers began to drive to stream-gaging stations, instead of traveling by train. This change allowed hydrographers to bring heavier sounding weights on field trips, which in turn allowed hydrographers to sound stream depth simultaneously while measuring velocity at high flow. At some stream-gaging stations, flow measurements made before this change were not comparable to those made afterward; however, these data were filtered out of this study.

Standard measurement procedures at stream-gaging stations

Flow measurements are made by measuring stream width, depth, and velocity (Wahl and others, 1995). When stream stage is low and the stream can be waded, flow measurements are made by wading with a current meter mounted on a wading rod. If the water is too deep for wading, then the measurement is made by lowering the meter either from a bridge or cableway that crosses the stream.

Because of changing flow or channel characteristics, wading measurements may be made at several different cross sections near a stream-gaging station. Bridge or cableway measurements are made at the same cross-section. Generally, if a bridge is available near a stream-gaging station, high-flow measurements are made from the bridge. A cableway is usually installed only if a stream-gaging station is far from the nearest bridge, or if accurate measurements cannot be made at the available bridge.

Database construction and quality assurance procedures

Data from more than 10,000 flow measurements were entered into a database. At stream-gaging stations with fewer than 30 years of record, all measurements made from a bridge or cableway were entered and analyzed. At stations with more than 30 years of record, at least the most recent 30 years of measurements were entered and analyzed. At stations where fewer than 30 measurements were made from a bridge or cableway, all measurements made from a bridge or cableway were entered and analyzed. All bridge or cableway measurements used to define the current (2003) stage-discharge relation were used for all stations, regardless of when the measurements were made. At stations where the gage datum had been changed, indicating a major shift in the channel, up to 30 years of measurements prior to the datum change were entered and analyzed. At stations where more than one bridge or cableway measuring section was identified, up to 30 years of measurements were entered and analyzed for each cross section. Finally, at stations where plots and regression diagnostics indicated a weak relation between flow and channel geometry characteristics, additional measurements were entered and analyzed if station records suggested that a temporary disturbance, such as bridge construction near the measuring bridge, was the cause of the weak relation.

For quality assurance of data entry, data were checked by calculating flow as the product of area and velocity, comparing the calculated flow to the entered flow, and resolving any discrepancy. Also, data entry was checked graphically; plots of flow and channel geometry characteristics of all measurements entered for a stream-gaging station were examined for outliers, and data entry of all outliers was checked. For all outliers used in the final computation of at-a-station curves, the original calculation of flow was checked. Station records were reviewed to see if the measurement was used in developing stage-discharge ratings; measurements that were not used in rating development, usually because of concerns about accuracy, were not used in developing at-a-station curves.

Factors affecting selection of stream-gaging stations for analysis

Not all stream-gaging stations in the West Virginia network had records suitable for use in this study. Stream-gaging stations with less than 10 years of record were not considered for data analysis, because for these stations, the 1.5 year recurrence interval could not be calculated with the desired accuracy (Wiley and others, 2002). Stream-gaging stations with contributing drainage areas greater than 2,000 mi^2 were not considered for data analysis. Data from regulated streams were not considered for analysis, although data collected from these streams before they were regulated were analyzed. The long-term stream-gaging network contained no streams that drain primarily urban areas. Data from discontinued stream-gaging stations were analyzed if the stations had more than 10 years of record.

Relations of flow with area, width, and average depth at cross sections

For many cross sections, the relations between flow and cross-sectional area, flow and width, and flow and average depth are linear at a logarithmic scale (Leopold and others, 1964). Dunne and Leopold (1978) recommend that to determine the relation between flow and other channel characteristics, a straight line should be fitted to data points by eye. Rosgen (1996) recommends obtaining all available flow-measurement data from a stream-gaging station and performing regression analysis on them to develop at-a-station curves. Regression analysis assumes that data are related linearly (Helsel and Hirsch, 1992). Dunne and Leopold (1978) note that at-a-station curves may not always be linear, although log-linear relations are a reasonable generalization.

Examination of graphs of cross-sectional area as a function of flow at several stream-gaging stations in West Virginia showed for most stations a set of complex and often nonlinear relations, rather than a single clear linear relation (fig. 7). The relations between area and flow for the Middle Fork near Audra were typical in that the graph showed measurements made by wading were widely scattered, but measurements made from cableways fit a curve tightly. These patterns are not unusual, and have been noted previously (Leopold and Maddock, 1953; Leopold and others, 1964; Dunne and Leopold, 1978; Leopold, 1994). At most stream-gaging stations, high-flow measurements are made at a single cross section, either at a cableway or a bridge, but at wadeable flow, measurements are made at many cross sections. Middle Fork near Audra is unusual in that most measurements made by wading are made at the same cross section, where it is particularly convenient to attach a tagline. Measurements made at this cross-section and the one at the cableway provide two sets of data, each from distinct cross sections in pools; low-flow measurements are made from several cross sections from a 50- to 100-foot reach in a riffle (fig. 7). Fitting a regression line through all available measurements gives a significant and strong correlation ($p < 0.001$, $R^2 = 0.936$), but also provides a regression line that does not pass through the measurements made at or near bankfull flows. This result is not surprising considering that the data violate linearity, the only assumption of linear regression necessary for all common uses of it (Helsel and Hirsch, 1991). Additionally, most of the measurements, particularly on smaller streams, were made by wading at medium and low flows, which violates the assumptions of randomness and normal distribution and biases the regression line, pulling it toward the majority of measurements and away from the measurements made at or near the flow of interest, and gives a greatly different line than would be produced by most analysts who fit a curve by eye to the same set of data.

For the Middle Fork near Audra, fitting lines by eye to the subsets of data that can be identified as linearly related points from distinct cross sections gives three lines that approach each other at bankfull (fig. 7). However, measurements were rarely documented well enough to determine at which cross section they were made. Fitting a line by eye to points that could not be documented as being from a particular cross section was considered highly subjective and less accurate than simply fitting the data from the high-flow cross section. Consequently, measurements made by wading were excluded from analysis (except at Taylor Run near Bowden, where measurements were made under the bridge from which high-flow measurements were made, so measurements made by wading were considered to be at the same cross section as measurements made from the bridge).

For many stream-gaging stations, the relation between flow, and area, width, and depth at a high-flow cross section is linear throughout the range of measured flows. For other stream-gaging stations, though, the overall relation is not linear, but there are often two approximately linear relations at different stages and an inflection point is typical at about half bankfull (fig. 8). Linear regression of log-transformed variables from stations where the overall relation is not linear often gives p-values less than 0.05, and R^2 values greater than 0.80, although the regression curve may not give a good fit of measurements made at flows at or near bankfull.

As a surrogate for fitting curves by eye to measurements made at or near bankfull, a procedure was developed in which measurement data were filtered to include those measurements made at the same cross section at flows between 0.5 and 5.0 times the 1.5-year recurrence flow. Regression equations were computed for these subsets of data, and data and curves were plotted to examine them for linearity; all the stream-gaging stations included in regional analysis had a linear relation in this subset of measurement data. Regression equations for flow near bankfull were used for regional analysis only if at least

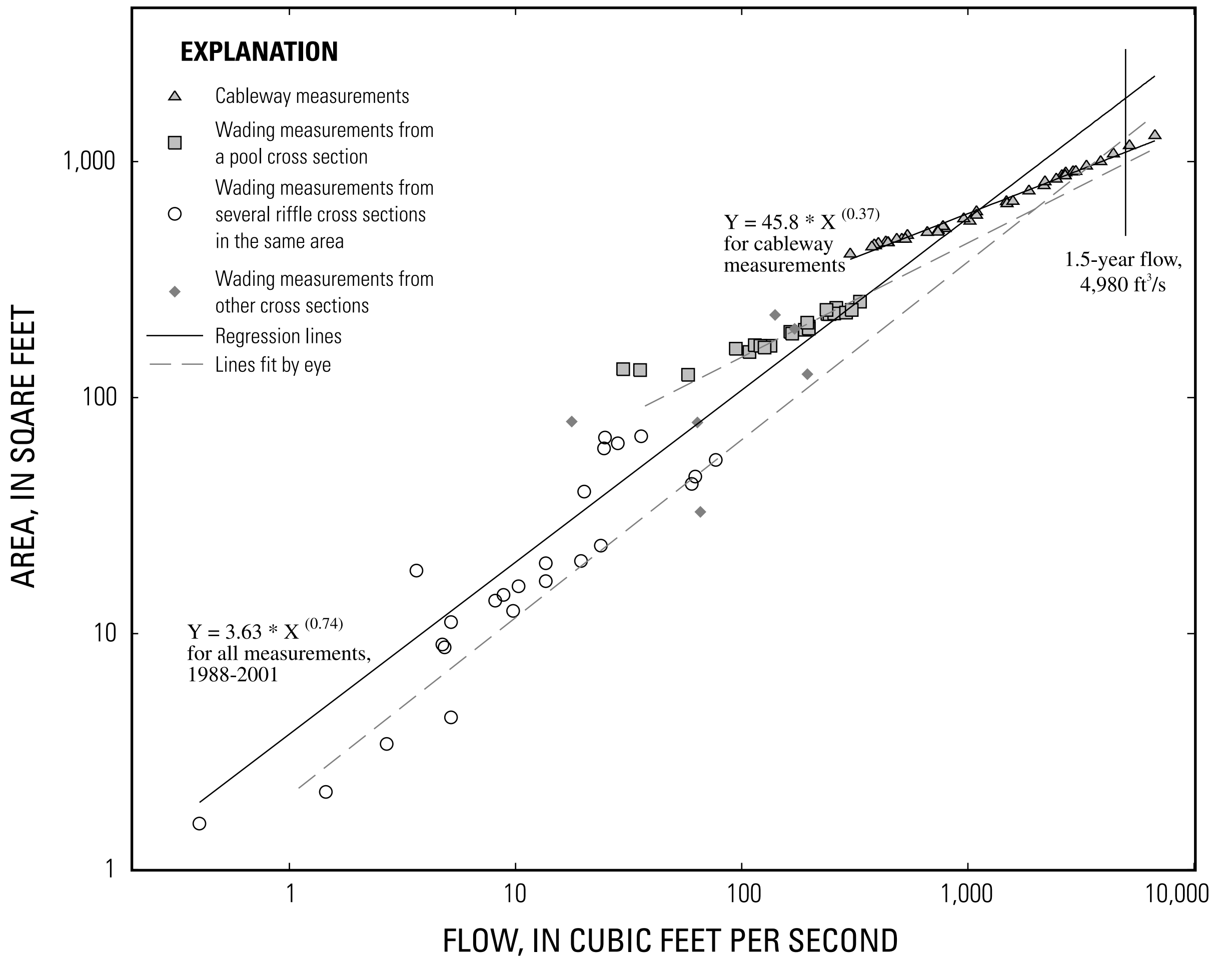

Figure 7. Relations between area and flow for (1) all flow measurements made at the Middle Fork near Audra, W.Va., 1988-20001, and selected earlier high-flow measurements, and (2) flow measurements made from the cableway.

three flow measurements had been made between 0.5 and 5.0 times bankfull, and linear regression of flow and cross-sectional area was statistically significant ($p < 0.05$), and had minimal scatter ($R^2 = 0.80$). Most stream-gaging stations with high scatter among measurements in this subset had poor measuring cross sections. In all, 74 stream-gaging stations met these criteria. Regression equations were also developed from all measurements available from a given bridge or cableway cross section (Appendix 1).

Bridges

Bridges can change channel dimensions and stream hydraulic properties. At some bridges, flow is confined between piers or abutments; and at these bridges, velocity and depth increase more rapidly with increasing flow than at cross sections without bridges (Dunne and Leopold, 1978). Increased depth and velocity at bridges can also cause scour of the stream bottom. Because of these characteristics, measurements made at bridges were a concern. Not all bridges, however, confine bankfull flow; some bridges are built so that the streams they span continue to increase in width as flow increases. Because of this, at-a-station curves were developed and analyzed for bridge cross sections, although (as discussed later) some stream characteristics at bridge cross sections that confine flow were not included in the regional analysis.

Backwater

On some stream reaches, backwater affects the stage-discharge relation and causes it to be a complex function of water-surface slope (Rantz and others, 1982). At cross sections in these reaches, the relation between flow and channel characteristics is also complex; any given flow at these stream-gaging stations may have a range of areas, widths, depths, and velocities, depending on downstream conditions, such as whether stage was rising and falling, or the stage of a receiving stream when a measurement was made on a tributary. Backwater most frequently affects these streams at high flow. Leading Creek at Glenville, Steer Creek near Grantsville, Little Kanawha River at Palestine, and Guyandotte River at Branchland were among the stream-gaging stations affected by backwater; therefore,

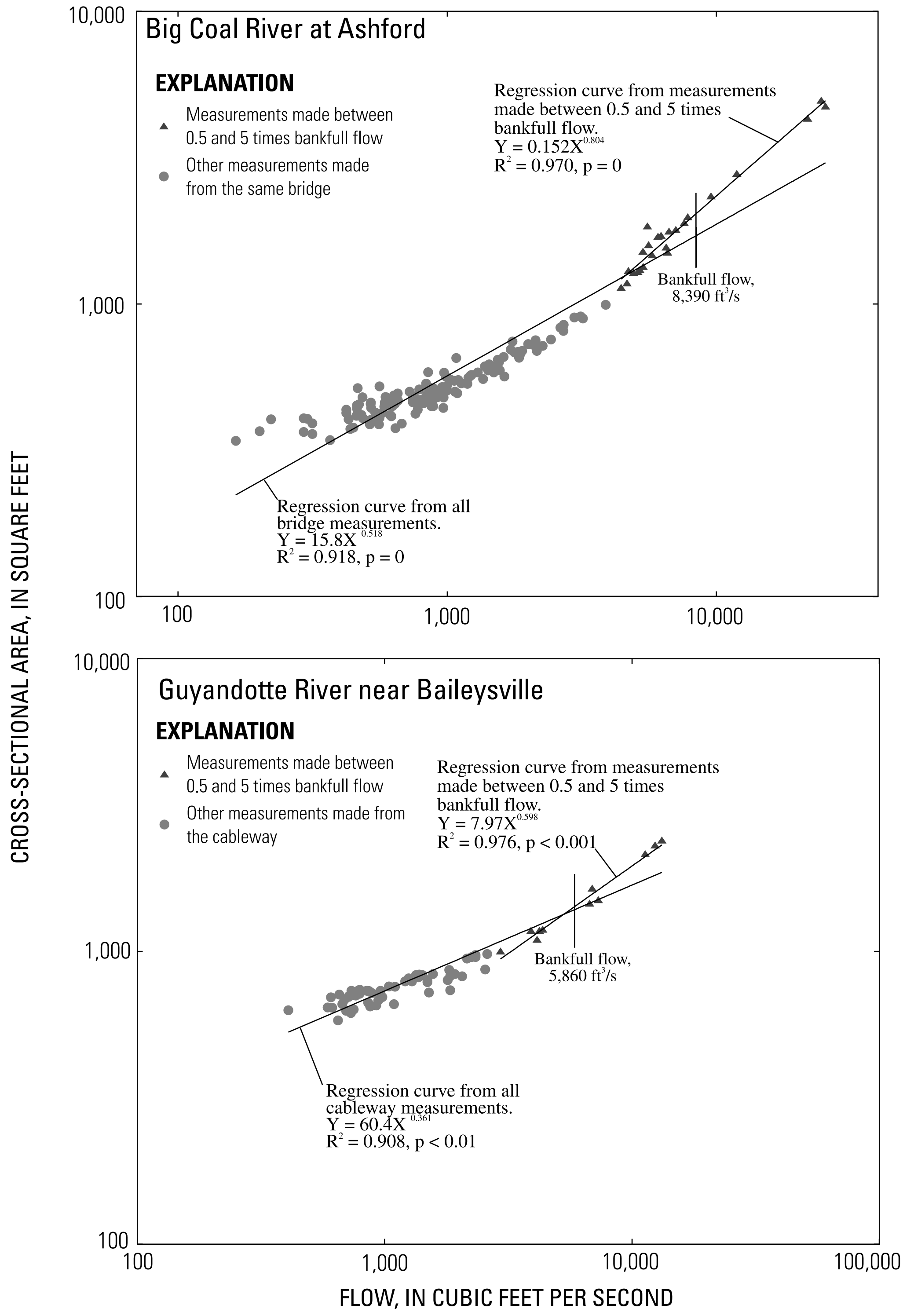

Figure 8. Relation between cross-sectional area and flow for flow measurements made at a bridge over Big Coal River at Ashford, W.Va., and a cableway over Guyandotte River near Baileysville, W.Va., compared to the relation for each stream-gaging station for only those measurements made at flows between 0.5 and 5 times bankfull flow.

they were excluded from regional analysis, but at-a-station curves (equations for the relations between flow and cross-sectional area, flow and width, and flow and average depth) were calculated for these stream-gaging stations.

Bankfull channel characteristics and regional relations

For the at-a-station curves for cross-sectional area, the factors, or intercepts in a logarithmic plot of the curves, ranged from 0.053 for Camp Creek near Camp Creek to 85.1 for South Fork of the South Branch of the Potomac River near Moorefield (table 2). The exponents, or slopes in logarithmic plots of the curves, ranged from 0.291 for South Fork of the South Branch of the Potomac River near Moorefield to 1.21 for Camp Creek near Camp Creek.

For the at-a-station curves for average depth, the factors ranged from 0.029 for Twelvepole Creek below Wayne, to 12.3 for Opequon Creek near Martinsburg, and the exponents ranged from –0.079 for Opequon Creek near Martinsburg to 0.652 for Little Kanawha River at Grantsville (table 3). The depth curve for Opequon Creek near Martinsburg was significant ($p < 0.05$), although the depth curves for six other stream-gaging stations were not significant. For the at-a-station curves for average width, the factors ranged from 0.0132 for Opequon Creek near Martinsburg, to 12.3 for 235 for Cheat River near Rowlesburg, and the exponents ranged from 0.0364 for Cheat River near Rowlesburg, to 1.03 for Opequon Creek near Martinsburg (table 4).

The range of values for slope and intercept of the at-a-station curves emphasizes that using a subset of available data to develop these curves so that they fit the near-bankfull data may make these curves unsuitable for computing the values of channel characteristics at flows that are less than the bankfull flow. The curves for several stream-gaging stations (such as the depth curve for Opequon Creek, which has a negative slope) are probably artifacts of this approach. These curves are a surrogate for graphically picking values from a plot; they are not equations for estimating channel characteristics throughout a range of flows. If determining channel characteristics at below-bankfull flows, consider using the equations in Appendix 1. The equations in Appendix1, however, include some that were developed from data that do not meet assumptions for linear regression, some that are not statistically significant ($p < 0.05$), some that describe data with weak correlations ($R^2 < 0.80$), or some that were developed from backwater-affected cross sections.

Regional relations in bankfull channel characteristics

Regional relations were determined from patterns in data, rather than by arbitrarily assigning stream-gaging stations to physiographic regions, and the methods used were similar to those used in regional analyses of streamflow characteristics (Riggs, 1973). In an iterative process, cross-sectional area was plotted in relation to drainage area, stream-gaging stations were grouped according to basin characteristics, multiple regressions were run, the basin characteristics that explained the greatest amount of variation among the stream-gaging stations were selected, and plots of residuals were examined. Cross-sectional area was used to delineate regions. Equations for the other characteristics were determined for the regions delineated from the area data.

Bankfull flow explained more variation in bankfull cross-sectional area ($R^2 = 0.938$) than did drainage area ($R^2 = 0.881$), when all stream-gaging stations were considered. There was also less regional variation in the relation between bankfull cross-sectional area and bankfull flow than in the relation between bankfull cross-sectional area and drainage area. Regression equations for the relation between bankfull area and flow, however, were less useful than regression equations for drainage area. Except at stream-gaging stations, bankfull flow would have to be determined by either directly measuring bankfull area and other characteristics, or by using regional equations (Wiley and others, 2002) which would introduce additional error. The strong relation between bankfull area and bankfull flow, however, suggests that more of the regional variation in bankfull area may be caused by basin-scale characteristics (such as total precipitation, precipitation intensity, basin relief, and drainage density) that cause the regional variation in bankfull flow, than by reach-specific characteristics (such as a rock unit in which a stream channel formed).

Velocity and drainage area were unrelated ($R^2 = 0.031$, $p > 0.05$), so regional relations between velocity and drainage area were not developed. Cross-sectional area, width, and average depth were significantly related to drainage area for the entire study area ($p < 0.0001$). On the basis of the regression analysis of cross-sectional area, West Virginia was divided into an Eastern Region and a Western Region, along physiographic province boundaries (fig. 1; table 5). Regression equations are defined for streams draining between 46.5 and 1,619 mi^2 for the Eastern Region, and between 2.78 and 1,354 mi^2 for the Western Region. Standard error for the six regression equations ranged between 8.7 and 16 percent. (In this report, "standard error" refers to residual standard error, which is also known as the standard error of the regression.)

Some of the bridges from which measurements were made apparently confined the streams which they crossed, by presenting barriers to prevent the streams from widening as flows increased. Apparently confining bridges could easily be distinguished by examining at-a-station curves for flow and width to see if width remained constant through a range of flows (fig. 9). Graphs of regional relations between drainage area and bankfull cross-sectional area, average depth, and width, which identified data from apparently confining bridges, were examined to determine if including data obtained at these bridges skewed regional relations. This analysis was done within regions so that possible effects of bridges on stream channels could be distinguished from regional differences in stream-channel characteristics.

Table 2. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and cross-sectional area for stream-gaging stations in West Virginia used to develop regression equations.

[R^2 = correlation coefficient; "number of measurements" refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; all equations are power curves of the form Area = Factor(Flow)^{Exponent}.]

			Area			
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
01595300	Abram Creek at Oakmont	4	3.85	0.557	0.9588	0.02
01599500	New Creek at Keyser	15	1.99	0.646	0.9717	0.00
01604500	Patterson Creek near Headsville	10	7.79	0.568	0.9515	0.00
01605500	South Branch Potomac River at Franklin	4	2.39	0.664	0.9983	0.00
01606500	South Branch Potomac River near Petersburg	12	10.2	0.534	0.8974	0.00
01607500	South Fork South Branch Potomac River at Brandywine	11	0.755	0.840	0.8073	0.00
01608000	South Fork South Branch Potomac River near Moorefield	9	85.1	0.291	0.8851	0.00
01608500	South Branch Potomac River near Springfield	8	6.50	0.650	0.8854	0.00
01610500	Cacapon River at Yellow Springs	4	14.6	0.562	0.9934	0.00
01611500	Cacapon River near Great Cacapon	14	2.09	0.767	0.9724	0.00
01614000	Back Creek near Jones Springs	6	28.1	0.422	0.9422	0.00
01616500	Opequon Creek near Martinsburg	6	0.388	0.949	0.9667	0.00
03050000	Tygart Valley River near Dailey	11	2.30	0.748	0.9741	0.00
03051000	Tygart Valley River at Belington	33	5.61	0.660	0.9811	0.00
03051500	Middle Fork River at Midvale	5	0.586	0.883	0.9130	0.01
03052000	Middle Fork River at Audra	12	32.1	0.419	0.9934	0.00
03052500	Sand Run near Buckhannon	6	4.08	0.537	0.8510	0.01
03053500	Buckhannon River at Hall	24	11.7	0.540	0.9897	0.00
03054500	Tygart Valley River at Philippi	24	10.5	0.615	0.9824	0.00
03056500	Tygart Valley River at Fetterman	14	17.1	0.554	0.9961	0.00
03057500	Skin Creek near Brownsville	6	0.539	0.906	0.8561	0.01
03058500	West Fork River at Butcherville	6	1.32	0.755	0.9132	0.00
03059000	West Fork River at Clarksburg	18	2.53	0.734	0.9830	0.00
03059500	Elk Creek at Quiet Dell	18	1.73	0.769	0.9331	0.00
03061500	Buffalo Creek at Barrackville	10	4.83	0.626	0.9001	0.00
03062400	Cobun Creek at Morgantown	4	1.15	0.658	0.9391	0.03
03066000	Blackwater River at Davis	21	4.73	0.643	0.9882	0.00

Table 2. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and cross-sectional area for stream-gaging stations in West Virginia used to develop regression equations.—Continued

[R^2 = correlation coefficient; “number of measurements” refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; all equations are power curves of the form Area = Factor(Flow)^{Exponent}.

			Area			
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
03069000	Shavers Fork at Parsons	16	20.0	0.449	0.9223	0.00
03069500	Cheat River near Parsons	6	29.2	0.470	0.9942	0.00
03070000	Cheat River at Rowlesburg	12	16.8	0.534	0.9932	0.00
03070500	Big Sandy Creek at Rockville	7	8.74	0.516	0.9878	0.00
03071000	Cheat River at Pisgah	4	11.4	0.572	0.9995	0.00
03114500	Middle Island Creek at Little	18	0.638	0.876	0.9770	0.00
03151400	Little Kanawha River near Wildcat	5	0.595	0.884	0.8702	0.02
03151500	Little Kanawha River near Burnsville	28	3.53	0.725	0.9198	0.00
03152000	Little Kanawha River at Glenville	14	1.66	0.812	0.9206	0.00
03153500	Little Kanawha River at Grantsville	13	0.341	0.977	0.9898	0.00
03154000	West Fork Little Kanawha River at Rocksdale	20	13.6	0.574	0.9619	0.00
03154500	Reedy Creek near Reedy	9	0.598	0.887	0.9153	0.00
03155200	South Fork Hughes River at Macfarlan	10	2.04	0.787	0.9611	0.00
03155500	Hughes River at Cisco	17	1.330	0.839	0.9010	0.00
03178500	Camp Creek near Camp Creek	9	0.053	1.21	0.8669	0.00
03179000	Bluestone River near Pipestem	15	26.2	0.409	0.9695	0.00
03180500	Greenbrier River at Durbin	7	6.68	0.569	0.9931	0.00
03182500	Greenbrier River at Buckeye	12	22.3	0.494	0.9902	0.00
03183000	Second Creek near Second Creek	10	0.250	0.924	0.8711	0.00
03183500	Greenbrier River at Alderson	4	4.11	0.690	0.9919	0.00
03184000	Greenbrier River at Hilldale	21	5.41	0.653	0.9867	0.00
03186500	Williams River at Dyer	12	2.29	0.679	0.8184	0.00
03189000	Cherry River at Fenwick	7	23.8	0.442	0.9314	0.00
03189100	Gauley River near Craigsville	7	14.5	0.549	0.9147	0.00
03189500	Gauley River near Summersville	8	32.3	0.458	0.9217	0.00
03189650	Collison Creek near Nallen	4	1.89	0.625	0.9902	0.00
03190000	Meadow River at Nallen	23	17.9	0.478	0.9819	0.00
03190400	Meadow River near Mt. Lookout	4	17.2	0.478	0.9990	0.00
03192000	Gauley River above Belva	8	8.95	0.610	0.9900	0.00

Table 2. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and cross-sectional area for stream-gaging stations in West Virginia used to develop regression equations.—Continued

[R^2 = correlation coefficient; "number of measurements" refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; all equations are power curves of the form Area = Factor(Flow)^{Exponent}.

			Area			
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
03194700	Elk River below Webster Springs	10	6.68	0.584	0.9649	0.00
03195000	Elk River at Centralia	8	48.9	0.409	0.9975	0.00
03195500	Elk River at Sutton	20	0.577	0.921	0.9732	0.00
03197000	Elk River at Queen Shoals	41	13.4	0.584	0.9539	0.00
03198500	Big Coal River at Ashford	24	1.42	0.804	0.9698	0.00
03199000	Little Coal River at Danville	33	0.941	0.845	0.9621	0.00
03200500	Coal River at Tornado	21	3.95	0.689	0.9718	0.00
03201000	Pocatalico River at Sissonville	28	3.02	0.758	0.9078	0.00
03201410	Poplar Fork at Teays	3	3.84	0.579	0.9988	0.02
03202400	Guyandotte River near Baileysville	12	9.32	0.579	0.9637	0.00
03203000	Guyandotte River at Man	18	12.9	0.538	0.9368	0.00
03203600	Guyandotte River at Logan	4	0.568	0.884	0.9993	0.00
03204500	Mud River at Milton	27	1.69	0.790	0.9663	0.00
03206600	East Fork Twelvepole Creek near Dunlow	3	6.58	0.562	0.9986	0.02
03207000	Twelvepole Creek at Wayne	17	2.21	0.759	0.9897	0.00
03207020	Twelvepole Creek below Wayne	5	1.40	0.833	0.9663	0.00
03212980	Dry Fork at Beartown	7	5.85	0.546	0.9976	0.00
03213500	Panther Creek near Panther	5	0.629	0.816	0.8659	0.02

Table 3. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and average depth for stream-gaging stations in West Virginia used to develop regression equations.

[R^2 = correlation coefficient; "number of measurements" refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; **bold type** distinguishes regression equations not significant at $p < 0.05$; *italic type* distinguishes regression equations for which $R^2 < 0.80$; all equations are power curves of the form Average depth = Factor(Flow)$^{\text{Exponent}}$.

			Average depth			
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
01599500	New Creek at Keyser	15	0.106	0.508	0.9565	0.00
01604500	Patterson Creek near Headsville	10	0.202	0.409	0.9024	0.00
01605500	South Branch Potomac River at Franklin	4	0.151	0.417	0.9983	0.00
01606500	***South Branch Potomac River near Petersburg***	12	***1.86***	***0.158***	***0.1574***	***0.20***
01608000	*South Fork South Branch Potomac River near Moorefield*	9	*2.51*	*0.123*	*0.4442*	*0.05*
01610500	Cacapon River at Yellow Springs	4	0.236	0.420	0.9977	0.00
01611500	Cacapon River near Great Cacapon	14	0.059	0.518	0.9752	0.00
01616500	*Opequon Creek near Martinsburg*	6	*12.3*	*-0.079*	*0.2993*	*0.61*
03050000	Tygart Valley River near Dailey	11	0.055	0.581	0.8917	0.00
03051000	Tygart Valley River at Belington	33	0.160	0.461	0.9142	0.00
03051500	***Middle Fork River at Midvale***	5	***0.318***	***0.365***	***0.5076***	***0.18***
03052000	Middle Fork River at Audra	12	0.574	0.317	0.9604	0.00
03054500	Tygart Valley River at Philippi	24	0.094	0.515	0.9587	0.00
03057500	*Skin Creek near Brownsville*	6	*0.624*	*0.295*	*0.7984*	*0.02*
03058500	***West Fork River at Butcherville***	6	***3.40***	***0.075***	***0.1881***	***0.39***
03059500	Elk Creek at Quiet Dell	18	0.148	0.512	0.8846	0.00
03066000	*Blackwater River at Davis*	21	*0.179*	*0.447*	*0.6597*	*0.00*
03069000	Shavers Fork at Parsons	16	0.365	0.307	0.9046	0.00
03069500	Cheat River near Parsons	6	0.199	0.398	0.9925	0.00
03070000	Cheat River at Rowlesburg	12	0.071	0.497	0.9931	0.00
03071000	Cheat River at Pisgah	4	0.163	0.446	0.9742	0.01
03114500	Middle Island Creek at Little	18	0.037	0.614	0.9737	0.00
03151400	Little Kanawha River near Wildcat	5	0.063	0.526	0.9956	0.00
03152000	*Little Kanawha River at Glenville*	14	*0.220*	*0.467*	*0.7436*	*0.00*
03153500	Little Kanawha River at Grantsville	13	0.031	0.652	0.9661	0.00
03154500	*Reedy Creek near Reedy*	9	*0.050*	*0.631*	*0.5584*	*0.02*

Table 3. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and average depth for stream-gaging stations in West Virginia used to develop regression equations.—Continued

[R^2 = correlation coefficient; "number of measurements" refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; **bold type** distinguishes regression equations not significant at $p < 0.05$; *italic type* distinguishes regression equations for which $R^2 < 0.80$; all equations are power curves of the form Average depth = Factor(Flow)^{Exponent}.

			Average depth			
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
03155200	South Fork Hughes River at Macfarlan	10	0.250	0.467	0.9698	0.00
03155500	***Hughes River at Cisco***	17	***0.130***	***0.507***	***0.9046***	***0.00***
03178500	Camp Creek near Camp Creek	9	0.566	0.221	0.1363	0.33
03179000	Bluestone River near Pipestem	15	0.843	0.264	0.9703	0.00
03180500	*Greenbrier River at Durbin*	7	*0.181*	*0.359*	*0.7943*	*0.01*
03186500	*Williams River at Dyer*	12	*0.093*	*0.461*	*0.6771*	*0.00*
03189000	Cherry River at Fenwick	7	0.332	0.368	0.9599	0.00
03189500	***Gauley River near Summersville***	8	***2.12***	***0.165***	***0.4327***	***0.08***
03190400	***Meadow River near Mt. Lookout***	4	***0.230***	***0.375***	***0.7989***	***0.11***
03192000	Gauley River above Belva	8	0.120	0.472	0.9668	0.00
03194700	Elk River below Webster Springs	10	0.121	0.453	0.9571	0.00
03195500	Elk River at Sutton	20	0.029	0.638	0.9689	0.00
03197000	Elk River at Queen Shoals	41	0.213	0.425	0.8923	0.00
03198500	Big Coal River at Ashford	24	0.107	0.519	0.8844	0.00
03200500	Coal River at Tornado	21	0.456	0.347	0.8731	0.00
03202400	Guyandotte River near Baileysville	12	0.399	0.376	0.9762	0.00
03203600	Guyandotte River at Logan	4	0.064	0.531	0.9945	0.00
03204500	Mud River at Milton	27	0.153	0.520	0.9807	0.00
03206600	East Fork Twelvepole Creek near Dunlow	3	0.430	0.348	1.0000	0.00
03212980	Dry Fork at Beartown	7	0.138	0.447	0.9963	0.00
03213500	Panther Creek near Panther	5	0.388	0.368	0.5064	0.18

Table 4. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and width for stream-gaging stations in West Virginia used to develop regression equations.

[R^2 = correlation coefficient; “number of measurements” refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; **bold type** distinguishes regression equations not significant at $p < 0.05$; *italic type* distinguishes regression equations for which $R^2 < 0.80$; all equations are power curves of the form Width = Factor(Flow)$^{\text{Exponent}}$.

		Width				
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
01599500	New Creek at Keyser	15	18.8	0.138	0.8054	0.00
01604500	***Patterson Creek near Headsville***	***10***	***38.6***	***0.159***	***0.6599***	***0.00***
01605500	South Branch Potomac River at Franklin	4	15.9	0.248	0.9695	0.02
01606500	South Branch Potomac River near Petersburg	12	17.8	0.249	0.8539	0.00
01608000	South Fork South Branch Potomac River near Moorefield	9	34.0	0.168	0.6914	0.01
01610500	Cacapon River at Yellow Springs	4	61.9	0.141	0.9674	0.02
01611500	*Cacapon River near Great Cacapon*	*14*	*35.8*	*0.248*	*0.7378*	*0.00*
01616500	*Opequon Creek near Martinsburg*	*6*	*0.0132*	*1.03*	*0.8763*	*0.01*
03050000	*Tygart Valley River near Dailey*	*11*	*42.2*	*0.168*	*0.5415*	*0.01*
03051000	*Tygart Valley River at Belington*	*33*	*35.0*	*0.199*	*0.4992*	*0.00*
03051500	Middle Fork River at Midvale	5	1.84	0.518	0.9675	0.00
03052000	*Middle Fork River at Audra*	*12*	*56.0*	*0.102*	*0.6861*	*0.00*
03054500	*Tygart Valley River at Philippi*	*24*	*111*	*0.0994*	*0.5665*	*0.00*
03057500	Skin Creek near Brownsville	6	0.863	0.611	0.8091	0.01
03058500	West Fork River at Butcherville	6	0.388	0.680	0.8428	0.01
03059500	*Elk Creek at Quiet Dell*	*18*	*11.7*	*0.256*	*0.7782*	*0.00*
03066000	*Blackwater River at Davis*	*21*	*26.5*	*0.196*	*0.2563*	*0.02*
03069000	*Shavers Fork at Parsons*	*16*	*54.8*	*0.141*	*0.4296*	*0.01*
03069500	Cheat River near Parsons	6	147	0.0722	0.9385	0.00
03070000	*Cheat River at Rowlesburg*	*12*	*235*	*0.0364*	*0.7253*	*0.00*
03071000	***Cheat River at Pisgah***	***4***	***70.2***	***0.125***	***0.8105***	***0.10***
03114500	*Middle Island Creek at Little*	*18*	*17.3*	*0.262*	*0.7895*	*0.00*
03151400	***Little Kanawha River near Wildcat***	***5***	***9.37***	***0.358***	***0.5423***	***0.16***
03152000	Little Kanawha River at Glenville	14	7.54	0.345	0.8185	0.00
03153500	Little Kanawha River at Grantsville	13	11.1	0.325	0.9417	0.00
03154500	***Reedy Creek near Reedy***	***9***	***12.0***	***0.257***	***0.1605***	***0.29***

Table 4. Regression equations, correlation coefficients, and p-values for the relations between near-bankfull flow and width for stream-gaging stations in West Virginia used to develop regression equations.—Continued

[R^2 = correlation coefficient; "number of measurements" refers to measurements made at 0.5 and 5 times the 1.5-year recurrence flow; **bold type** distinguishes regression equations not significant at $p < 0.05$; *italic type* distinguishes regression equations for which $R^2 < 0.80$; all equations are power curves of the form Width = Factor(Flow)^{Exponent}.

			Width			
Station number	Stream-gaging station	Number of measurements	Factor	Exponent	R^2	p-value
03155200	South Fork Hughes River at Macfarlan	10	8.16	0.320	0.8500	0.00
03155500	*Hughes River at Cisco*	*17*	*10.2*	*0.332*	*0.8497*	*0.00*
03178500	*Camp Creek near Camp Creek*	*9*	*0.094*	*0.990*	*0.9065*	*0.00*
03179000	Bluestone River near Pipestem	15	31.1	0.145	0.8596	0.00
03180500	***Greenbrier River at Durbin***	***7***	***36.9***	***0.210***	***0.5641***	***0.05***
03186500	*Williams River at Dyer*	*12*	*24.6*	*0.217*	*0.4866*	*0.01*
03189000	***Cherry River at Fenwick***	***7***	***71.7***	***0.0740***	***0.2664***	***0.24***
03189500	*Gauley River near Summersville*	*8*	*15.3*	*0.292*	*0.7270*	*0.01*
03190400	***Meadow River near Mt. Lookout***	***4***	***74.7***	***0.104***	***0.2068***	***0.55***
03192000	Gauley River above Belva	8	74.3	0.138	0.9153	0.00
03194700	*Elk River below Webster Springs*	*10*	*55.0*	*0.131*	*0.6252*	*0.01*
03195500	Elk River at Sutton	20	19.7	0.283	0.8083	0.00
03197000	*Elk River at Queen Shoals*	*41*	*63.0*	*0.159*	*0.6983*	*0.00*
03198500	*Big Coal River at Ashford*	*24*	*13.2*	*0.285*	*0.7770*	*0.00*
03200500	Coal River at Tornado	21	8.67	0.343	0.9119	0.00
03202400	*Guyandotte River near Baileysville*	*12*	*23.3*	*0.202*	*0.7826*	*0.00*
03203600	Guyandotte River at Logan	4	8.83	0.353	0.9898	0.01
03204500	Mud River at Milton	27	11.1	0.270	0.8512	0.00
03206600	**East Fork Twelvepole Creek near Dunlow**	**3**	**15.3**	**0.214**	**0.9922**	**0.06**
03212980	Dry Fork at Beartown	7	42.5	0.0986	0.9457	0.00
03213500	***Panther Creek near Panther***	***5***	***1.62***	***0.448***	***0.4552***	***0.21***

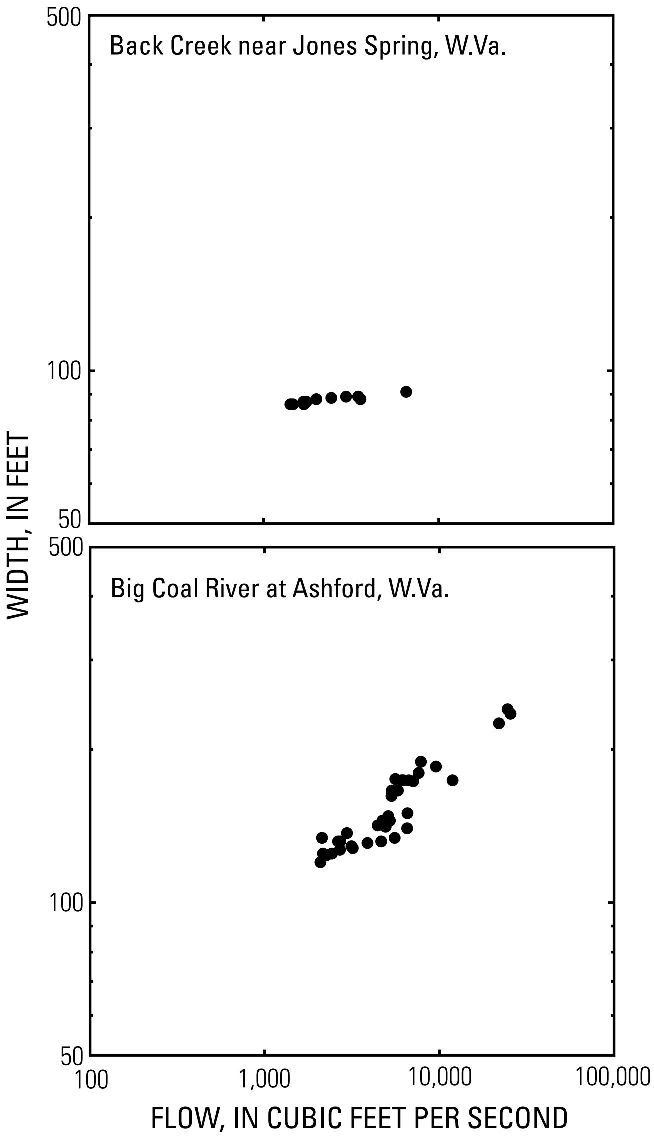

Figure 9. Relation of flow and width at bridges where flow is apparently confined (top) and not confined (bottom) by the bridge structure.

Cross-sectional area

Stream-gaging stations on streams draining the Valley and Ridge Province could be distinguished from stations on streams draining only the Appalachian Plateaus Province on a scatter plot of cross-sectional area and drainage area (fig. 10). Cross sections of streams draining the Appalachian Plateaus Province had a greater area relative to their drainage area than did cross sections of streams draining only the Valley and Ridge Province. Stations on streams draining both Valley and Ridge and

Table 5. Equations and regression statistics describing regional relations in drainage area and bankfull channel characteristics at selected stream-gaging stations in West Virginia.

[DA, drainage area in square miles; %, percent; R^2, correlation coefficient; <, less than; area is in square feet, and depth and width are in feet; all equations are power curves of the form Characteristic = Factor(Drainage Area)$^{\text{Exponent}}$]

Regression equation	Standard error (%)	R^2	number of sites	p-value
		Western Region		
Area =18.2(DA)$^{0.797}$	12.8	0.931	56	< 0.001
Depth = 1.32(DA)$^{0.351}$	11.0	0.712	36	< 0.001
Width = 16.0(DA)$^{0.423}$	9.0	0.842	36	< 0.001
		Eastern Region		
Area = 5.48(DA)$^{0.917}$	13.8	0.899	18	< 0.001
Depth = 0.59(DA)$^{0.411}$	8.7	0.723	11	< 0.001
Width = 8.76(DA)$^{0.503}$	16.0	0.537	11	0.01

Appalachian Plateaus Provinces plotted in a cluster with Valley and Ridge Province stations. The other analyses described in the previous section confirmed this relation. On the basis of these analyses, stream-gaging stations were grouped into two regions: the Western Region, comprised of stations on streams draining only the Appalachian Plateaus, and the Eastern Region, comprised of stations on streams draining the Valley and Ridge Province, including stations on streams draining some area within the Appalachian Plateaus Province.

Including the stream-gaging stations on streams that drained parts of both the Appalachian Plateaus and Valley and Ridge Provinces with the Eastern Region did not change the factor or exponent in the first three significant figures of the Eastern Region regression equation. Excluding these stream-gaging stations from the Western Region regression equation changed that equation substantially. Streams in West Virginia that drain areas in both the Valley and Ridge and Appalachian Plateaus Provinces include the North Branch of the Potomac River, the Greenbrier River, all of the Greenbrier River tributaries that are south of the river, the Bluestone River, and Dry Fork, a Tug Fork tributary.

The physiographic province boundary may not be the best line to divide the two regions, but it was used because no other explanatory data provide either sufficient measurement precision or a convincing justification for dividing the regions elsewhere. The 43-in. contour line of total annual precipitation, if used as a boundary, provides for slightly decreased regression residuals compared to separating the regions by physiography, but the precipitation line does not seem reasonable as a regional boundary.

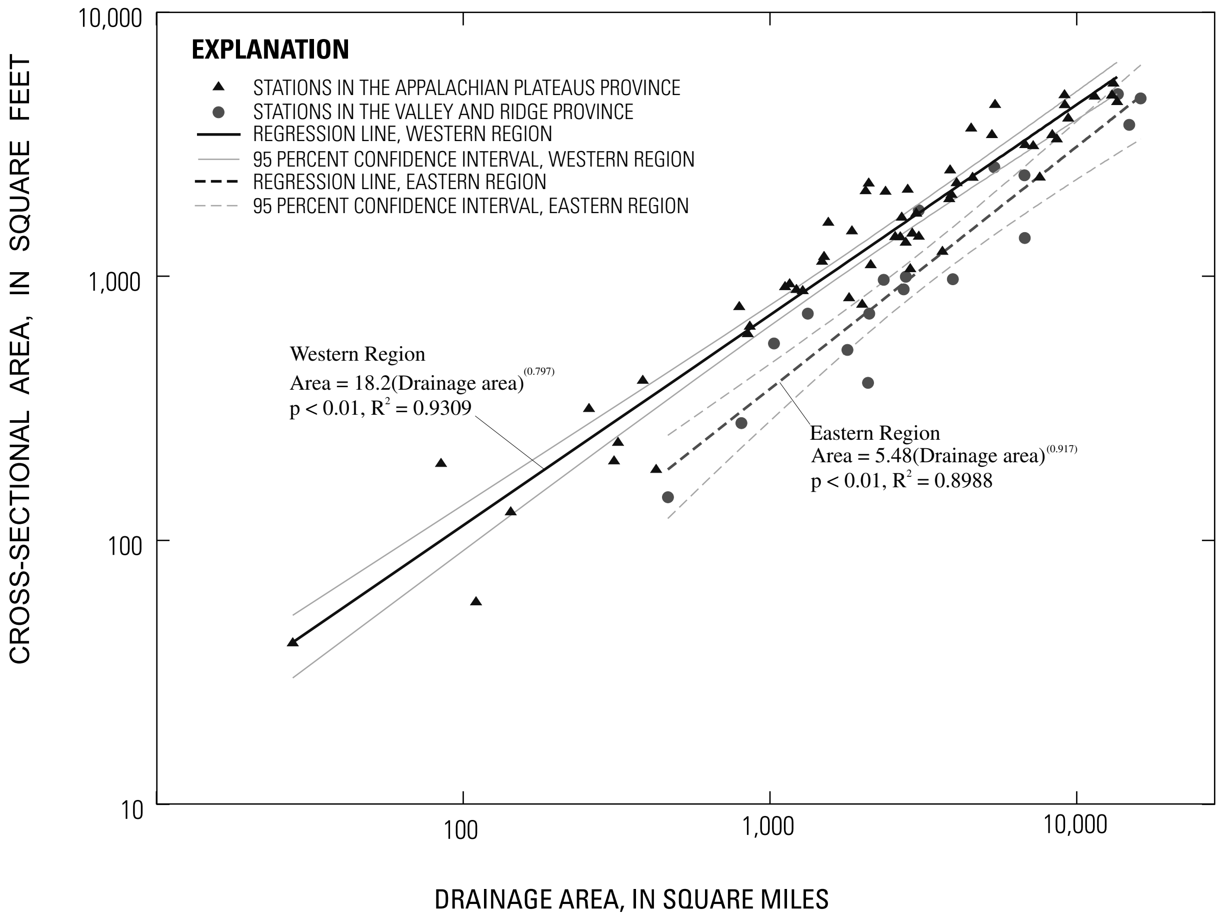

Figure 10. Regional relations between drainage area and bankfull cross-sectional area measured during current-meter flow measurements at selected stream-gaging stations in West Virginia.

The basin divide between the Potomac River Basin and the Ohio River Basin is near the border between the Valley and Ridge and Appalachian Plateaus Provinces. Dividing West Virginia into two regions on the basis of major river basin rather than physiographic province boundary would provide for greater convenience in using regional equations, because drainage areas of streams draining both provinces would not have to be prorated. The single station on a stream in the Potomac River Basin that drains the Appalachian Plateaus Province plots near the regression line for the Eastern Region. However, three gaging stations on streams in the Ohio River Basin that drain parts of both the Valley and Ridge and Appalachian Plateaus Provinces plot well to the right of the Eastern Region curve, and would strongly affect the position of the regression line for a region consisting of the Ohio River Basin.

Some of the cross sections in the Western Region with the most area relative to drainage area, or high positive residuals, are in the part of the region near the Ohio River. These include cross sections at stream-gaging stations in the Middle Island Creek and Little Kanawha River Basins. None of the stream-gaging stations in this part of the region have negative residuals. The Western Region should probably be subdivided into two subregions, one representing upland areas with relatively high annual precipitation, predominantly forested land cover, and streams with a high gradient, and the other representing lowland areas near the Ohio River, with a greater proportion of agriculture, a larger human population, and streams with a lower gradient than the other subregion. However, there are not enough stream-gaging stations in the Appalachian Plateaus lowlands to fully document differences between the lowlands and the highlands.

Cross-sectional area measured from cableways and non-confining bridges was compared to cross-sectional area measured from apparently confining bridges for each region. No pattern of clustering was observed (fig. 11).

Average depth

Width and average depth of cross sections measured from apparently confining bridges were different from width and average depth of cross sections measured from cableways and non-confining bridges (figs. 12, 13). Cross sections from medium and large streams (> 100 mi^2) measured from cableways and non-confining bridges were generally shallower and wider relative to their drainage area than were cross sections measured from apparently confining bridges. Some cross sections measured from apparently confining bridges had similar width and average depth relative to drainage area as cross sec-

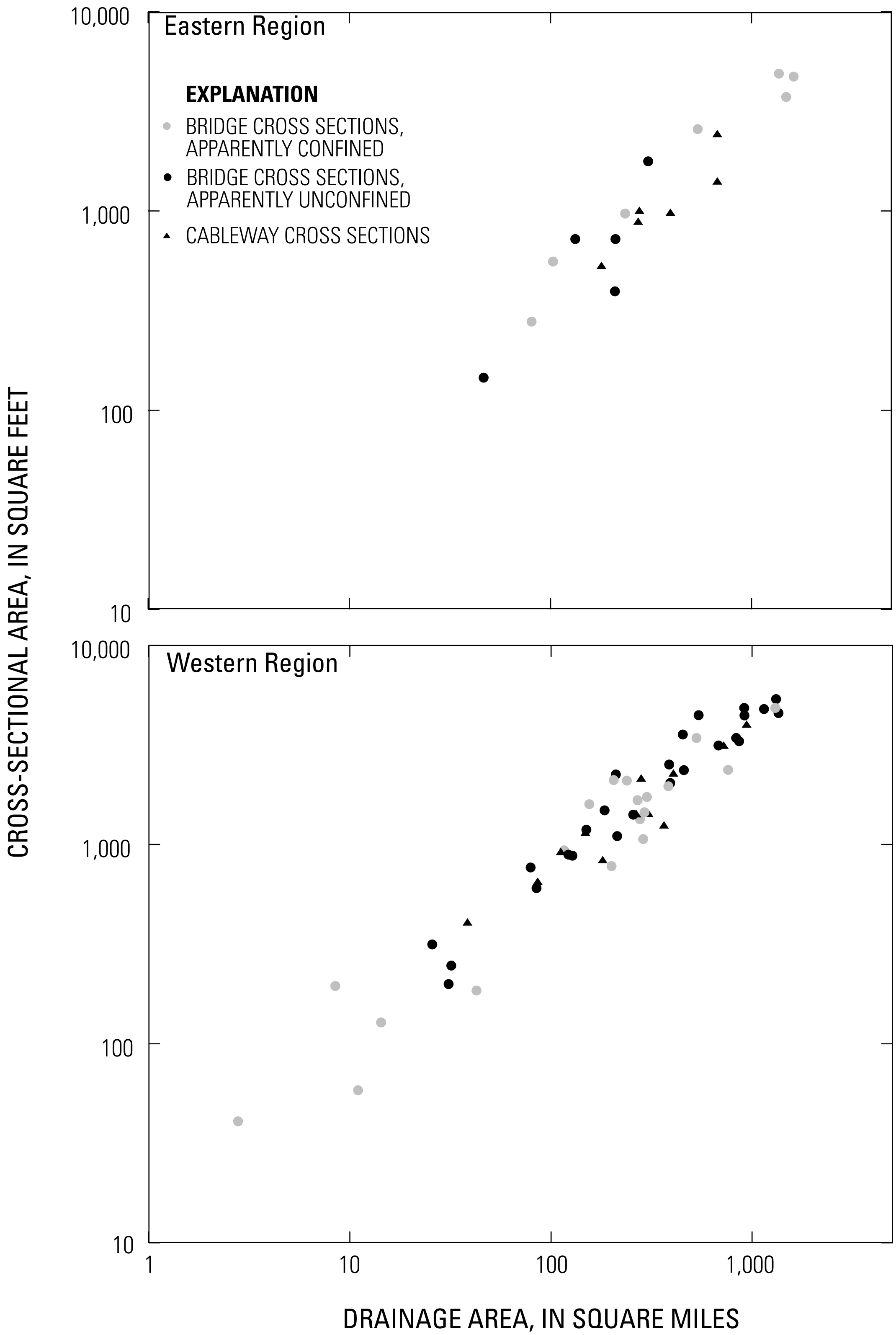

Figure 11. Comparison of the area of stream channels at bankfull flow at bridge and cableway cross sections in the Eastern and Western Regions in West Virginia.

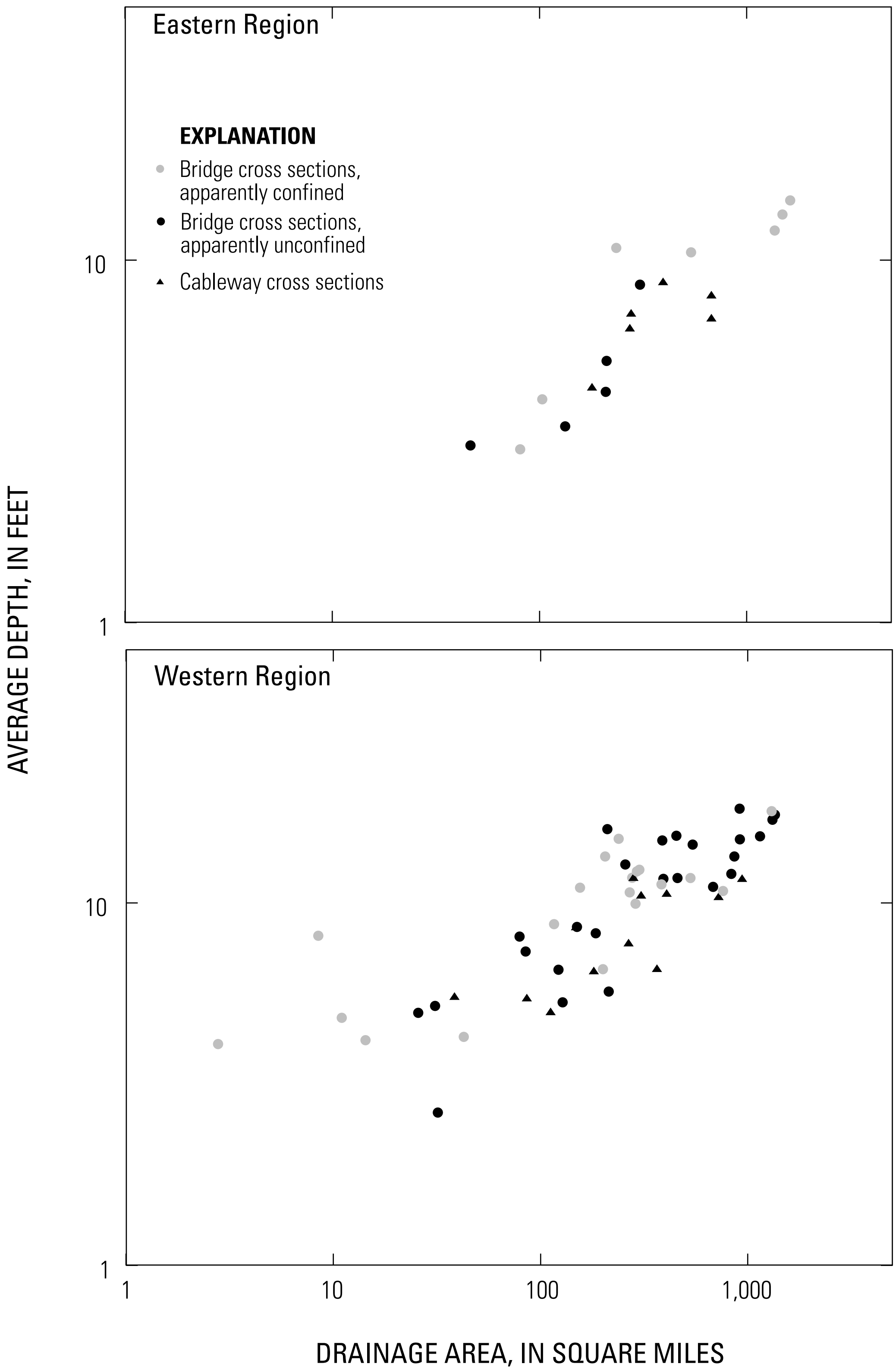

Figure 12. Comparison of the average depth of stream channels at bankfull flow at bridge and cableway cross sections in the Eastern and Western Regions in West Virginia.

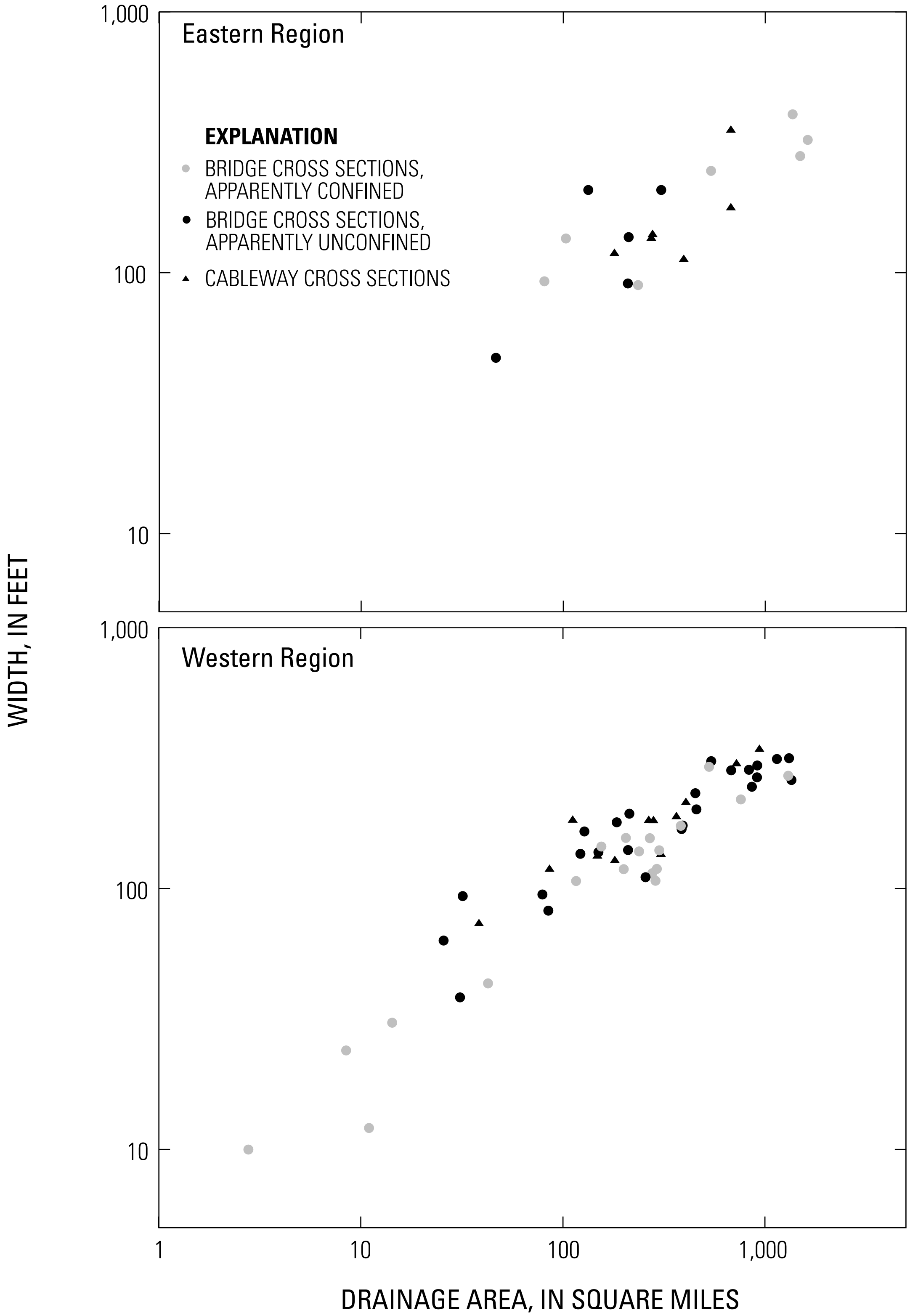

Figure 13. Comparison of the width of stream channels at bankfull flow at bridge and cableway cross sections in the Eastern and Western Regions in West Virginia.

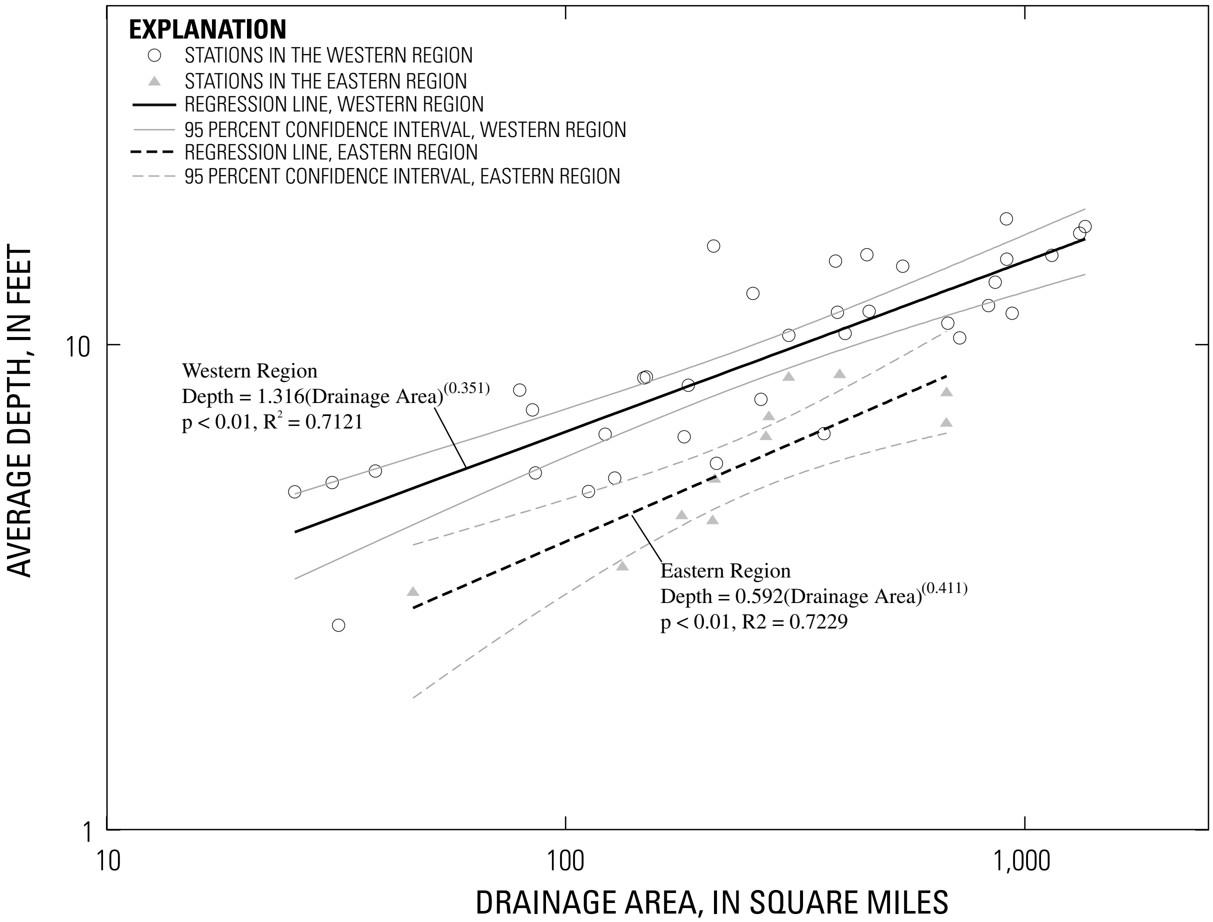

Figure 14. Regional relations between bankfull average depth determined from current-meter flow measurements and drainage area at selected stream-gaging stations in West Virginia.

tions measured from non-confining bridges. Width and depth of cross sections measured from cableways were not apparently different from width and depth measured from non-confining bridges. On the basis of this analysis, cross sections measured from apparently confining bridges were excluded from regional analysis for width and depth.

The relation between drainage area and bankfull average depth was significant in both regions ($p < 0.001$), but was weaker than the relation between drainage area and bankfull area (R^2, 0.712 for the Western Region, and 0.723 for the Eastern Region; fig. 14). The 95-percent confidence intervals of the two regional regressions did not overlap. Average depth of cross sections in the Western Region was greater relative to drainage area than for cross sections in the Eastern Region.

Generally, the stream-gaging stations that had greater cross-sectional area relative to drainage area were the same stations that were deeper at bankfull flow. As with the regional relation between cross-sectional area and drainage area, however, not enough stations were available in areas with lower altitude, less relief, and higher human population to fully explore a regional difference within the Appalachian Plateaus.

Width

The relation between drainage area and bankfull width in both regions was statistically significant ($p < 0.001$ for the Western Region, and $p = 0.01$ for the Eastern Region), but was weaker than the relation between drainage area and bankfull area (R^2, 0.842 for the Western Region, and 0.537 for the Eastern Region). The regression line for the Eastern Region plotted outside the 95-percent confidence interval for the Western Region, but the entire 95-percent confidence interval for the Western Region plotted inside the 95-percent confidence interval for the Eastern Region (fig. 15). These aspects of the regional relations are caused by the weak relation of the Eastern Regional regression.

Stream-gaging stations with two or more high-flow cross sections

Measurements at more than one bridge or cableway cross section were made at flows between 0.5 and 5.0 times bankfull flow at five stream-gaging stations in the Western Region. Plot

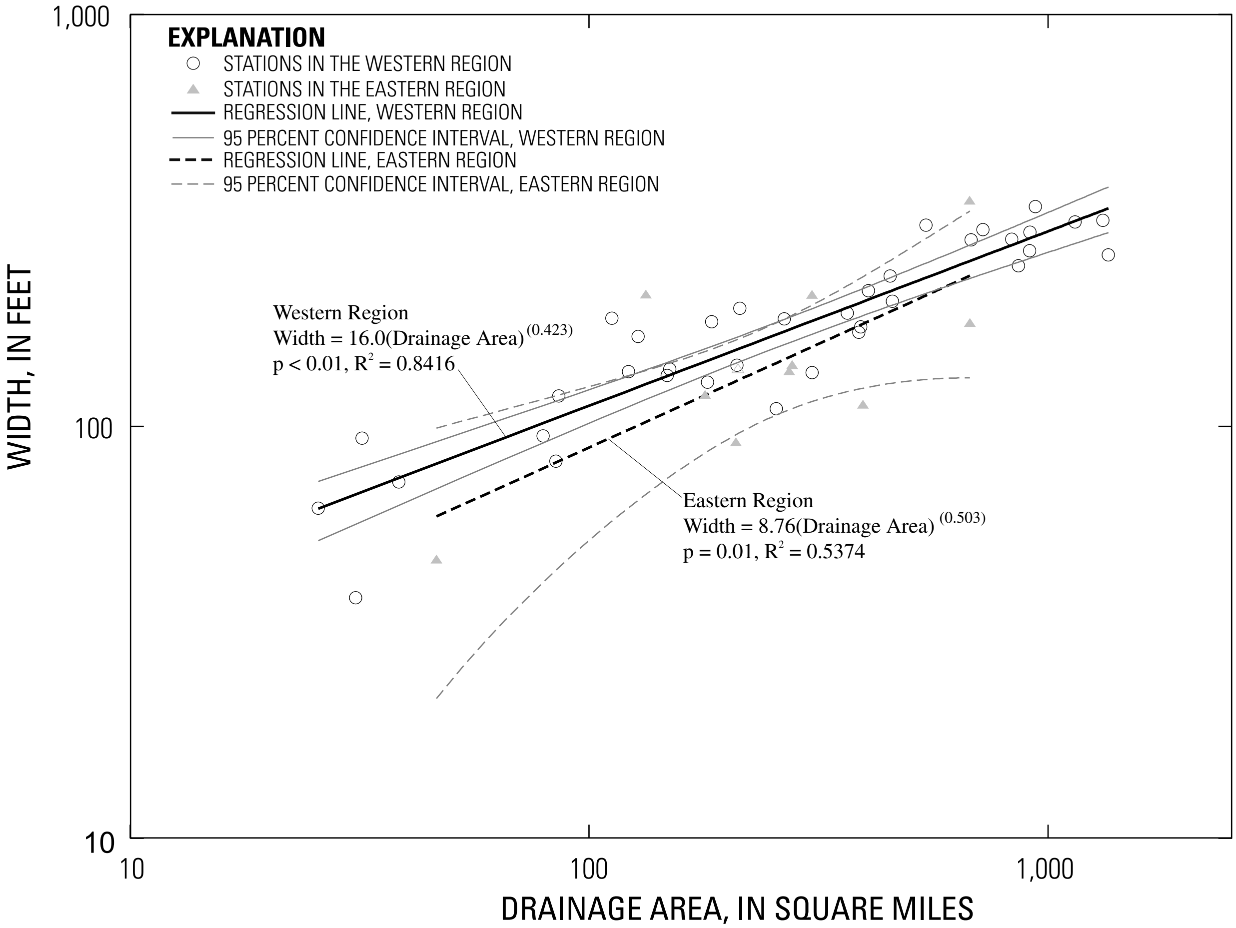

Figure 15. Regional relations between bankfull width determined from current-meter flow measurements and drainage area at selected stream-gaging stations in West Virginia.

ting bankfull channel characteristics for these stream-gaging stations in relation to the regression lines and 95-percent confidence intervals for the regional relations among all stream-gaging stations is one of the few measures of within-reach variability available for this study (fig. 16). This measure does not provide the information about variability that would be obtained from a study where bankfull channel characteristics were determined from multiple cross sections in many reaches, and where a measure of variance, such as the standard deviation, was calculated for each reach. Several of the cross sections at the five stream-gaging stations did not meet the criteria to be included in regional analysis, so the information about within-reach variability is extremely limited and may not be representative of within-reach variability throughout the study area. It is still, however, the best information available for this study.

At the Greenbrier River at Alderson stream-gaging station, measurements were made from a cableway and two bridges. Measurements were made from two bridges at West Fork at Clarksburg, Greenbrier River at Durbin, Williams River at Dyer, and Peters Creek near Lockwood. One of the bridges at Greenbrier River at Durbin and Williams River at Dyer was a "swinging" footbridge. This type of bridge was typically built without concrete abutments that confine streams at high flow. Conditions for some of the cross sections were not conducive for accurate measurements; at two of the stream-gaging stations where measurements were made from more than one bridge, Greenbrier River at Durbin and Peters Creek near Lockwood, hydrographers stopped using the original bridge when a new one became available, because it was difficult to measure flow accurately from the original bridge. At four stream-gaging stations—Greenbrier River at Alderson, Williams River at Dyer, West Fork at Clarksburg, and Peters Creek near Lockwood—one of the two bridges at which measurements were made was apparently confining.

Of the stream-gaging stations with more than one cross section, only area at one station (Greenbrier River at Durbin), width at one station (West Fork at Clarksburg), and average depth at one station (Greenbrier River at Alderson) plotted within the 95-percent confidence interval for all stations in the Western Region. For 6 of the 15 characteristics at examined replicated cross sections, characteristics for both cross sections plotted outside the 95-percent confidence interval. One of the cross sections for Greenbrier River at Durbin, a stream-gaging station just downstream from the confluence of the East and

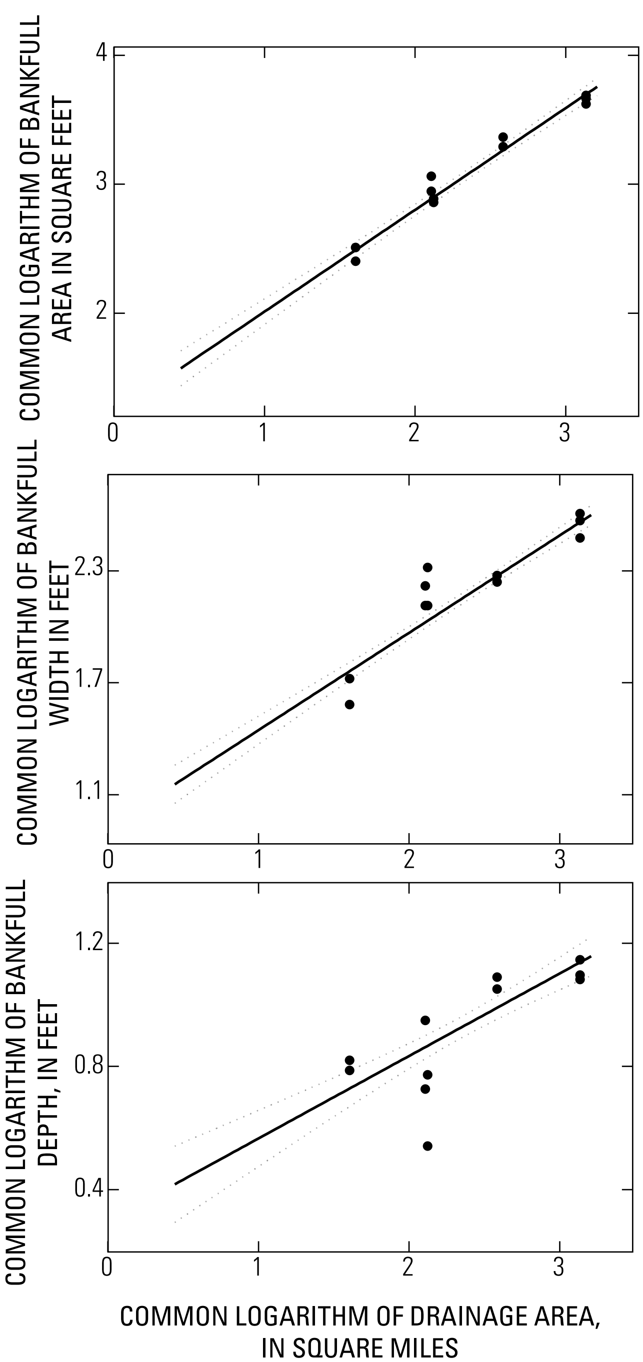

Figure 16. Relation of bankfull area, width, and average depth to drainage area at five stream-gaging stations in the Western Region with flow measurements at more than one cross section, compared to regression lines and 95 percent confidence intervals for all stream-gaging stations in the Western Region of West Virginia.

West Forks of the Greenbrier River, was actually two cross sections on the tributaries upstream from the confluence; few researchers would consider this location to be part of the same reach as the location of the other bridge, downstream from the confluence. The difference in reaches explains why cross-sectional area at this stream-gaging station fit the regional pattern well but width and average depth did not.

Variability in cross sections measured at single stream-gaging stations may indicate that variability of cross sections within reaches may be greater than is suggested by the low standard errors and high R^2 values of the regional regression equations; therefore, applying the regression equations from this report may provide dubious results. The regression equations from this report, however, do provide useful information supporting field identification of bankfull indicators. Unless the cross sections from which they were developed can be shown to be representative of the reaches containing the cross sections, these equations are not adequate for designing channels.

Summary

Three bankfull channel characteristics—cross-sectional area, width, and average depth—were significantly correlated with drainage area in two regions in West Virginia. Channel characteristics were determined from analysis of historical flow measurements at 74 U.S. Geological Survey stream-gaging stations. Measurements made between 0.5 and 5.0 times the flow at the 1.5-year recurrence interval (referred to in this report as "bankfull flow") were analyzed by graphical and regression analysis of selected channel characteristic in relation to flow. Channel characteristic values were calculated for bankfull flow.

Two regions, the Western Region and the Eastern Region, were delineated using the relation between bankfull cross-sectional area and drainage area. Regression equations of bankfull width and average depth in relation to drainage area were determined for those regions. The boundary between the Eastern and Western Region was the same as the boundary between the Appalachian Plateaus and Valley and Ridge Provinces. Streams that drained parts of both the Appalachian Plateaus and Valley and Ridge Provinces were included in the Eastern Region. No stream-gaging stations were available from the small part of the Blue Ridge Province in West Virginia. Standard error for the six regression equations ranged between 8.7 and 16 percent. Cross-sectional area and average depth were greater for the Western Region than for the Eastern Region. Regression equations were defined for streams draining between 46.5 and 1,619 mi^2 for the Eastern Region, and between 2.78 and 1,354 mi^2 for the Western Region.

Many of the cross sections were at bridges, which alter stream-channel characteristics. Cross sections from bridges that appeared to confine flow were excluded from regional analysis of width and average depth, because values for these characteristics from these bridges appeared to have a skewed distribution. Cross-sectional area measured from bridges that apparently confined flow did not appear to have a skewed distribution among other stream-gaging stations in each region, and these cross sections were included in regional analysis.

For stream-gaging stations with two or more cross sections that met data-quality standards, characteristics of one or more cross sections fell outside the 95-percent confidence intervals of the regional regression. This suggests that within-reach variability for the stream-gaging stations may be greater than expected from the low standard error and high R^2 values of the regional regression equations.

This study had several other limitations, including a skewed distribution of available stream-gaging stations with respect to location and stream size. A disproportionate number of stream-gaging stations were on large (>100 mi^2 drainage area) streams in the central highlands of West Virginia. Only one stream-gaging station that met data-quality criteria was available to represent the region within about 50 miles of the Ohio River north of Parkersburg.

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Appendix 1. Regression equations for the relations between flow and cross-sectional area, flow and width, flow and average depth, and flow and velocity at selected stream-gaging stations in West Virginia.

Table 1-1. Regression equations for the relation between flow and cross-sectional area, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two or more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.

[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Area			Width		
Station number	Stream-gaging station	n	Equation	R^2	p	Equation	R^2	p
01595300	Abram Creek at Oakmont	36	$10.09Q^{0.41}$	0.91	0.00	$34.96Q^{0.03}$	0.16	0.02
03182700	Anthony Creek near Anthony	5	$0.15Q^{1.09}$	0.97	0.00	**$0.37Q^{0.83}$**	**0.55**	**0.15**
01614000	Back Creek near Jones Springs	73	$31.83Q^{0.39}$	0.94	0.00	$63.68Q^{0.04}$	0.56	0.00
03198500	Big Coal River at Ashford	162	$14.98Q^{0.52}$	0.92	0.00	$51.16Q^{0.13}$	0.71	0.00
03070500	Big Sandy Creek at Rockville	104	$15.67Q^{0.44}$	0.95	0.00	$42.74Q^{0.11}$	0.38	0.00
03066000	Blackwater River at Davis	62	$6.38Q^{0.60}$	0.99	0.00	$29.73Q^{0.18}$	0.57	0.00
03179500	Bluestone River at Lilly	11	$103.60Q^{0.28}$	0.74	0.00	$104.10Q^{0.07}$	0.43	0.03
03179000	Bluestone River near Pipestem	95	$26.03Q^{0.40}$	0.99	0.00	$36.37Q^{0.13}$	0.91	0.00
03202480	Briar Creek at Fanrock	3	$184.65Q^{-0.22}$	1.00	0.04	**$30.11Q^{0.00}$**	**0.00**	**0.99**
03053500	Buckhannon River at Hall	147	$11.02Q^{0.54}$	0.99	0.00	$82.00Q^{0.04}$	0.35	0.00
03061500	Buffalo Creek at Barrackville	56	$5.27Q^{0.60}$	0.93	0.00	$20.94Q^{0.20}$	0.72	0.00
03069880	Buffalo Creek near Rowlesburg	2	$2.79Q^{0.58}$	1.00	NA	$18.48Q^{0.16}$	1.00	NA
03114650	Buffalo Run near Little	**3**	**$23.43Q^{0.18}$**	**0.72**	**0.36**	**$14.90Q^{0.12}$**	**0.78**	**0.31**
01610500	Cacapon River at Yellow Springs	27	$4.96Q^{0.68}$	0.97	0.00	$21.49Q^{0.26}$	0.83	0.00
01611500	Cacapon River near Great Cacapon	75	$4.90Q^{0.66}$	0.97	0.00	$11.29Q^{0.36}$	0.82	0.00
03178500	Camp Creek near Camp Creek	19	$1.78Q^{0.69}$	0.87	0.00	$18.07Q^{0.20}$	0.34	0.01
03071000	Cheat River at Pisgah	190	$113.73Q^{0.32}$	0.98	0.00	$129.74Q^{0.05}$	0.81	0.00
03070000	Cheat River at Rowlesburg	308	$63.61Q^{0.37}$	0.68	0.00	$119.90Q^{0.13}$	0.31	0.00

Table 1-1. Regression equations for the relation between flow and cross-sectional area, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two or more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Area			Width		
Station number	Stream-gaging station	n	Equation	R^2	p	Equation	R^2	p
03069500	Cheat River near Parsons	214	$108.17Q^{0.32}$	0.89	0.00	$157.69Q^{0.07}$	0.55	0.00
03189000	Cherry River at Fenwick	178	$97.02Q^{0.25}$	0.64	0.00	$41.92Q^{0.14}$	0.72	0.00
03202750	Clear Fork at Clear Fork	17	$25.05Q^{0.40}$	0.77	0.00	$46.10Q^{0.10}$	0.39	0.01
03200500	Coal River at Tornado	120	$229.34Q^{0.25}$	0.78	0.00	$86.63Q^{0.10}$	0.71	0.00
03062400	Cobun Creek at Morgantown	7	$1.55Q^{0.60}$	0.93	0.00	**$8.12Q^{0.07}$**	**0.41**	**0.12**
03189650	Collison Creek near Nallen	4	$1.89Q^{0.62}$	0.99	0.00	$10.00Q^{0.00}$	NA	NA
03187500	Cranberry River near Richwood	43	$16.39Q^{0.44}$	0.93	0.00	$62.17Q^{0.08}$	0.32	0.00
03062500	Deckers Creek at Morgantown	28	$5.62Q^{0.54}$	0.75	0.00	$44.92Q^{0.04}$	0.25	0.01
03198450	Drawdy Creek near Peytona	3	$0.89Q^{0.70}$	1.00	0.00	**$14.73Q^{0.01}$**	**0.30**	**0.63**
03212980	Dry Fork at Beartown	16	$9.34Q^{0.48}$	0.98	0.00	$40.83Q^{0.10}$	0.95	0.00
03065000	Dry Fork at Hendricks	150	$35.13Q^{0.41}$	0.64	0.00	$155.99Q^{0.03}$	0.51	0.00
03206600	East Fork Twelvepole Creek near Dunlow	13	$6.08Q^{0.57}$	0.98	0.00	$16.12Q^{0.20}$	0.60	0.00
03206800	East Fork Twelvepole Creek near East Lynn	12	$2.08Q^{0.77}$	0.97	0.00	$5.25Q^{0.38}$	0.87	0.00
03059500	Elk Creek at Quiet Dell	45	$8.93Q^{0.55}$	0.93	0.00	$22.52Q^{0.17}$	0.89	0.00
03195000	Elk River at Centralia	97	$155.52Q^{0.27}$	0.96	0.00	$107.77Q^{0.05}$	0.72	0.00
03197000	Elk River at Queen Shoals	220	$195.28Q^{0.30}$	0.94	0.00	$120.70Q^{0.09}$	0.77	0.00
03195500	Elk River at Sutton	121	$9.69Q^{0.60}$	0.95	0.00	$37.65Q^{0.20}$	0.82	0.00
03194700	Elk River below Webster Springs	98	$41.95Q^{0.36}$	0.91	0.00	$99.36Q^{0.06}$	0.38	0.00
03192000	Gauley River above Belva	164	$133.22Q^{0.33}$	0.92	0.00	$197.63Q^{0.04}$	0.56	0.00
03189100	Gauley River at Camden-on-Gauley	153	$13.91Q^{0.55}$	0.98	0.00	$93.44Q^{0.08}$	0.68	0.00
03189100	Gauley River near Craigsville	80	$72.32Q^{0.37}$	0.92	0.00	$95.52Q^{0.11}$	0.77	0.00
03189500	Gauley River near Summersville	242	$53.82Q^{0.39}$	0.99	0.00	$137.19Q^{0.06}$	0.61	0.00
03195600	Granny Creek at Sutton	6	$0.52Q^{0.88}$	0.99	0.00	**$9.84Q^{0.14}$**	**0.31**	**0.25**
03183500	Greenbrier River at Alderson	306	$108.35Q^{0.34}$	0.87	0.00	**$295.59Q^{0.01}$**	**0.00**	**0.52**

Table 1-1. Regression equations for the relation between flow and cross-sectional area, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two or more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Area			Width		
Station number	Stream-gaging station	n	Equation	R^2	p	Equation	R^2	p
03182500	Greenbrier River at Buckeye	189	$47.18Q^{0.41}$	0.98	0.00	$190.94Q^{0.03}$	0.28	0.00
03180500	Greenbrier River at Durbin	32	$8.15Q^{0.54}$	0.93	0.00	$28.69Q^{0.23}$	0.29	0.00
03184000	Greenbrier River at Hilldale	150	$42.97Q^{0.44}$	0.90	0.00	$78.48Q^{0.13}$	0.53	0.00
03204000	Guyandotte River at Branchland*	139	$4.80Q^{0.68}$	0.93	0.00	$45.81Q^{0.18}$	0.71	0.00
03203600	Guyandotte River at Logan	80	$1.96Q^{0.73}$	0.98	0.00	$49.78Q^{0.17}$	0.80	0.00
03203000	Guyandotte River at Man	162	$32.31Q^{0.43}$	0.94	0.00	$152.03Q^{0.03}$	0.66	0.00
03202400	Guyandotte River near Baileysville	84	$61.03Q^{0.36}$	0.90	0.00	$66.50Q^{0.08}$	0.54	0.00
03155500	Hughes River at Cisco	118	$8.72Q^{0.61}$	0.94	0.00	$30.71Q^{0.21}$	0.61	0.00
03177500	Indian Creek at Indian Mills	8	$39.53Q^{0.35}$	0.98	0.00	$49.57Q^{0.08}$	0.91	0.00
03182000	Knapp Creek at Marlinton	14	$18.14Q^{0.40}$	0.62	0.00	$\mathbf{55.96Q^{0.11}}$	**0.22**	**0.09**
03152500	Leading Creek near Glenville*	59	$6.24Q^{0.71}$	0.83	0.00	$14.50Q^{0.27}$	0.56	0.00
03195250	Left Fork Holly River near Replete	13	$7.02Q^{0.50}$	0.99	0.00	$21.40Q^{0.18}$	0.77	0.00
01609800	Little Cacapon River near Levels	7	$\mathbf{146.49Q^{0.14}}$	**0.53**	**0.06**	$\mathbf{46.51Q^{0.06}}$	**0.43**	**0.11**
03199000	Little Coal River at Danville	141	$2.78Q^{0.71}$	0.95	0.00	$51.40Q^{0.12}$	0.78	0.00
03199400	Little Coal River at Julian	28	$3.37Q^{0.71}$	0.94	0.00	$69.56Q^{0.06}$	0.74	0.00
03113700	Little Grave Creek near Glendale	5	$0.57Q^{0.77}$	0.99	0.00	$3.95Q^{0.30}$	1.00	0.00
03152000	Little Kanawha River at Glenville	94	$11.19Q^{0.56}$	0.91	0.00	$13.60Q^{0.27}$	0.72	0.00
03153500	Little Kanawha River at Grantsville*	83	$4.91Q^{0.69}$	0.97	0.00	$38.25Q^{0.18}$	0.66	0.00
03155000	Little Kanawha River at Palestine*	181	$150.58Q^{0.35}$	0.58	0.00	$144.71Q^{0.07}$	0.27	0.00
03151500	Little Kanawha River near Burnsville	149	$11.82Q^{0.56}$	0.94	0.00	$23.31Q^{0.21}$	0.81	0.00
03151400	Little Kanawha River near Wildcat	21	$1.62Q^{0.75}$	0.96	0.00	$19.18Q^{0.26}$	0.82	0.00
03190000	Meadow River at Nallen	171	$30.86Q^{0.40}$	0.37	0.00	$\mathbf{106.15Q^{0.00}}$	**0.00**	**0.39**
03190400	Meadow River near Mt. Lookout	101	$26.65Q^{0.42}$	0.97	0.00	$69.28Q^{0.11}$	0.72	0.00
03052000	Middle Fork River at Audra	91	$51.40Q^{0.35}$	0.97	0.00	$62.04Q^{0.09}$	0.46	0.00
03051500	Middle Fork River at Midvale	42	$11.45Q^{0.52}$	0.90	0.00	$38.00Q^{0.15}$	0.43	0.00

Table 1-1. Regression equations for the relation between flow and cross-sectional area, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two or more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

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			Area			Width		
Station number	Stream-gaging station	n	Equation	R^2	p	Equation	R^2	p
03114500	Middle Island Creek at Little	156	$2.72Q^{0.70}$	0.93	0.00	$57.91Q^{0.13}$	0.72	0.00
03204500	Mud River at Milton	132	$2.67Q^{0.72}$	0.98	0.00	$11.53Q^{0.26}$	0.90	0.00
01599500	New Creek at Keyser	16	$4.40Q^{0.52}$	0.91	0.00	$23.05Q^{0.11}$	0.75	0.00
03185500	New River at Caperton	71	$214.99Q^{0.28}$	0.97	0.00	$109.36Q^{0.11}$	0.70	0.00
03187300	North Fork Cranberry River near Hillsboro	3	$3.98Q^{0.52}$	1.00	NA	$27.32Q^{0.10}$	1.00	NA
01606000	North Fork South Branch Potomac at Cabins	8	$60.82Q^{0.34}$	0.97	0.00	**$162.29Q^{0.04}$**	**0.24**	**0.22**
01616500	Opequon Creek near Martinsburg	58	$1.62Q^{0.79}$	0.84	0.00	$3.83Q^{0.46}$	0.59	0.00
03213500	Panther Creek near Panther	27	$3.11Q^{0.60}$	0.76	0.00	$17.47Q^{0.14}$	0.21	0.02
01604500	Patterson Creek near Headsville	83	$9.91Q^{0.56}$	0.39	0.00	$31.00Q^{0.19}$	0.41	0.00
03191500	Peters Creek near Lockwood	29	$5.57Q^{0.52}$	0.78	0.00	**$31.68Q^{0.05}$**	**0.08**	**0.13**
03185000	Piney Creek at Raleigh	16	$1.79Q^{0.69}$	0.87	0.00	**$30.34Q^{0.12}$**	**0.08**	**0.29**
03201000	Pocatalico River at Sissonville	192	$3.48Q^{0.71}$	0.94	0.00	$12.33Q^{0.28}$	0.82	0.00
03201410	Poplar Fork at Teays	7	$2.52Q^{0.64}$	0.99	0.00	**$21.96Q^{0.01}$**	**0.11**	**0.47**
01610000	Potomac River at Paw Paw	76	$8.52Q^{0.62}$	0.91	0.00	$48.68Q^{0.19}$	0.50	0.00
01618000	Potomac River at Shepherdstown	230	$189.22Q^{0.35}$	0.94	0.00	$427.90Q^{0.03}$	0.40	0.00
03154500	Reedy Creek near Reedy	31	$7.50Q^{0.56}$	0.96	0.00	$33.15Q^{0.13}$	0.74	0.00
03177000	Rich Creek near Peterstown	2	$1.37Q^{0.78}$	1.00	NA	$0.82Q^{0.65}$	1.00	NA
03195100	Right Fork Holly River at Guardian	2	$9.81Q^{0.47}$	1.00	NA	$134.58Q^{-0.18}$	1.00	NA
03052500	Sand Run near Buckhannon	22	$7.00Q^{0.44}$	0.76	0.00	$8.13Q^{0.21}$	0.79	0.00
03069000	Shavers Fork at Parsons	66	$21.18Q^{0.43}$	0.94	0.00	$83.39Q^{0.09}$	0.46	0.00
01636500	Shenandoah River at Millville	38	$10.08Q^{0.61}$	0.99	0.00	$355.47Q^{0.08}$	0.39	0.00
03057500	Skin Creek near Brownsville	17	$10.14Q^{0.47}$	0.96	0.00	$32.87Q^{0.08}$	0.40	0.01
01605500	South Branch Potomac River at Franklin	33	$8.32Q^{0.49}$	0.78	0.00	$22.49Q^{0.20}$	0.48	0.00

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			Area			Width		
Station number	Stream-gaging station	n	Equation	R^2	p	Equation	R^2	p
01606500	South Branch Potomac River near Petersburg	259	$19.42Q^{0.46}$	0.72	0.00	$48.90Q^{0.15}$	0.28	0.00
01608500	South Branch Potomac River near Springfield	216	$21.64Q^{0.50}$	0.79	0.00	$45.75Q^{0.18}$	0.37	0.00
03155200	South Fork Hughes River at Macfarlan	66	$27.45Q^{0.47}$	0.96	0.00	$47.15Q^{0.11}$	0.80	0.00
01607500	South Fork South Branch Potomac River at Brandywine	38	$3.81Q^{0.62}$	0.78	0.00	$23.45Q^{0.22}$	0.48	0.00
01608000	South Fork South Branch Potomac River near Moorefield	53	$22.37Q^{0.44}$	0.68	0.00	$67.78Q^{0.09}$	0.18	0.01
03153000	Steer Creek near Grantsville*	137	$12.11Q^{0.54}$	0.88	0.00	$26.66Q^{0.17}$	0.67	0.00
03154250	Tanner Run at Spencer	2	$15.48Q^{0.19}$	1.00	NA	$26.00Q^{0.00}$	NA	NA
03068610	Taylor Run at Bowden	7	$3.14Q^{0.57}$	0.88	0.00	$29.12Q^{-0.01}$	0.00	0.90
03056250	Three Forks Creek near Grafton	15	$6.34Q^{0.57}$	0.98	0.00	$26.64Q^{0.12}$	0.89	0.00
03214900	Tug Fork at Glenhayes	62	$1.44Q^{0.82}$	0.99	0.00	$18.50Q^{0.26}$	0.81	0.00
03214500	Tug Fork at Kermit	63	$3.44Q^{0.72}$	0.97	0.00	$47.01Q^{0.15}$	0.82	0.00
03213000	Tug Fork at Litwar	196	$25.47Q^{0.44}$	0.95	0.00	$58.37Q^{0.08}$	0.91	0.00
03212750	Tug Fork at Welch	7	$4.88Q^{0.57}$	0.98	0.00	$26.45Q^{0.13}$	0.91	0.00
03213700	Tug Fork at Williamson	132	$6.47Q^{0.63}$	0.97	0.00	$39.76Q^{0.16}$	0.93	0.00
03214000	Tug Fork near Kermit	259	$2.75Q^{0.74}$	0.99	0.00	$44.66Q^{0.16}$	0.67	0.00
01617000	Tuscarora Creek above Martinsburg	5	$\mathbf{39.26Q^{0.03}}$	**0.01**	**0.91**	$\mathbf{78.24Q^{-0.29}}$	**0.69**	**0.17**
03207000	Twelvepole Creek at Wayne	102	$16.10Q^{0.51}$	0.89	0.00	$28.51Q^{0.16}$	0.74	0.00
03207020	Twelvepole Creek below Wayne	22	$5.00Q^{0.66}$	0.96	0.00	$12.35Q^{0.27}$	0.90	0.00
03051000	Tygart Valley River at Belington	186	$10.23Q^{0.59}$	0.99	0.00	$78.77Q^{0.11}$	0.77	0.00
03056500	Tygart Valley River at Fetterman	102	$168.10Q^{0.30}$	0.91	0.00	$250.97Q^{0.01}$	0.34	0.00
03054500	Tygart Valley River at Philippi	201	$18.61Q^{0.55}$	0.99	0.00	$102.16Q^{0.11}$	0.72	0.00
03050000	Tygart Valley River near Dailey	56	$1.03Q^{0.84}$	0.99	0.00	$1.78Q^{0.60}$	0.74	0.00
03050500	Tygart Valley River near Elkins	105	$36.91Q^{0.39}$	0.90	0.00	$43.53Q^{0.14}$	0.39	0.00

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[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Area			Width		
Station number	Stream-gaging station	n	Equation	R^2	p	Equation	R^2	p
03154000	West Fork Little Kanawha River at Rocksdale	140	$11.36Q^{0.57}$	0.87	0.00	$34.70Q^{0.16}$	0.81	0.00
03058500	West Fork River at Butcherville	50	$9.57Q^{0.51}$	0.97	0.00	$41.34Q^{0.12}$	0.60	0.00
03059000	West Fork River at Clarksburg	104	$11.24Q^{0.58}$	0.85	0.00	$93.50Q^{0.07}$	0.31	0.00
03061000	West Fork River at Enterprise	7	$5.62Q^{0.65}$	0.97	0.00	$37.31Q^{0.19}$	0.77	0.01
03057300	West Fork River at Walkersville	12	$12.10Q^{0.56}$	0.88	0.00	$10.99Q^{0.29}$	0.75	0.00
03112000	Wheeling Creek at Elm Grove	72	$3.80Q^{0.64}$	0.96	0.00	$23.73Q^{0.20}$	0.57	0.00
03186500	Williams River at Dyer	78	$23.15Q^{0.41}$	0.73	0.00	$72.18Q^{0.08}$	0.50	0.00

Table 1-2. Regression equations for the relation between flow and average depth, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two to more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.

[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Depth			Velocity		
Station number	Station	n	Equation	R^2	p	Equation	R^2	p
01595300	Abram Creek at Oakmont	36	$0.29Q^{0.37}$	0.87	0.00	$0.10Q^{0.59}$	0.95	0.00
03182700	Anthony Creek near Anthony	**5**	$\mathbf{0.42Q^{0.27}}$	**0.17**	**0.49**	$\mathbf{6.54Q^{-0.10}}$	**0.18**	**0.48**
01614000	Back Creek near Jones Springs	73	$0.50Q^{0.35}$	0.92	0.00	$0.03Q^{0.61}$	0.97	0.00
03198500	Big Coal River at Ashford	162	$0.29Q^{0.40}$	0.93	0.00	$0.07Q^{0.47}$	0.91	0.00
03070500	Big Sandy Creek at Rockville	104	$0.37Q^{0.33}$	0.91	0.00	$0.06Q^{0.56}$	0.97	0.00
03066000	Blackwater River at Davis	62	$0.21Q^{0.43}$	0.90	0.00	$0.16Q^{0.40}$	0.98	0.00
03179500	Bluestone River at Lilly	11	$1.00Q^{0.22}$	0.56	0.01	$0.01Q^{0.71}$	0.95	0.00

Table 1-2. Regression equations for the relation between flow and average depth, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two to more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Depth			Velocity		
Station number	Station	n	Equation	R^2	p	Equation	R^2	p
03179000	Bluestone River near Pipestem	95	$0.72Q^{0.28}$	0.97	0.00	$0.04Q^{0.59}$	0.99	0.00
03202480	Briar Creek at Fanrock	3	**$6.13Q^{-0.22}$**	**0.79**	**0.30**	$0.01Q^{1.22}$	1.00	0.01
03053500	Buckhannon River at Hall	147	$0.13Q^{0.51}$	0.98	0.00	$0.09Q^{0.45}$	0.98	0.00
03061500	Buffalo Creek at Barrackville	56	$0.25Q^{0.41}$	0.85	0.00	$0.19Q^{0.39}$	0.84	0.00
03069880	Buffalo Creek near Rowlesburg	2	$0.15Q^{0.43}$	NA	NA	$0.35Q^{0.41}$	NA	NA
03114650	Buffalo Run near Little	3	**$1.57Q^{0.06}$**	**0.62**	**0.42**	**$0.04Q^{0.82}$**	**0.98**	**0.09**
01610500	Cacapon River at Yellow Springs	27	$0.23Q^{0.42}$	0.99	0.00	$0.20Q^{0.32}$	0.87	0.00
01611500	Cacapon River near Great Cacapon	75	$0.43Q^{0.31}$	0.84	0.00	$0.20Q^{0.33}$	0.89	0.00
03178500	Camp Creek near Camp Creek	19	$0.10Q^{0.50}$	0.80	0.00	$0.56Q^{0.31}$	0.56	0.00
03071000	Cheat River at Pisgah	190	$0.88Q^{0.28}$	0.98	0.00	$0.01Q^{0.67}$	1.00	0.00
03070000	Cheat River at Rowlesburg	308	$0.53Q^{0.25}$	0.25	0.00	$0.02Q^{0.62}$	0.85	0.00
03069500	Cheat River near Parsons	214	$0.69Q^{0.26}$	0.85	0.00	$0.01Q^{0.68}$	0.97	0.00
03189000	Cherry River at Fenwick	178	$2.31Q^{0.12}$	0.26	0.00	$0.01Q^{0.74}$	0.94	0.00
03202750	Clear Fork at Clear Fork	17	$0.54Q^{0.31}$	0.80	0.00	$0.04Q^{0.59}$	0.88	0.00
03200500	Coal River at Tornado	120	$2.65Q^{0.16}$	0.76	0.00	$0.00Q^{0.75}$	0.97	0.00
03062400	Cobun Creek at Morgantown	7	$0.19Q^{0.54}$	0.86	0.00	$0.64Q^{0.39}$	0.85	0.00
03189650	Collison Creek near Nallen	4	$0.19Q^{0.62}$	0.99	0.00	$0.51Q^{0.38}$	0.98	0.01
03187500	Cranberry River near Richwood	43	$0.26Q^{0.36}$	0.76	0.00	$0.06Q^{0.55}$	0.95	0.00
03062500	Deckers Creek at Morgantown	28	$0.13Q^{0.50}$	0.73	0.00	$0.18Q^{0.46}$	0.68	0.00
03198450	Drawdy Creek near Peytona	3	$0.06Q^{0.70}$	1.00	0.01	$1.11Q^{0.30}$	1.00	0.00
03212980	Dry Fork at Beartown	16	$0.23Q^{0.38}$	0.96	0.00	$0.11Q^{0.52}$	0.99	0.00
03065000	Dry Fork at Hendricks	150	$0.23Q^{0.39}$	0.62	0.00	$0.03Q^{0.58}$	0.77	0.00
03206600	East Fork Twelvepole Creek near Dunlow	13	$0.38Q^{0.37}$	0.86	0.00	$0.16Q^{0.43}$	0.96	0.00
03206800	East Fork Twelvepole Creek near East Lynn	12	$0.40Q^{0.40}$	0.85	0.00	$0.48Q^{0.22}$	0.72	0.00
03059500	Elk Creek at Quiet Dell	45	$0.40Q^{0.38}$	0.92	0.00	$0.11Q^{0.44}$	0.90	0.00

Table 1-2. Regression equations for the relation between flow and average depth, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two to more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

[n, number of measurements; R^2, correlation coefficient; p, probability; ft^2, square feet; ft, feet; ft/s, feet per second; Q, flow in cubic feet per second; NA, not applicable for mathematical reasons; * signifies stations where area and width did not always increase as a function of flow because of the effects of backwater; **bold type** signifies that a regression line was not significant at $p < 0.05$; stations listed in this table but not in Table 2 had fewer than 5 flow measurements between 0.5 and 5 times the 1.5-year recurrence flow made at a single identifiable cross section, or the measurements were not significantly related ($p < 0.05$), not linearly related, or fit a regression line with excessive scatter ($R^2 > 0.80$); stations listed in this table and Table 2, but not Table 3 were those where flow measurements were made from a bridge that appeared to confine flow]

			Depth			Velocity		
Station number	Station	n	Equation	R^2	p	Equation	R^2	p
03195000	Elk River at Centralia	97	$1.44Q^{0.22}$	0.95	0.00	$0.01Q^{0.72}$	0.99	0.00
03197000	Elk River at Queen Shoals	220	$1.62Q^{0.21}$	0.88	0.00	$0.01Q^{0.69}$	0.99	0.00
03195500	Elk River at Sutton	121	$0.26Q^{0.40}$	0.97	0.00	$0.10Q^{0.39}$	0.90	0.00
03194700	Elk River below Webster Springs	98	$0.42Q^{0.31}$	0.82	0.00	$0.02Q^{0.63}$	0.97	0.00
03192000	Gauley River above Belva	164	$0.67Q^{0.29}$	0.94	0.00	$0.01Q^{0.67}$	0.98	0.00
03189100	Gauley River at Camden-on-Gauley	153	$0.15Q^{0.47}$	0.97	0.00	$0.07Q^{0.45}$	0.97	0.00
03189100	Gauley River near Craigsville	80	$0.76Q^{0.27}$	0.87	0.00	$0.01Q^{0.62}$	0.97	0.00
03189500	Gauley River near Summersville	242	$0.39Q^{0.34}$	0.98	0.00	$0.02Q^{0.60}$	0.99	0.00
03195600	Granny Creek at Sutton	6	$0.05Q^{0.75}$	0.97	0.00	$1.90Q^{0.11}$	0.66	0.05
03183500	Greenbrier River at Alderson	306	$0.37Q^{0.34}$	0.46	0.00	$0.01Q^{0.65}$	0.96	0.00
03182500	Greenbrier River at Buckeye	189	$0.25Q^{0.38}$	0.97	0.00	$0.02Q^{0.59}$	0.99	0.00
03180500	Greenbrier River at Durbin	32	$0.28Q^{0.32}$	0.37	0.00	$0.12Q^{0.45}$	0.90	0.00
03184000	Greenbrier River at Hilldale	150	$0.55Q^{0.31}$	0.93	0.00	$0.02Q^{0.55}$	0.93	0.00
03204000	Guyandotte River at Branchland*	139	$0.10Q^{0.51}$	0.96	0.00	$0.21Q^{0.31}$	0.74	0.00
03203600	Guyandotte River at Logan	80	$0.04Q^{0.56}$	0.95	0.00	$0.51Q^{0.27}$	0.85	0.00
03203000	Guyandotte River at Man	162	$0.21Q^{0.40}$	0.93	0.00	$0.03Q^{0.56}$	0.96	0.00
03202400	Guyandotte River near Baileysville	84	$0.92Q^{0.28}$	0.93	0.00	$0.02Q^{0.64}$	0.97	0.00
03155500	Hughes River at Cisco	118	$0.28Q^{0.41}$	0.90	0.00	$0.11Q^{0.38}$	0.86	0.00
03177500	Indian Creek at Indian Mills	8	$0.80Q^{0.27}$	0.98	0.00	$0.03Q^{0.65}$	0.99	0.00
03182000	Knapp Creek at Marlinton	14	$0.32Q^{0.29}$	0.38	0.02	$0.05Q^{0.59}$	0.78	0.00
03152500	Leading Creek near Glenville*	59	$0.43Q^{0.45}$	0.85	0.00	$0.16Q^{0.28}$	0.43	0.00
03195250	Left Fork Holly River near Replete	13	$0.33Q^{0.33}$	0.92	0.00	$0.15Q^{0.49}$	0.99	0.00
01609800	Little Cacapon River near Levels	7	**$3.15Q^{0.09}$**	**0.27**	**0.23**	$0.01Q^{0.85}$	0.97	0.00
03199000	Little Coal River at Danville	141	$0.05Q^{0.59}$	0.97	0.00	$0.36Q^{0.29}$	0.78	0.00
03199400	Little Coal River at Julian	28	$0.05Q^{0.65}$	0.94	0.00	$0.30Q^{0.28}$	0.72	0.00
03113700	Little Grave Creek near Glendale	5	$0.15Q^{0.47}$	0.97	0.00	$1.72Q^{0.23}$	0.86	0.02

Table 1-2. Regression equations for the relation between flow and average depth, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two to more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

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			Depth			Velocity		
Station number	Station	n	Equation	R^2	p	Equation	R^2	p
03152000	Little Kanawha River at Glenville	94	$0.82Q^{0.30}$	0.78	0.00	$0.09Q^{0.43}$	0.84	0.00
03153500	Little Kanawha River at Grantsville*	83	$0.13Q^{0.51}$	0.91	0.00	$0.20Q^{0.31}$	0.85	0.00
03155000	Little Kanawha River at Palestine*	181	$1.04Q^{0.28}$	0.57	0.00	$0.01Q^{0.64}$	0.86	0.00
03151500	Little Kanawha River near Burnsville	149	$0.51Q^{0.36}$	0.93	0.00	$0.08Q^{0.43}$	0.90	0.00
03151400	Little Kanawha River near Wildcat	21	$0.08Q^{0.49}$	0.95	0.00	$0.63Q^{0.24}$	0.77	0.00
03190000	Meadow River at Nallen	171	$0.29Q^{0.40}$	0.36	0.00	$0.03Q^{0.61}$	0.99	0.00
03190400	Meadow River near Mt. Lookout	101	$0.38Q^{0.32}$	0.96	0.00	$0.04Q^{0.58}$	0.99	0.00
03052000	Middle Fork River at Audra	91	$0.83Q^{0.27}$	0.95	0.00	$0.02Q^{0.64}$	0.99	0.00
03051500	Middle Fork River at Midvale	42	$0.30Q^{0.37}$	0.91	0.00	$0.09Q^{0.48}$	0.88	0.00
03114500	Middle Island Creek at Little	156	$0.05Q^{0.58}$	0.90	0.00	$0.37Q^{0.29}$	0.69	0.00
03204500	Mud River at Milton	132	$0.23Q^{0.47}$	0.98	0.00	$0.37Q^{0.27}$	0.86	0.00
01599500	New Creek at Keyser	16	$0.19Q^{0.42}$	0.91	0.00	$0.23Q^{0.47}$	0.89	0.00
03185500	New River at Caperton	71	$1.97Q^{0.17}$	0.87	0.00	$0.00Q^{0.72}$	1.00	0.00
03187300	North Fork Cranberry River near Hillsboro	3	$0.15Q^{0.42}$	1.00	NA	$0.25Q^{0.48}$	1.00	NA
01606000	North Fork South Branch Potomac at Cabins	8	$0.37Q^{0.30}$	0.94	0.00	$0.02Q^{0.65}$	1.00	0.00
01616500	Opequon Creek near Martinsburg	58	$0.42Q^{0.34}$	0.55	0.00	$0.61Q^{0.21}$	0.27	0.00
03213500	Panther Creek near Panther	27	$0.18Q^{0.47}$	0.58	0.00	$0.32Q^{0.40}$	0.58	0.00
01604500	Patterson Creek near Headsville	83	$0.32Q^{0.37}$	0.33	0.00	$0.10Q^{0.44}$	0.28	0.00
03191500	Peters Creek near Lockwood	29	$0.18Q^{0.47}$	0.78	0.00	$0.18Q^{0.48}$	0.74	0.00
03185000	Piney Creek at Raleigh	16	$0.06Q^{0.58}$	0.80	0.00	$0.56Q^{0.30}$	0.56	0.00
03201000	Pocatalico River at Sissonville	192	$0.28Q^{0.44}$	0.90	0.00	$0.29Q^{0.28}$	0.69	0.00
03201410	Poplar Fork at Teays	7	$0.12Q^{0.63}$	0.98	0.00	$0.39Q^{0.36}$	0.98	0.00
01610000	Potomac River at Paw Paw	76	$0.18Q^{0.43}$	0.98	0.00	$0.12Q^{0.38}$	0.80	0.00
01618000	Potomac River at Shepherdstown	230	$0.44Q^{0.32}$	0.94	0.00	$0.01Q^{0.64}$	0.98	0.00
03154500	Reedy Creek near Reedy	31	$0.23Q^{0.44}$	0.93	0.00	$0.13Q^{0.43}$	0.93	0.00

Table 1-2. Regression equations for the relation between flow and average depth, and flow and width for all stream-gaging stations in West Virginia draining less than 2,000 square miles, and with 10 or more years of record and two to more current-meter flow measurements at an identifiable cross section, for all measurements at that cross section.—Continued

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			Depth			Velocity		
Station number	Station	n	Equation	R^2	p	Equation	R^2	p
03177000	Rich Creek near Peterstown	2	$1.67Q^{0.14}$	NA	NA	$0.72Q^{0.22}$	NA	NA
03195100	Right Fork Holly River at Guardian	2	$0.07Q^{0.65}$	NA	NA	$0.11Q^{0.52}$	NA	NA
03052500	Sand Run near Buckhannon	22	$0.86Q^{0.23}$	0.38	0.01	$0.14Q^{0.56}$	0.86	0.00
03069000	Shavers Fork at Parsons	66	$0.25Q^{0.35}$	0.94	0.00	$0.05Q^{0.56}$	0.96	0.00
01636500	Shenandoah River at Millville	38	$0.03Q^{0.54}$	0.96	0.00	$0.10Q^{0.38}$	0.98	0.00
03057500	Skin Creek near Brownsville	17	$0.31Q^{0.40}$	0.98	0.00	$0.10Q^{0.52}$	0.97	0.00
01605500	South Branch Potomac River at Franklin	33	$0.37Q^{0.30}$	0.53	0.00	$0.12Q^{0.50}$	0.79	0.00
01606500	South Branch Potomac River near Petersburg	259	$0.40Q^{0.32}$	0.71	0.00	$0.05Q^{0.54}$	0.77	0.00
01608500	South Branch Potomac River near Springfield	216	$0.47Q^{0.32}$	0.67	0.00	$0.05Q^{0.50}$	0.79	0.00
03155200	South Fork Hughes River at Macfarlan	66	$0.58Q^{0.36}$	0.97	0.00	$0.04Q^{0.53}$	0.97	0.00
01607500	South Fork South Branch Potomac River at Brandywine	38	$0.16Q^{0.40}$	0.54	0.00	$0.26Q^{0.37}$	0.54	0.00
01608000	South Fork South Branch Potomac River near Moorefield	53	$0.33Q^{0.36}$	0.42	0.00	$0.02Q^{0.63}$	0.79	0.00
03153000	Steer Creek near Grantsville*	137	$0.45Q^{0.38}$	0.92	0.00	$0.08Q^{0.45}$	0.84	0.00
03154250	Tanner Run at Spencer	2	$0.60Q^{0.20}$	NA	NA	$0.06Q^{0.80}$	NA	NA
03068610	Taylor Run at Bowden	7	$0.11Q^{0.58}$	0.75	0.01	$0.32Q^{0.43}$	0.81	0.01
03056250	Three Forks Creek near Grafton	15	$0.24Q^{0.45}$	0.97	0.00	$0.16Q^{0.43}$	0.96	0.00
03214900	Tug Fork at Glenhayes	62	$0.08Q^{0.57}$	0.95	0.00	$0.69Q^{0.18}$	0.77	0.00
03214500	Tug Fork at Kermit	63	$0.07Q^{0.58}$	0.98	0.00	$0.29Q^{0.27}$	0.84	0.00
03213000	Tug Fork at Litwar	196	$0.44Q^{0.36}$	0.93	0.00	$0.04Q^{0.56}$	0.97	0.00
03212750	Tug Fork at Welch	7	$0.18Q^{0.45}$	0.98	0.00	$0.21Q^{0.42}$	0.96	0.00
03213700	Tug Fork at Williamson	132	$0.16Q^{0.47}$	0.95	0.00	$0.15Q^{0.36}$	0.91	0.00
03214000	Tug Fork near Kermit	259	$0.06Q^{0.59}$	0.98	0.00	$0.36Q^{0.25}$	0.89	0.00
01617000	Tuscarora Creek above Martinsburg	5	$\mathbf{0.50Q^{0.33}}$	**0.83**	**0.09**	$0.03Q^{0.97}$	0.90	0.05
03207000	Twelvepole Creek at Wayne	102	$0.56Q^{0.36}$	0.83	0.00	$0.06Q^{0.48}$	0.87	0.00

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			Depth			Velocity		
Station number	Station	n	Equation	R^2	p	Equation	R^2	p
03207020	Twelvepole Creek below Wayne	22	$0.41Q^{0.40}$	0.97	0.00	$0.20Q^{0.33}$	0.87	0.00
03051000	Tygart Valley River at Belington	186	$0.13Q^{0.48}$	0.99	0.00	$0.10Q^{0.41}$	0.98	0.00
03056500	Tygart Valley River at Fetterman	102	$0.67Q^{0.30}$	0.91	0.00	$0.01Q^{0.69}$	0.98	0.00
03054500	Tygart Valley River at Philippi	201	$0.18Q^{0.45}$	0.99	0.00	$0.05Q^{0.45}$	0.98	0.00
03050000	Tygart Valley River near Dailey	56	$0.58Q^{0.25}$	0.32	0.00	$0.97Q^{0.15}$	0.68	0.00
03050500	Tygart Valley River near Elkins	105	$0.85Q^{0.26}$	0.58	0.00	$0.03Q^{0.61}$	0.96	0.00
03154000	West Fork Little Kanawha River at Rocksdale	140	$0.33Q^{0.41}$	0.80	0.00	$0.09Q^{0.43}$	0.79	0.00
03058500	West Fork River at Butcherville	50	$0.23Q^{0.39}$	0.96	0.00	$0.11Q^{0.48}$	0.97	0.00
03059000	West Fork River at Clarksburg	104	$0.12Q^{0.51}$	0.74	0.00	$0.09Q^{0.42}$	0.75	0.00
03061000	West Fork River at Enterprise	7	$0.15Q^{0.46}$	0.99	0.00	$0.18Q^{0.34}$	0.91	0.00
03057300	West Fork River at Walkersville	12	$1.10Q^{0.27}$	0.41	0.02	$0.08Q^{0.44}$	0.82	0.00
03112000	Wheeling Creek at Elm Grove	72	$0.16Q^{0.44}$	0.85	0.00	$0.26Q^{0.36}$	0.90	0.00
03186500	Williams River at Dyer	78	$0.32Q^{0.33}$	0.58	0.00	$0.04Q^{0.59}$	0.83	0.00