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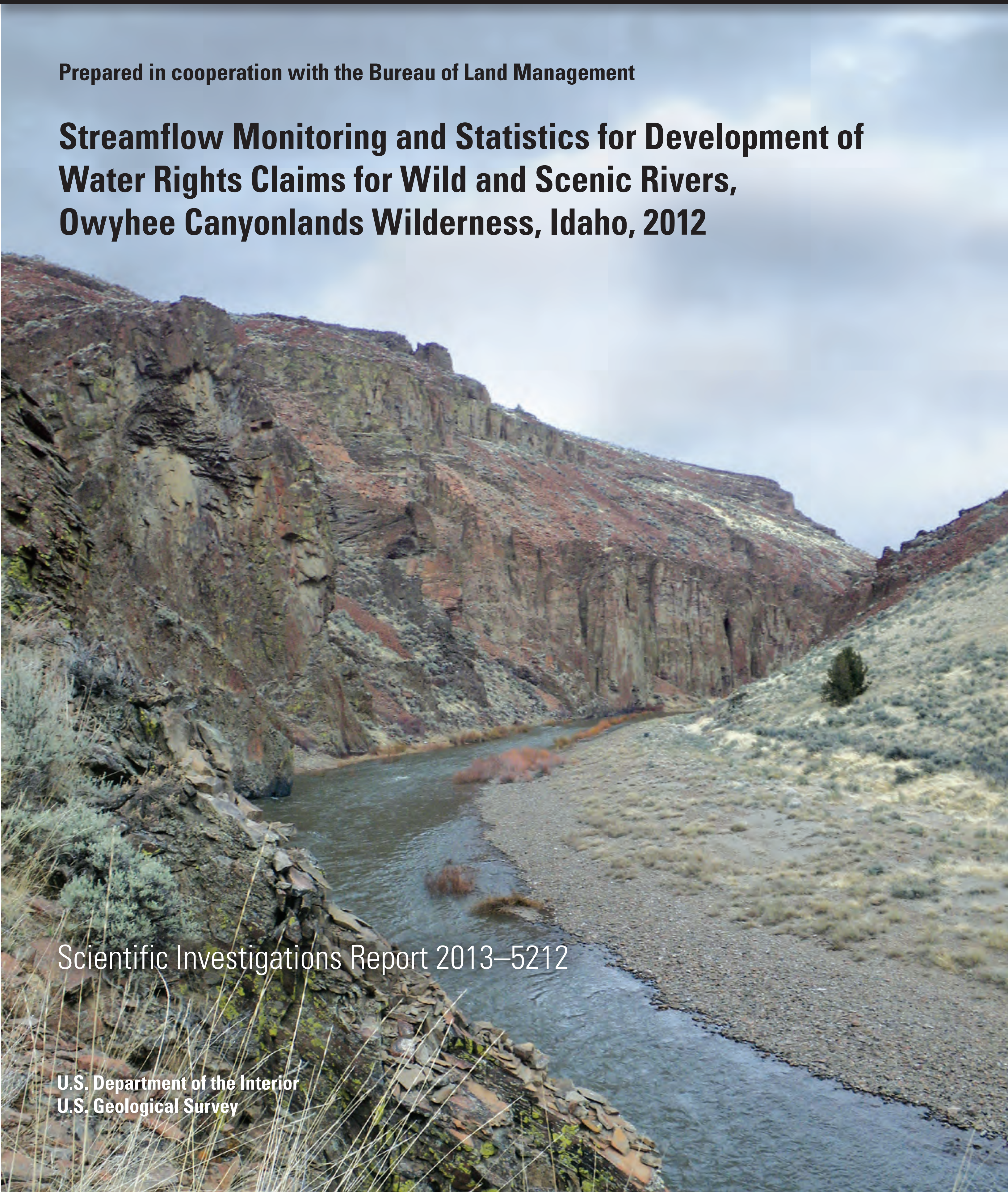
Streamflow Monitoring and Statistics for Development of Water Rights Claims for Wild and Scenic Rivers, Owyhee Canyonlands Wilderness, Idaho, 2012



Scientific Investigations Report 2013–5212

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

Covers

Front: Portion of monitored reach on Deep Creek near Riddle, Idaho (USGS 13176305). Photograph taken looking upstream by David Evetts, U.S. Geological Survey, March 12, 2012.

Back: Measurement of streamflow with an acoustic Doppler velocimeter in the East Fork Owyhee River at Crutcher Crossing, Idaho (USGS 13176400). Photograph taken looking downstream by Douglas Ott, U.S. Geological Survey, May 10, 2012.

Streamflow Monitoring and Statistics for Development of Water Rights Claims for Wild and Scenic Rivers, Owyhee Canyonlands Wilderness, Idaho, 2012

By Molly S. Wood and Ryan L. Fosness

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

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

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2013

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Conversion Factors, Datums, and Abbreviations and Acronyms

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
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 Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8.

Datums

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

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

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

Abbreviations and Acronyms

Abbreviation or acronym	Definition
AAF	average annual streamflow
AEP	annual exceedance probability
ARPD	Absolute value Relative Percent Difference
BCF	bias correction factor
BLM	Bureau of Land Management
CSG	crest-stage gage
GIS	Geographic Information System
IFIM	Instream Flow Incremental Methodology
MOVE.1	Maintenance of Variance Extension, Type 1, regression technique
OLS	ordinary least squares regression technique
ORV	outstanding remarkable value
RMSE	root mean square error
USGS	U.S. Geological Survey
WIE	Weighted Independent Estimate
WSR	Wild and Scenic River

Streamflow Monitoring and Statistics for Development of Water Rights Claims for Wild and Scenic Rivers, Owyhee Canyonlands Wilderness, Idaho, 2012

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Abstract

The U.S. Geological Survey, in cooperation with the Bureau of Land Management (BLM), collected streamflow data in 2012 and estimated streamflow statistics for stream segments designated "Wild," "Scenic," or "Recreational" under the National Wild and Scenic Rivers System in the Owyhee Canyonlands Wilderness in southwestern Idaho. The streamflow statistics were used by BLM to develop and file a draft, federal reserved water right claim in autumn 2012 to protect federally designated "outstanding remarkable values" in the stream segments. BLM determined that the daily mean streamflow equaled or exceeded 20 and 80 percent of the time during bimonthly periods (two periods per month) and the bankfull streamflow are important streamflow thresholds for maintaining outstanding remarkable values. Prior to this study, streamflow statistics estimated using available datasets and tools for the Owyhee Canyonlands Wilderness were inaccurate for use in the water rights claim.

Streamflow measurements were made at varying intervals during February–September 2012 at 14 monitoring sites; 2 of the monitoring sites were equipped with telemetered streamgaging equipment. Synthetic streamflow records were created for 11 of the 14 monitoring sites using a partial-record method or a drainage-area-ratio method. Streamflow records were obtained directly from an operating, long-term streamgage at one monitoring site, and from discontinued streamgages at two monitoring sites. For 10 sites analyzed using the partial-record method, discrete measurements were related to daily mean streamflow at a nearby, telemetered "index" streamgage. Resulting regression equations were used to estimate daily mean and annual peak streamflow at the monitoring sites during the full period of record for the index sites. A synthetic streamflow record for Sheep Creek was developed using a drainage-area-ratio method, because measured streamflows did not relate well to any index site to allow use of the partial-record method. The synthetic and actual daily mean streamflow records were used to estimate daily mean streamflow that was exceeded 80, 50, and 20 percent of the time (80-, 50-, and 20-percent exceedances) for bimonthly and annual periods. Bankfull streamflow statistics were calculated by fitting the synthetic and actual annual peak streamflow records to a log Pearson Type III distribution using Bulletin 17B guidelines in the U.S. Geological Survey PeakFQ program.

The coefficients of determination (R^2) for the regressions between the monitoring and index sites ranged from 0.74 for Wickahoney Creek to 0.98 for the West Fork Bruneau River and Deep Creek. Confidence in computed streamflow statistics is highest among other sites for the East Fork Owyhee River and the West Fork Bruneau River on the basis of regression statistics, visual fit of the related data, and the range and number of streamflow measurements. Streamflow statistics for sites with the greatest uncertainty included Big Jacks, Little Jacks, Cottonwood, Wickahoney, and Sheep Creeks. The uncertainty in computed streamflow statistics was due to a number of factors which included the distance of index sites relative to monitoring sites, relatively low streamflow conditions that occurred during the study, and the limited number and range of streamflow measurements. However, the computed streamflow statistics are considered the best possible estimates given available datasets in the remote study area. Streamflow measurements over a wider range of hydrologic and climatic conditions would improve the relations between streamflow characteristics at monitoring and index sites. Additionally, field surveys are needed to verify if the streamflows selected for the water rights claims are sufficient for maintaining outstanding remarkable values in the Wild and Scenic rivers included in the study.

Introduction

The Bureau of Land Management (BLM) is required to define the minimum streamflows or streamflow statistics needed to maintain outstanding remarkable values (ORVs) in stream segments designated "Wild," "Scenic," or "Recreational" under the National Wild and Scenic Rivers System in the Owyhee Canyonlands Wilderness in southwestern Idaho (fig. 1). ORVs are attributes that are considered unique, rare, or exemplary at a comparative regional or national scale, including wildlife habitat, scenic

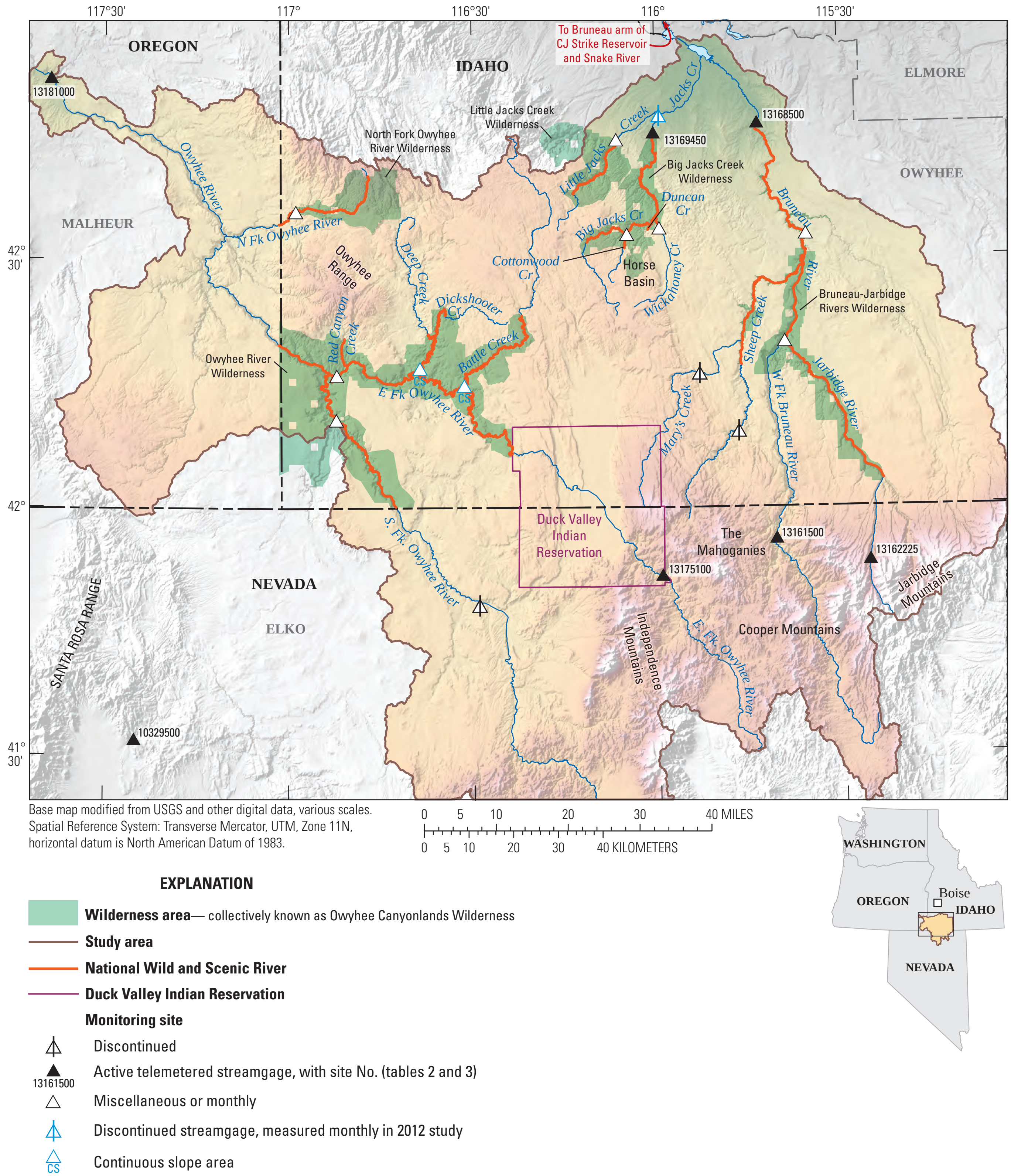

Figure 1. Study area extent, designated National Wild and Scenic Rivers and streamgaging sites in the Owyhee Canyonlands Wilderness, Idaho. Monitoring site information is shown in tables 1–3.

qualities, and recreational opportunities. The identified streamflow statistics are the basis of a draft, federal reserved water right proposal filed by BLM in autumn 2012, which is intended to protect the rivers in the study area from future upstream development and associated water demands. The streamflow statistics were selected to meet needs for recreation (typically high streamflow) and fish and wildlife (high streamflow for channel maintenance, and low or minimum streamflow for movement and habitat). Historically, the study area has lacked sufficient streamflow data, and streamflow statistics obtained from Geographic Information System (GIS)-based tools and regional regression models are imprecise. BLM required improved methods for calculating streamflow statistics in the study area, but had limited time to gather additional data because of a strict deadline for the water rights proposal. To support BLM's proposal, the U.S. Geological Survey (USGS) collected short-term streamflow data during February–September 2012 at selected sites in the study area basins, and indexed measured data to long-term streamgages at most study sites to produce synthetic streamflow records and exceedance probability distributions.

Background

Wild and Scenic River Designation

The Wild and Scenic Rivers Act of 1968 (Public Law 90-542; 16 U.S.C. 1271 et seq.) was created by Congress to preserve free-flowing rivers that have outstanding scenic, recreational, cultural, and ecological values for the enjoyment of present and future generations. As of April 2012, the Act protects about 12,600 mi of 203 rivers in 39 states. In Idaho, 891 river miles are designated as Wild, Scenic, or Recreational (hereinafter referred to as Wild and Scenic Rivers or WSR) under the Act. Rivers are classified as

- "Wild" if they are "free of impoundments and generally inaccessible except by trail, with watershed or shorelines essentially primitive and waters unpolluted";
- "Scenic" if they are "free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads"; and
- "Recreational" if they are "readily accessible by road or railroad, that may have some development on their shorelines, and that may have undergone some impoundment or diversion in the past" (Public Law 90-542; 16 U.S.C. 1271 et seq.).

In addition to these classifications, rivers must have one or more ORVs such as cultural/historical, fish, geologic, recreational, scenic, wildlife, or other similar values. The Omnibus Public Lands Management Act of 2009 (Public Law 111-11; 16 U.S.C. 7202) designated 324.5 mi of southern Idaho rivers as WSR and 517,000 acres of public lands in Owyhee County as Wilderness. The BLM has published a draft plan and environmental assessment (Bureau of Land Management, 2013) for managing and preserving ORVs in 16 river segments in the Owyhee Canyonlands Wilderness that were designated in the Act of 2009 (table 1).

Previous Data and Investigations

Streamflow statistics are sometimes used to define the minimum streamflows needed to sustain inherent qualities or beneficial uses of a river. These statistics typically are generated using long-term streamflow data collected at a streamgage, which ideally represent a range of climatic and hydrologic conditions. For this study, no USGS streamgages were located along any of the 16 WSR segments, although some discrete measurements have been made at various locations within the WSR segments (table 1). Six currently (2012) active, telemetered USGS streamgages are located either upstream or downstream of some of the WSR segments (fig. 1).

Defining the range and seasonality of streamflows is needed for implementing a WSR management strategy that protects the recognized ORVs. Estimates of streamflow statistics are available at ungaged locations in the study area through the USGS StreamStats program for Idaho (Ries and others, 2004; U.S. Geological Survey, 2013). The statistics in StreamStats were generated through use of regression techniques between basin characteristics and available streamflow data from long-term streamgages, and are documented in Hortness and Berenbrock (2001), Berenbrock (2002), Hortness and Berenbrock (2004), and Hortness (2006). The regression equations available for this region of Idaho were developed using data from 25 streamgages on free-flowing rivers with at least 10 years of streamflow record. Only four of these streamgages (USGS 13162200, 13162500, 13169500, 13170000) were in the study area described in this report. Additionally, two of the streamgages used in the regression analyses (USGS 13169500 and 13170000) were influenced by streamflow losses to groundwater, and are not representative of regional conditions. The other two streamgages (USGS 13162200 and 13162500) were discontinued in the 1970s. Uncertainty is high for streamflow statistics generated using StreamStats in the study area because of the paucity of long-term streamgages and the uniqueness of topography and other basin characteristics that are not well represented by regional regression models. Additionally, StreamStats generates only streamflow statistics at frequency intervals for which regional regression equations have been developed and published. For example, exceedance probability streamflows based on mean daily streamflow records are available for monthly and annual periods. Exceedance probability streamflows at smaller time increments, such as bimonthly (two statistics per month), must be interpolated or extrapolated from the monthly estimates.

Table 1. Characteristics of National Wild and Scenic Rivers in the Owyhee Canyonlands Wilderness, Idaho.

[Designations, length of river segment, and outstanding remarkable values are from Bureau of Land Management (2013, table 1.2). **Outstanding remarkable values:** An “X” denotes an outstanding remarkable value that has been identified for the river. **Abbreviations:** mi, miles; WY, water year (October 1–September 30); WSR, Wild and Scenic River]

River	Designation	Length of river segment designated wild, scenic, or recreational (mi)	Outstanding remarkable values							Number of sites in WSR segment with discrete measurements prior to WY 2012
			Cultural/ historical	Fish	Geologic	Recreational	Scenic	Wildlife	Other	
Big Jacks Creek Wilderness										
Big Jacks Creek	Wild	36.2		X		X	X	X	X	0
Cottonwood Creek	Wild	2.5		X		X	X	X	X	0
Duncan Creek[1]	Wild	0.9		X		X	X	X		0
Wickahoney Creek	Wild	1.5		X			X	X		0
Bruneau-Jarbidge Rivers Wilderness										
Bruneau River[1]	Wild/ Recreational	38.8/0.6	X	X	X	X	X	X	X	3
Jarbidge River	Wild	29.6	X	X	X	X	X	X	X	0
Sheep Creek	Wild	26.2	X	X	X	X	X	X		0
West Fork Bruneau River	Wild	0.3	X	X	X	X	X	X		2
Little Jacks Creek Wilderness										
Little Jacks Creek	Wild	12.4		X		X	X	X	X	1
North Fork Owyhee River Wilderness										
North Fork Owyhee River	Wild/ Recreational	16.1/5.8	X	X	X	X	X	X	X	1
Owyhee River Wilderness										
Battle Creek	Wild	24.3		X	X	X	X	X	X	1
Deep Creek	Wild	13.6		X	X	X	X	X		2
Dickshooter Creek[1]	Wild	9.5		X	X	X		X		0
East Fork Owyhee River	Wild	69.7		X	X	X	X	X	X	0
Red Canyon Creek[1]	Wild	4.7		X	X	X	X	X		1
South Fork Owyhee River	Wild/ Recreational	30.6/1.2	X	X	X	X	X	X		3

[1] Streamflow not evaluated for the study described in this report.

Riggs (1969) developed a method to estimate monthly and annual mean streamflow by relating monthly streamflow measurements at an ungaged site to a record of daily mean streamflows at a streamgage on a nearby river. He assumed that the ratio of concurrent daily mean streamflows of two rivers measured at about the middle of the month equaled the ratio of their monthly mean streamflows. Riggs evaluated the technique using data from the Bruneau and Jarbidge Rivers in Idaho, among other rivers, and determined that the technique had the greatest utility in areas where streamflow is not closely related to drainage area, such as in the mountainous western United States. Riggs determined that an annual mean streamflow estimated using this method was generally within 10 percent of the value calculated if using continuous streamgage data, but that monitoring costs would be one-third the cost of a streamgage. The Riggs (1969) method relied on measurements being made at about the middle of each month; making measurements with this timing and frequency can be difficult at sites with limited and weather-dependent access. The method does not allow for the calculation of statistics other than monthly or annual means or at smaller time scales, unless more frequent measurements are made.

Streamflow Statistics Used for Similar Studies

Establishing a minimum streamflow threshold is important for supporting aquatic habitat, passage for cold water biota, scenic qualities, and recreation. Often the determination of minimum instream flows requires extensive analysis and site characterization to evaluate habitat and water demands specific to a particular reach. Methods used in the Pacific Northwest for establishing these minimum flows at specific sites include the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service in the late 1970s (Bovee, 1982), and the Toe-Width Method (Swift 1975, 1977). Limited time and funding, as well as Wilderness Area restrictions, prevented full site characterizations during this study. The Tennant (1976) method was developed as a rapid assessment, non-site-specific tool to determine instream flow requirements for fish, and is based on percentiles of average annual streamflow (AAF). Tennant (1976) evaluated the method in 11 streams in Montana, Nebraska, and Wyoming, and determined that 10 percent of the AAF is the minimum instream flow needed for short-term fish survival, 30 percent AAF is required to sustain fair survival conditions, and 60 percent AAF results in excellent to outstanding habitat and high quality recreational use. Mann (2006) evaluated the Tennant (1976) method in additional rivers in the western United States, including Idaho, and determined that the Tennant method was most applicable to low-gradient streams with slopes less than 1 percent. As a result, the Tennant method is probably not applicable to the study area described in this report because mean stream slopes range from 6 to 26 percent.

In 1984, BLM sought a federal reserved water right to protect ORVs in the lower 4 mi of the Red River, a tributary of the Rio Grande River in northern New Mexico that is part of the National Wild and Scenic River System. The identified streamflow requirements for fish and wildlife, scenic, recreational, and water-quality purposes, documented in Garn (1986), were developed using IFIM. These values were compared to monthly values for the 50-, 75-, and 90-percent exceedance streamflows, or the streamflows that are equaled or exceeded 50, 75, and 90 percent of the time during a given month, respectively. The minimum streamflows required by IFIM corresponded to about the 80- to 90-percent exceedance streamflows. Similarly, the U.S. Department of Agriculture Forest Service issued a partial decree for a federal reserved water right in 2003 for the Salmon Wild and Scenic River, in central Idaho (Idaho Department of Water Resources, 2004). A water right claim was specified for bimonthly periods when streamflow measured at the USGS streamgage at Salmon River near Shoup (USGS 13307000) is less than 13,600 ft^3/s. The water right claim was based on the daily mean 80-percent exceedance streamflow. The water right claim also states that the Federal government is entitled to all streamflows between 13,600 and 28,400 ft^3/s, adjusted for upstream junior water right depletions. The water right precludes any diversion of water out of the drainage basin upstream of the endpoint of the WSR designation area.

Rationale for Selected Streamflow Statistics

Both high and low (minimum) streamflows can be important for ensuring long-term protection of the ecological health and recreational value of a river. The BLM has identified the 20-, 50-, and 80-percent exceedance bimonthly streamflow and the bankfull streamflow as important metrics for sustaining ORVs in the Owyhee Canyonlands Wilderness. Bimonthly streamflow statistics, as opposed to monthly or annual statistics, were selected to align proposed water right claims with short-term seasonal changes and instream flow needs. BLM considers the 20-percent exceedance bimonthly streamflows to be important for sustaining fish habitat, based on the typical life cycle of salmonids. Salmonid population dynamics are variable over time, and sustained populations are dependent on periodic ‘good’ years with favorable environmental conditions. These conditions often are associated with streamflows greater than the median monthly streamflow and are a recognized characteristic of the streamflow regime that affects fish populations (Thomas Clifford, Bureau of Land Management, written commun., 2013). The 20-percent exceedance bimonthly streamflows also are considered important for supporting fish passage, optimal stream temperature, and aquatic insect (food) production for redband trout (Thomas Clifford, Bureau of Land Management, written commun., 2013). The 80-percent exceedance bimonthly streamflows were selected by BLM because they are considered necessary to maintain healthy aquatic macroinvertebrate communities. These lower, minimum streamflows are critical for allowing aquatic macroinvertebrates to disperse into available habitats by drifting downstream with the streamflow (Malmqvist, 2002), which allows populations to expand and diversify. Additionally, minimum streamflows are important for sustaining hiding pools and for providing passage for bull and redband trout throughout drier periods in late summer and early autumn (Bureau of Land Management, 2013). The 50-percent exceedance, or median, bimonthly streamflow is important to the BLM, not as a basis for a water rights claim, but for determining whether future measured conditions are greater than, equal to, or less than median conditions.

Recreational uses also depend on streamflows during the relatively short runoff period in these drainage basins. Several of the rivers, particularly the Bruneau, Jarbidge, and Owyhee Rivers, are nationally renowned for class III/IV whitewater. Boating is typically possible only during the seasonal high streamflows in early spring and summer. The BLM will base their water rights claims for recreational uses on a combination of the 20- and 80-percent exceedance bimonthly streamflow statistics presented in this report, and the professional judgment of BLM river rangers.

Periodic high streamflows are thought to maintain aquatic habitat through channel scour and cleaning as well as deposition of nutrient-rich sediments in riparian areas (Hortness and Berenbrock, 2004). Additionally, seasonal high streamflows help preserve scenic and geomorphic qualities and support recreational opportunities such as boating. The bankfull streamflow, which is the streamflow and corresponding stage at which a river begins to flood, often is considered an important metric for river health. According to Leopold (1994, p. 135), “The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work results in the average morphologic characteristics of channels.” Periodic bankfull streamflows help maintain habitat for fish and other aquatic animals, and promote growth of riparian vegetation because they move streambed materials and nutrients within the channel and to upper channel banks, develop and maintain hiding pools, and increase channel diversity. Additionally, substrate for riverside campsites is deposited and maintained by periodic bankfull streamflows. Peak streamflows with a 66.7-percent annual exceedance probability (AEP) (1.5-year recurrence interval) generally are considered representative of bankfull conditions (Leopold, 1994; Hortness and Berenbrock, 2004). Similarly, Castro and Jackson (2001) completed a regional study and determined that the average AEP for bankfull streamflows in rivers in the Pacific Northwest states (Oregon, Washington, and Idaho) is 71.4 percent (1.4-year recurrence interval). Castro and Jackson (2001) suggested a 66.7-percent AEP (1.5-year recurrence interval) for use in Idaho. A streamflow with a 66.7-percent AEP has a 66.7 percent chance of occurring at any time in any given year.

Overall, BLM bases their water rights claims for the WSR segments in the Owyhee Canyonlands Wilderness on a combination of the 20- and 80-percent exceedance bimonthly streamflow statistics, bankfull streamflow statistics, and professional judgment of BLM River Rangers (for recreational ORVs) (Thomas Clifford, Bureau of Land Management, written commun., 2013). When streamflows are less than the bankfull streamflow, a water right is claimed for each bimonthly period, determined by water needs for sustaining ORVs applicable to that period. When streamflows are equal to or greater than the bankfull streamflow, the Federal government claims all streamflows for use in sustaining ORVs. The initial water rights proposal submitted by the BLM in autumn 2012 was based on provisional calculations provided by the USGS.

Purpose and Scope

This report provides streamflow data and statistics in support of BLM’s efforts to determine streamflows required to sustain outstanding remarkable values for rivers designated “Wild,” “Scenic,” or “Recreational” in southwestern Idaho. The study was conducted in water year (WY) 2012, and included field reconnaissance to select suitable monitoring sites, installing streamgages, measuring and monitoring streamflow, correlating measured data to long-term “index” streamgages to calculate synthetic streamflow records, and calculating streamflow statistics.

Description of Study Area

The study area included five Wilderness Areas collectively known as the Owyhee Canyonlands Wilderness: Big Jacks Creek, Bruneau-Jarbidge Rivers, Little Jacks Creek, North Fork Owyhee River, and Owyhee River Wilderness Areas (table 1; fig. 1).

Wild and Scenic Rivers

Sixteen river segments within the Owyhee Canyonlands Wilderness are identified as “Wild” or “Recreational” and are under the umbrella of the National Wild and Scenic River (WSR) system. No river segments in the study area are officially designated “Scenic,” although all have scenic ORVs (table 1). Fish and wildlife ORVs are present in all studied WSR segments. All WSR segments, except Wickahoney Creek, are identified as having a recreational ORV, and many segments have geologic and cultural or historical ORVs. Among the scenic values deemed remarkable for this area are the wide range of landscapes in the study area, from open sagebrush-dominated highlands to deep, narrow canyons. The wilderness areas are pristine, free of human development, and display a range of color and contrast between the rhyolite and basalt geology and the lush, green riparian vegetation. The scenic landscape and solitude also offer outstanding opportunities for hiking, camping, photography, and other outdoor pursuits. Many rivers in the study area offer challenging whitewater recreational opportunities for rafters, canoers, and kayakers.

The Owyhee Canyonlands Wilderness provides habitat for greater sage grouse (*Centrocercus urophasianus*), California bighorn sheep (*Ovis Canadensis californiana*), and redband trout (*Oncorhynchus mykiss*). The Bruneau and Jarbidge Rivers contain critical habitat for threatened bull trout (*Salvelinus confluentus*), and the endangered Bruneau hot springsnail (*Pyrgulopsis bruneauensis*) is found in the lower reaches of the Bruneau River. The southernmost population of bull trout in North America exists in the Jarbidge River (U.S. Fish and Wildlife Service, 2012). These bull trout are genetically distinct and are isolated from other bull trout populations by more than 150 mi. Little Jacks Creek supports the highest densities of redband trout of any surveyed stream in southwest Idaho (Zoellick and others, 2005). Additionally, the North Fork Owyhee River drainage basin includes some of the most diverse habitats of all Wilderness Areas in the study area, and supports several of the special status plants that are listed, or proposed for listing, as threatened or endangered under the Endangered Species Act.

Topography, Land Use, and Hydrology

The Owyhee Canyonlands Wilderness is part of the Northern Basin and Range Ecoregion and Columbia Plateau physiographic province in southwestern Idaho. Topography is characterized by elevated plateaus with mountains and canyons. All rivers in the study area drain to the Snake River and ultimately to the Columbia River and Pacific Ocean. Landforms and topography in the Owyhee Canyonlands Wilderness are diverse and include sagebrush steppe, dramatic cliffs, canyons with depths exceeding 800 ft, and lower montane woodlands. The study area is in the Owyhee Uplands sub-province of the Columbia Intermontane geologic province. Geology is dominated by Miocene Era volcanic formations, particularly rhyolite, and a younger overlying layer of basalt. Weathering and erosion have formed monolithic cliffs and rock pinnacle formations called hoodoos that create a unique landscape with high scenic value. The Owyhee, Bruneau, and Jarbidge River Basins contain the largest concentration of sheer-walled rhyolite and basalt canyons in the Western United States (Bureau of Land Management, 2013).

Federal and state governments own 82.7 percent of the land in Owyhee County, which contains the Owyhee Canyonlands Wilderness (Owyhee County, 2010; fig. 1). The remaining land is owned by private citizens or Indian Tribes, and dominant land uses outside of the Wilderness are cattle grazing and irrigated agriculture with small pockets of residential areas (Owyhee County, 2010). The landscape in the Wilderness is pristine with few or no human developments. The Wilderness is within a 2- to 4-hour drive of Boise, Idaho (fig. 1), which is the largest metropolitan area in Idaho, but the remote and rugged nature of the area limits visitor use (Bureau of Land Management, 2013).

Climate generally is semiarid and cool (Bailey, 1995), but summertime temperatures in some areas can exceed 100 °F. Mean annual precipitation in the study area ranges from 10.6 in. in the Sheep Creek drainage basin to 18.3 in. in the North Fork Owyhee River drainage basin (U.S. Geological Survey, 2013) (table 2). High streamflows usually are the result of snowmelt and rain-on-snow events, but because of the nearly 5,000 ft range in maximum basin elevations across the study area, timing of peak streamflow can vary substantially. Drainage basins for the East Fork Owyhee, South Fork Owyhee, West Fork Bruneau, and Jarbidge Rivers and Sheep Creek extend into Nevada (fig. 1). The Jarbidge River originates in the Jarbidge Mountains to the south in Nevada and has one of the highest mean basin elevations among all WSR segments studied (table 2). Sheep Creek and the Bruneau River originate in the Mahoganies and Cooper Mountains, also in Nevada. Streamflows in the Jarbidge and Bruneau River Basins typically peak in May–June, a little later than other rivers in the study area, because of the streamflow contribution from high elevation areas. The Sheep Creek Basin contains a number of contributing tributaries that primarily drain high elevation desert lands with irregular runoff patterns. The Big and Little Jacks Creeks and their tributaries primarily drain non-forested high-elevation desert lands in the Horse Basin (fig. 1). These rivers join the Bruneau River before flowing into the Bruneau arm of CJ Strike Reservoir on the Snake River (fig. 1). Streamflows in the Big and Little Jacks Creeks at discontinued streamgage locations have been intermittent because of interactions between groundwater and surface water and a high degree of infiltration into the alluvium. A streamflow value of zero was recorded for long periods, primarily from July to February, for most years of record at these streamgages. The East and South Forks of the Owyhee River originate in the Independence Mountains in northern Nevada, and the East Fork Owyhee River flows through the Duck Valley Indian Reservation (fig. 1). Runoff in drainage basins for Battle and Deep Creeks, tributaries of the East Fork Owyhee River, is rapid, and peak streamflows are short-lived. Streamflow in the East and South Forks of the Owyhee River and their tributaries generally peak in March–May. Maximum basin elevations are higher for the East and South Forks of the Owyhee River than the North Fork Owyhee River and Battle and Deep Creeks. Additionally, drainage areas are larger in the East and South Forks than the North Fork and include more low elevation areas. Streamflow in the East and South Forks of the Owyhee River is affected to an unknown degree by numerous irrigation diversions and small reservoirs. The North Fork Owyhee drainage basin originates in the Owyhee Range and is more wooded and supports more diverse habitats than the other drainage basins in the study.

Monitoring Sites

This study focused on 12 of the 16 WSRs in the study area (table 1), primarily those with the least historical streamflow data and (or) the greatest risk of upstream development that might affect streamflow within the WSR segments. Duncan, Dickshooter, and Red Canyon Creeks, and the main stem Bruneau River, were not part of the analysis described in this report; they were considered lower priority by the BLM because of a lower risk of upstream development compared to other WSR segments. The BLM used estimates from the USGS StreamStats program as the basis for their water rights claims for these sites, and acknowledged that substantial uncertainty might exist in these estimates.

Streamflow data were collected in the study area from February to September 2012. Fourteen monitoring sites in the 12 WSRs were selected and categorized on the basis of ease of access and availability of streamgages elsewhere in the drainage basin to serve as indexes or reference points (table 2).

Table 2. Monitoring sites used to estimate streamflow statistics for National Wild and Scenic Rivers, Owyhee Canyonlands Wilderness, Idaho, 2012.

[**USGS StreamStats**: Source is U.S. Geological Survey (2013). **Abbreviations:** USGS, U.S. Geological Survey; in., inches; mi², square miles]

USGS site No.	Site name	Latitude	Longitude	USGS StreamStats				Site type	Record computation method
				Mean basin elevation (ft)	Maximum basin elevation (ft)	Mean annual precipitation in basin (in.)	Drainage area (mi^2)		
Big Jacks Creek Basin									
13169450	Big Jacks Creek at Al Sadie Ranch, near Bruneau, Idaho	42°45′09″	116°00′16″	5,230	6,280	13.9	237	Telemetered streamgage	Partial-record
13169500	Big Jacks Creek near Bruneau, Idaho	42°47′08″	115°59′00″	5,170	6,280	13.8	244	Monthly	Direct[1]
13169420	Cottonwood Creek near Harvey Point, near Bruneau, Idaho	42°32′41″	116°04′41″	5,640	5,890	15.0	11.4	Miscellaneous	Partial-record
13169400	Wickahoney Creek near Grasmere, Idaho	42°33′26″	115°59′21″	5,250	6,130	12.8	56.6	Miscellaneous	Partial-record
Bruneau River Basin									
13162050	West Fork Bruneau River above Jarbidge River, near Grasmere, Idaho	42°19′40″	115°39′12″	6,380	9,910	16.3	557	Miscellaneous	Partial-record
13164600	Sheep Creek above mouth, near Grasmere, Idaho	42°29′48″	115°36′16″	5,690	8,530	10.6	600	Miscellaneous	Drainage area ratio
Jarbidge River Basin									
13162225	Jarbidge River below Jarbidge, Nevada	41°53′26″	115°25′40″	6,300	10,800	15.8	30.6	Telemetered streamgage	Direct
Little Jacks Creek Basin									
13169800	Little Jacks Creek above Wilderness Road, near Bruneau, Idaho	42°43′45″	116°06′16″	5,470	6,280	14.9	74.1	Monthly	Partial-record
13170000	Little Jacks Creek near Bruneau, Idaho	42°47′15″	115°58′47″	5,040	6,280	14.2	104	Monthly	Direct[1]
Owyhee River Basin									
13177845	South Fork Owyhee River below Little Owyhee River, near Crutcher Crossing, Idaho	42°10′04″	116°52′15"	5,810	10,400	14.0	1,800	Miscellaneous	Partial-record
13176400	East Fork Owyhee River at Crutcher Crossing, Idaho	42°15′37″	116°52′09″	5,760	9,110	13.6	2,140	Miscellaneous	Partial-record
13177910	North Fork Owyhee River near Fairylawn, Idaho	42°35′31″	116°58′49″	5,790	7,810	18.3	98.5	Monthly	Partial-record
13176195	Battle Creek above mouth, near Riddle, Idaho	42°14′24″	116°31′27″	5,730	6,890	12.3	263	Continuous slope area	Partial-record
13176305	Deep Creek above mouth, near Riddle, Idaho	42°16′07″	116°38′30″	5,530	6,890	13.7	450	Continuous slope area	Partial-record

[1] Using discontinued streamflow records.

Four types of monitoring sites were installed or used as part of the study:

- Telemetered (real-time) streamgages,
- Continuous slope area (CSA) sites,
- Monthly measurement sites, and
- Miscellaneous measurement sites.

A telemetered streamgage was installed at Big Jacks Creek during the study period because no other streamgages existed within the basin for correlation with measured data. A telemetered streamgage has been operated in the Jarbidge River since 1998, under an agreement separate from this study. All other sites were measured at various intervals during the study period, depending on ease of access. Sites with reasonable access were visited monthly, unless conditions prevented access during a particular month. Miscellaneous measurements were made less frequently than monthly at sites with difficult access, particularly at sites that required multi-day rafting or long hiking trips. Sites were selected for CSA streamgages if they had extremely difficult access, such as Battle and Deep Creeks, but had a suitable reach for measurement of water-surface profiles at a series of cross sections along the reach.

The installation of monitoring equipment was limited to preserve the wild and scenic nature of the sites. All equipment and attachment infrastructure had to be unobtrusive to boaters and wildlife, had to visually blend in with the surrounding landscape, and had to be removable at the end of the project. Permits were required to install any equipment or reference markers within the Wilderness Area boundaries.

Methods

The study included two phases in 2012: field data collection, which included site selection, the installation of monitoring equipment and streamgages, and streamflow data collection; and statistical analysis, which included data compilation, development of synthetic streamflow records, and calculation of relevant statistics.

Field Data Collection

Site Selection

USGS personnel visited the study area in February and March 2012 to select monitoring sites (table 2, figs. 2–5), install equipment where possible, and make preliminary streamflow measurements. CSA site locations were selected on the basis of the availability of a stream reach of sufficient length, minimum variability in channel shape between cross sections, and sufficient slope in water surface along the reach. Monthly and miscellaneous measurement sites were selected based on site access, proximity to a wilderness area downstream boundary, and the availability of a suitable measurement cross section as defined in Mueller and Wagner (2009) and Turnipseed and Sauer (2010).

Telemetered Streamgages

The USGS has historically operated streamgages on Big Jacks Creek near Bruneau, Idaho (USGS 13169500); Little Jacks Creek near Bruneau, Idaho (USGS 13170000); Sheep Creek near Tindall, Idaho (USGS 13163000), and the South Fork Owyhee River near Whiterock, Nev. (USGS 13177800) (figs. 1–5). A USGS streamgage on the Jarbidge River below Jarbidge, Nev. (USGS 13162225; fig. 1) is maintained according to an agreement separate from this study. A telemetered streamgage was installed in March 2012 on Big Jacks Creek at Al Sadie Ranch near Bruneau, Idaho (USGS 13169450) (figs. 2 and 6). The streamgage was installed about 3 mi upstream of the discontinued streamgage location (Big Jacks Creek near Bruneau, Idaho; USGS 13169500). Streamflow losses to groundwater have been observed in the past along the stream reach, specifically the section from the Wilderness Area boundary downstream to the confluence with Little Jacks Creek (fig. 2). The discontinued streamgage on Big Jacks Creek was considered a hydrologic benchmark station and was part of a national evaluation of environmental characteristics and water quality in the United States described in Mast and Clow (2000). The historical streamgage recorded zero flow for long periods most years from July to February and was discontinued in September 2004. The creek was noted as perennial at a point about 4 mi upstream of the discontinued streamgage, where it emerges from the canyon mouth (Mast and Clow, 2000). The location for the new streamgage used for this study was selected because it was expected to have more consistent streamflow and reasonable access (fig. 7*A*). However, only three measurements could be made at streamgage USGS 13169450 before the stream went dry on May 16, 2012 (fig. 7*B*). The termination of streamflow seemed to migrate upstream on subsequent field visits. USGS personnel began making measurements at the downstream boundary of the wilderness area, about 4 mi upstream of the discontinued streamgage (USGS 13169500), and planned to install a continuously recording pressure transducer to monitor stage. When USGS personnel visited the new location in June 2012 to install the pressure transducer, no streamflow was observed at the wilderness boundary nor as far as access would permit up the stream reach. The three streamflow measurements made at the Big Jacks Creek streamgage (USGS 13169450) were made and processed according to methods described in Mueller and Wagner (2009) and Turnipseed and Sauer (2010). Gage height was measured at the streamgage using a Sutron Accubar non-submersible pressure transducer. Data were recorded and transmitted by satellite using a Sutron Satlink2 data collection platform. A rating was created between the limited streamflow measurements and corresponding gage heights and used to generate a continuous record of streamflow in WY 2012. Computed daily mean streamflows are published in the U.S. Geological Survey (2012) Annual Data Report.

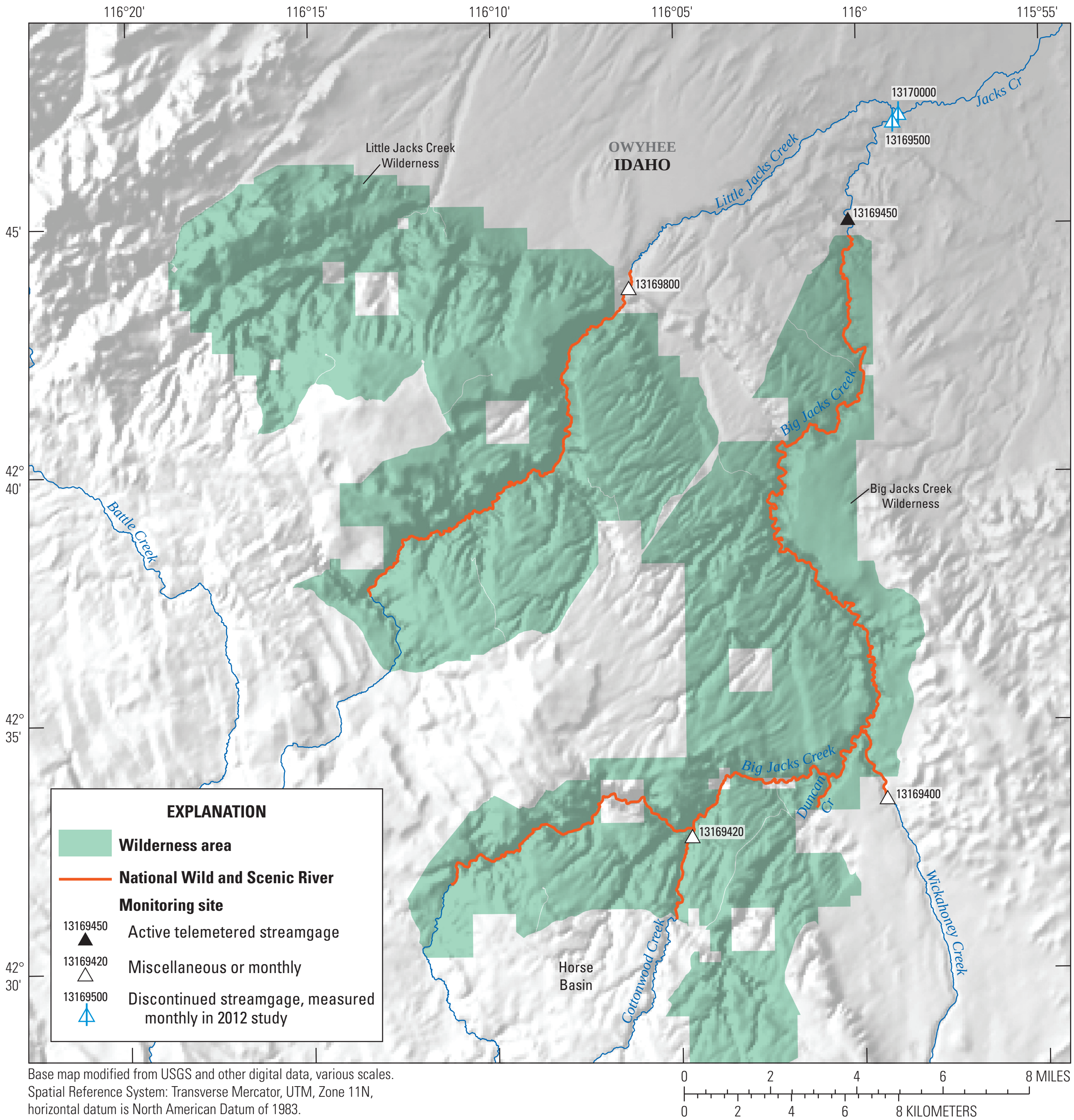

Figure 2. Locations of monitoring sites in the Big and Little Jacks Creeks Basins, Idaho, 2012. Monitoring site information is shown in tables 2 and 3.

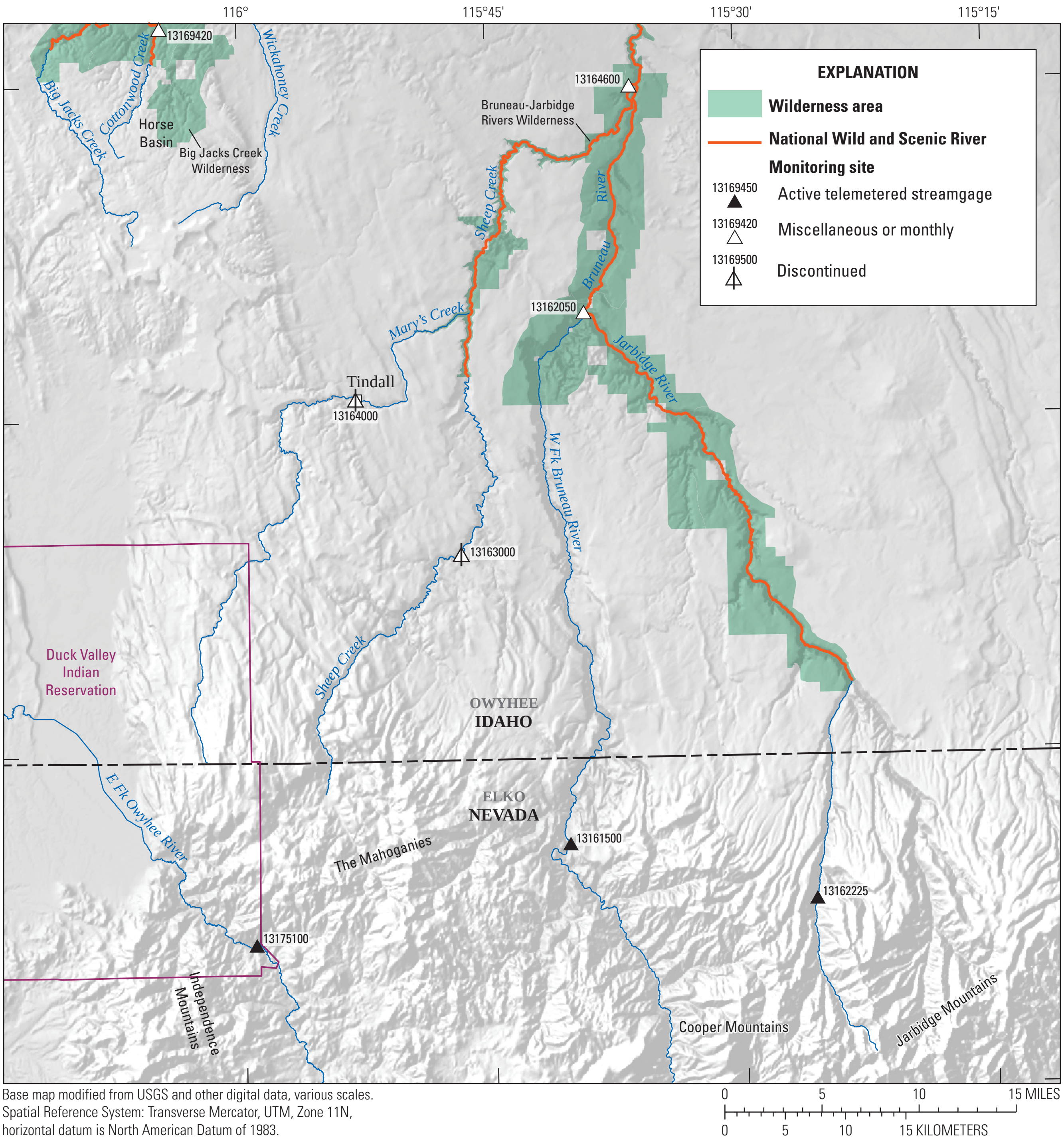

Figure 3. Locations of monitoring sites in the Bruneau and Jarbidge River Basins, 2012. Monitoring site information is shown in tables 2 and 3.

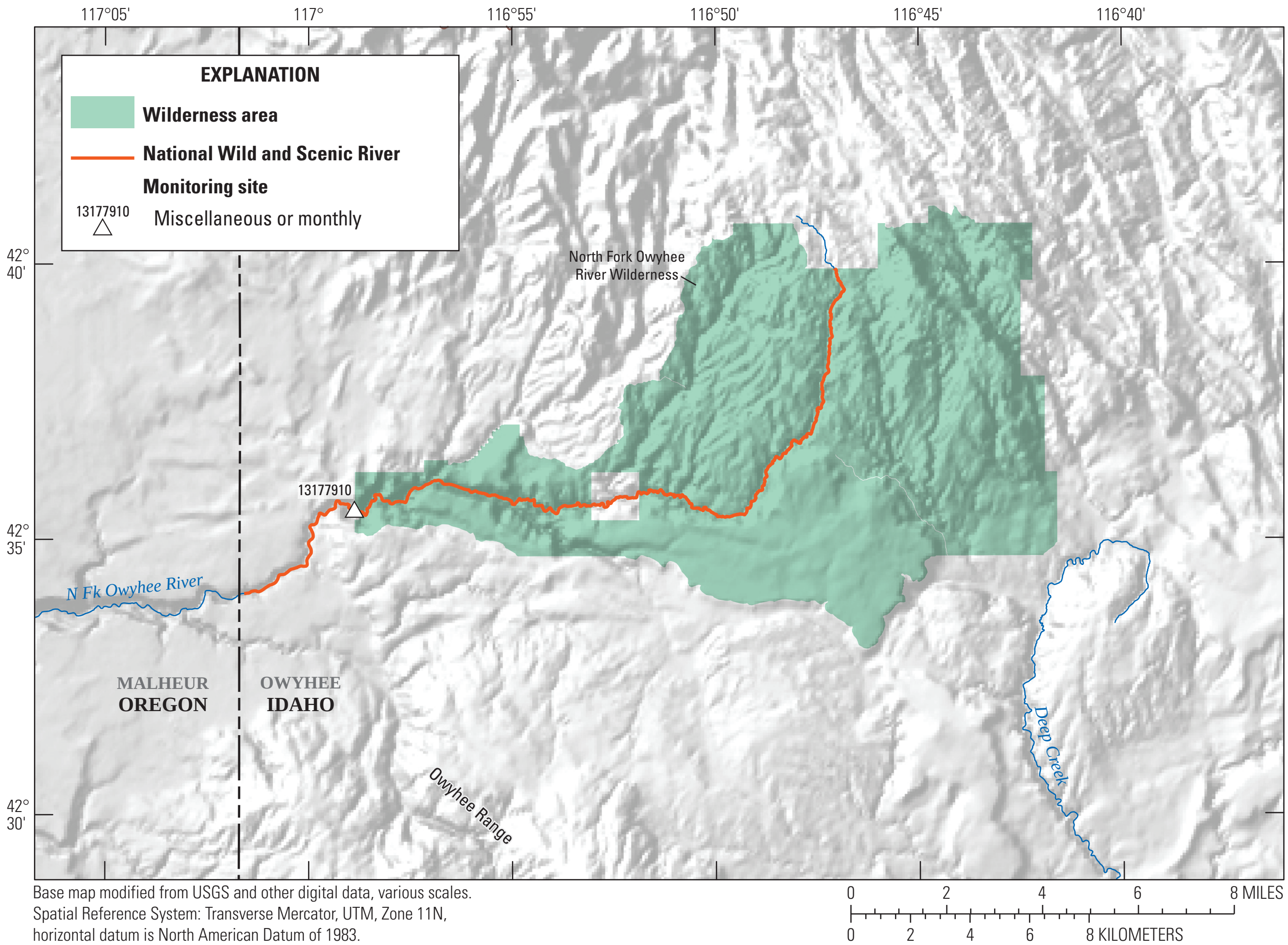

Figure 4. Location of monitoring site in the North Fork Owyhee River, Owyhee River Basin, 2012. Monitoring site information is shown in table 2.

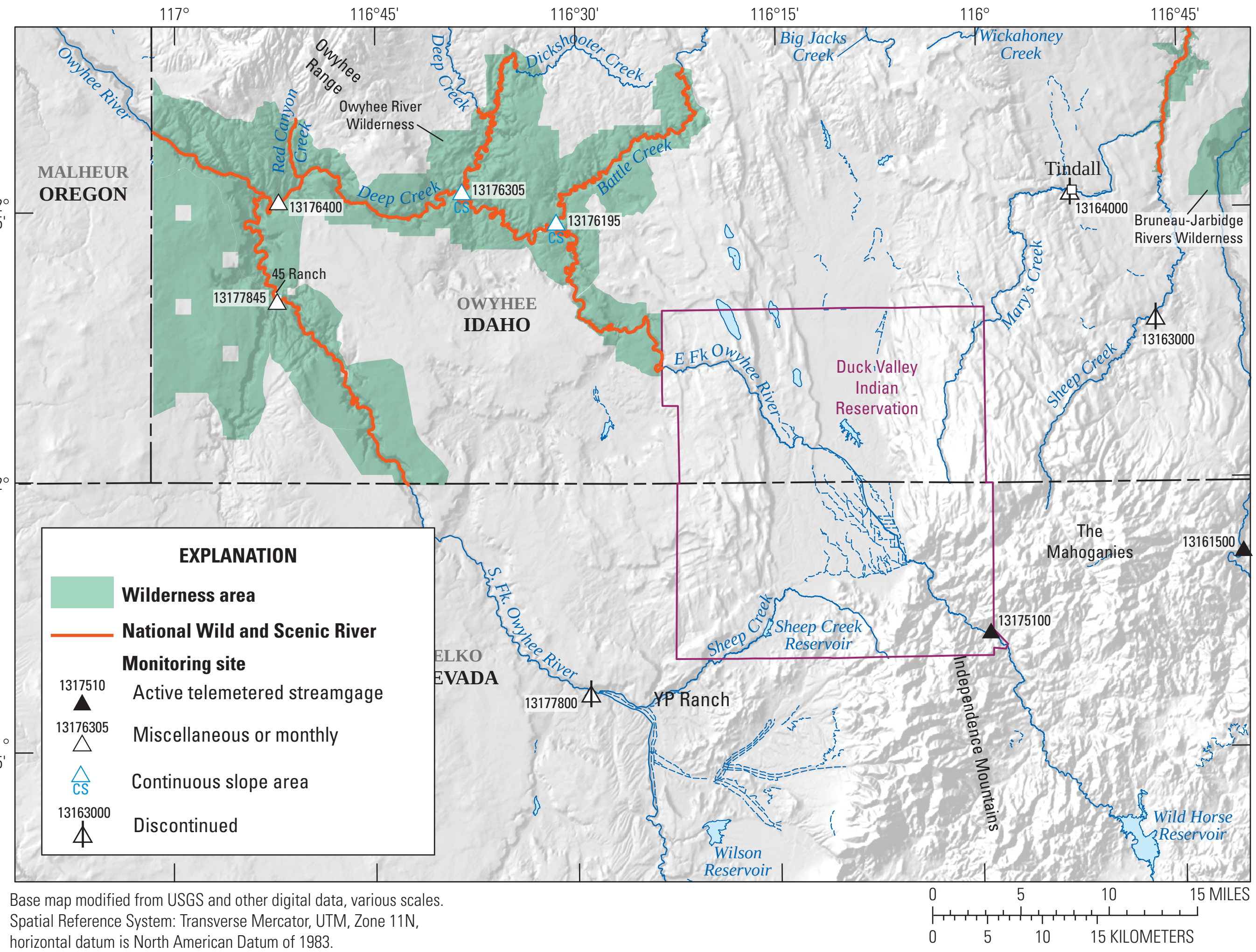

Figure 5. Locations of monitoring sites in the East and South Forks of the Owyhee River, Owyhee River Basin, 2012. Monitoring site information is shown in tables 2 and 3.

Figure 6. Telemetered streamgage installed on Big Jacks Creek at Al Sadie Ranch near Bruneau, Idaho (USGS 13169450). Photograph taken by Douglas Ott, U.S. Geological Survey, May 18, 2012.

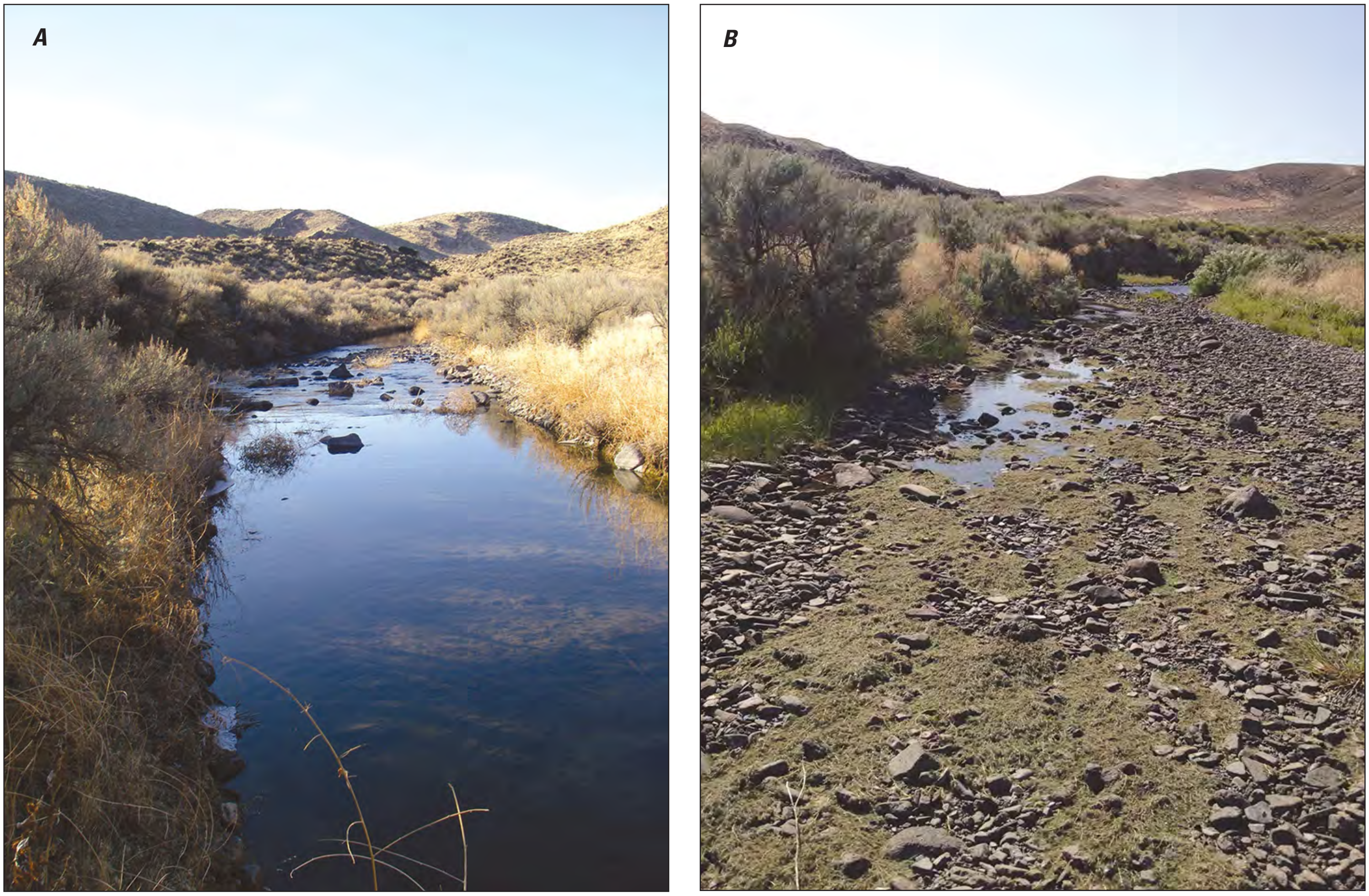

Figure 7. Surface-water to groundwater loss zone conditions at Big Jacks Creek at Al Sadie Ranch near Bruneau, Idaho (USGS 13169450). (*A*) February 13, 2012, and (*B*) May 18, 2012. Photograph *B* shows zero streamflow about 800 feet upstream of the streamgage. Streamgage records indicate that streamflow ceased on May 16, 2012 (U.S. Geological Survey, 2012). Photographs taken by Douglas Ott, U.S. Geological Survey.

Continuous Slope Area Streamgages

Monitoring sites on Battle and Deep Creeks (fig. 5) were selected for continuous slope area (CSA) streamgages because access was difficult and limited the ability to make routine measurements. CSA streamgages have been used in Arizona as a cost-effective alternative to a telemetered streamgage in remote areas and are described in detail in Smith and others (2010). Onset HOBO® non-vented submersible pressure transducers and steel reference pins were installed at three locations along a stream reach (fig. 8). USGS examined debris lines and high-water marks to define and install pressure transducers near any breaks in water surface slope. At locations where these marks were poor or not available, the pressure transducers were installed at locations where changes in bed slope or channel width were noted. Each stream cross section and reference pin was surveyed using Real-Time Kinematic Global Positioning System (RTK-GPS) equipment at the location of each pressure transducer. The pressure transducers were housed in a 1.5 in. galvanized pipe with drilled holes (fig. 8), and were attached to a 6-ft steel pin driven into the streambed (fig. 8). Streamflow was relatively high when the CSA streamgages were installed in March 2012, so the pressure transducers could not be installed in the stream thalweg. USGS personnel moved the pressure transducers and steel pins to the thalweg during a subsequent site visit in May 2012. Reference marks were established at the time of the CSA streamgage installation so future measurements could be referenced to the same gage height after removal of the pressure transducers and steel pins. Additional Onset HOBO® pressure sensors were mounted in air on the banks near the Battle and Deep Creek CSA streamgages to correct the non-vented pressure sensors for fluctuations in barometric pressure.

Figure 8. Continuous slope area streamgage at Deep Creek above mouth near Riddle, Idaho (USGS 13176305), June 8, 2012. A pressure transducer was housed inside a steel pipe with holes and was attached to a steel pin in the streambed. Three pins and transducers were installed at each continuous slope area streamgage in Battle and Deep Creeks. Photographs taken by Douglas Ott, U.S. Geological Survey.

Streamflow at these monitoring sites was first calculated using the slope-area method described in Dalrymple and Benson (1968) on the basis of the Manning uniform-flow equation involving channel characteristics, estimates of water-surface slope (as measured by the pressure transducers), and channel roughness. The CSA method is an expansion of the slope-area method in that it involves the continuous estimation of water-surface slope and the resulting streamflow hydrograph. The slope-area method works well when channel shape, conveyance, and roughness are uniform along the study reach. Additionally, the reach should be fairly straight. The length of the reach should be equal to or greater than 75 times the mean depth of the channel, and fall in the reach must be equal to or greater than the velocity head and at least 0.50 ft (Dalrymple and Benson, 1968).

The Slope-Area Computation program described in Fulford (1994) and the corresponding Graphical User Interface described in Bradley (2012) (SAC-GUI) were used to process the continuous water-level data and to compute streamflow from CSA streamgages. The CSA2SAC utility program described in Smith and others (2010) was used to batch process the data and generate the computed hydrograph for each monitoring site.

Initially only 2 or 3 streamflow measurements were expected to be made at the Battle and Deep Creek sites for calibration of the CSA computations, because accessing the sites was difficult. Ultimately, five streamflow measurements were made at each site during the study period. The measurements were first used to verify the results from the CSA computations. The CSA computations were extremely poor during all periods, except during brief periods of high flows, because of insufficient fall in water surface in the reach. Instead of using the CSA computations for continuous streamflow records, stage-discharge ratings were developed between the available streamflow measurements and the water levels measured by the pressure transducer at one cross section at each site. Pressure transducers were selected for the rating at each site depending on their proximity upstream from a well-defined control. The transducer farthest downstream in the study reach at Battle Creek and the transducer in the middle cross section at Deep Creek were selected for development of the ratings. The water-level records from these pressure transducers and streamflow ratings were then used to generate 201 days of continuous streamflow record for Battle Creek and 200 days of continuous streamflow record for Deep Creek.

Monthly and Miscellaneous Measurement Sites

Sites not selected for telemetered or CSA streamgages were visited when possible, as often as monthly, depending on site accessibility (table 2). Streamflow measurements made at this type of monitoring site are hereinafter referred to as "discrete" streamflow measurements. Measurements were made over a range of streamflows, where possible, from February to September 2012. For some sites, high streamflow events were difficult to capture because the lack of telemetered streamgages in most of the basins prohibited monitoring the exact timing of basin response to rain and snowmelt. Additionally, many of the basins are small, and streams respond rapidly to runoff. Rapid deployment of field crews to make measurements was at times difficult because of the planning and preparation required to visit sites with limited access. In particular, monitoring sites on Cottonwood, Wickahoney, and Sheep Creeks were extremely difficult to access, and fewer measurements were made than at other sites.

Streamflow measurements were made using acoustic Doppler current profilers and acoustic Doppler velocimeters, and were processed according to methods described in Mueller and Wagner (2009) and Turnipseed and Sauer (2010) (fig. 9). Six-foot-long steel pins with reference marks were driven into the streambed at each site as an alternative to USGS staff plates, which were visually obtrusive. Water level was measured on the steel pin and recorded at the time of each measurement to develop a streamflow rating. The rating was not used to generate continuous estimates of streamflow

Figure 9. Measurement of streamflow with an acoustic Doppler velocimeter in the West Fork Bruneau River above the Jarbidge River near Grasmere, Idaho (USGS 13162050). Photograph taken by Gregory Clark, U.S. Geological Survey, April 26, 2012.

because the sites were not equipped with pressure transducers to continuously monitor stage. The stage readings and rating can be used as a reference if continuous monitoring is implemented at these sites in the future.

After initial site selection, the South Fork Owyhee River monitoring site (USGS 13177845) was found to be affected by upstream regulation and irrigation diversions beginning about late April or early May 2012. Streamflow in the South Fork Owyhee River is regulated by upstream diversions on YP Ranch (fig. 5). Streamflow is diverted to hay fields, then to nearby Sheep Creek (a different Sheep Creek from the creek described elsewhere in this report), eventually flowing back into the South Fork Owyhee River upstream of the monitoring site. Some streamflow also is regulated by Sheep Creek Reservoir, in upper Sheep Creek Basin (again, a different Sheep Creek from the one described elsewhere in this report), and Wilson Reservoir, in upper South Fork Owyhee River Basin (fig. 5). Streamflow at the monitoring site also is regulated by a reservoir and irrigation diversions on the 45 Ranch (fig. 5). Water is diverted by pipe from the 45 Ranch reservoir and routed to several wetlands. Measurements made at these sites in April were the only measurements made during an unregulated period. Similarly, streamflow in the East Fork Owyhee River is regulated to an unknown degree by numerous small reservoirs in the Duck Valley Indian Reservation (figs. 1 and 5). After discussion with BLM, the USGS decided to continue to make measurements at these sites to represent regulated conditions. The BLM plans to research operational timelines for the reservoirs, as well as the magnitude of water rights claims in the drainage basin to determine the effect to natural streamflows.

Statistical Analysis

Streamflow frequency statistics are most accurately estimated at the location of a telemetered streamgage. Only two sites in this study were located at operating telemetered streamgages, so an alternative method was needed to estimate the streamflow statistics. As mentioned in the Previous Data and Investigations section, Riggs (1969) developed a method to estimate mean monthly and annual streamflows at ungaged sites. This method required a streamflow measurement on a monthly basis, including additional measurements during high streamflow conditions. The Riggs approach could not be used for this study because time allotted for data collection was limited to 6–8 months. Risley and others (2008) described three methods to estimate streamflow statistics at ungaged sites: (1) a drainage area ratio method, (2) a regression equation method, and (3) a partial-record site method. The drainage area ratio method is appropriate for use if the ungaged site is near a reference streamgage and shares similar unit area runoff characteristics, which was not possible for most sites in this study because of the lack of streamgages. The regression equation method involves creating a multiple linear regression equation using drainage basin characteristics such as drainage area, precipitation, mean elevation, slope, and soil type. The USGS StreamStats program uses the regression equation method to estimate streamflow statistics in ungaged locations, but as mentioned in the Previous Data and Investigations section, could not be used to produce reliable estimates for most sites in the study because of the lack of streamgages in the greater region and the high variability of basin characteristics. The partial-record site method involves developing a relation between available data at ungaged and gaged sites. The relation is developed from a series of miscellaneous streamflow measurements at an ungaged site and the corresponding daily mean streamflows at an operating telemetered streamgage.

Data Compilation and Record Development

For this study, three methods were used to develop the streamflow records needed to calculate bimonthly and peak streamflow statistics for the BLM water rights claims: (1) a partial-record method, (2) a drainage area ratio method, and (3) a direct computation method. The partial-record method was used at almost all the monthly, miscellaneous, and CSA sites, hereinafter referred to as “partial-record” sites (table 2). The drainage area ratio method was used at the Sheep Creek monitoring site because the number and range of streamflow measurements were inadequate for use of the partial-record method. A long-term, telemetered streamgage is at the Jarbidge River monitoring site, so streamflow records at the site were computed using a stage-discharge relation developed under an agreement separate from this project. Discontinued streamgage records exist for Big Jacks Creek (USGS 13169500) and Little Jacks Creek (USGS 13170000) monitoring sites. Streamflow records for the Jarbidge River, Big Jacks Creek, and Little Jacks Creek were used directly to calculate streamflow statistics (direct computation method), and no further adjustments were needed.

Partial-Record Method

All discrete streamflow measurements, including any miscellaneous streamflow measurements made prior to this study at a given monitoring site, were compiled and organized by date for each of the partial-record sites. The computed daily mean streamflow record was compiled for the two CSA sites at Battle and Deep Creeks, which were also considered partial-record sites. The measurements from the partial-record sites were assumed to represent daily mean conditions at the sites, although this could not be verified. The measurements from the partial-record sites and computed streamflow data from the CSA partial-record sites were then compared to the daily mean streamflow values at any operating telemetered streamgages in the overall drainage basins (fig. 1). The telemetered streamgages were evaluated as “index” sites for the partial-record sites. Synthetic daily mean and annual peak streamflow records were created for each partial-record site through use of a regression between the discrete streamflow measurements and the corresponding daily mean streamflow at the corresponding index site on the same day.

Selection of Index Sites and Development of Regressions

Six telemetered streamgages were evaluated as index sites for the partial-record sites (table 3). A minimum of two telemetered streamgages were compared to measurements at each partial-record site to determine the single most suitable index site. Initially, each potential index site was qualitatively selected on the basis of distance from the partial-record sites and similarities in drainage basin characteristics. The index sites were required to have a daily mean streamflow value on the day of each discrete measurement at the partial-record site. Maintenance of Variance Extension, Type 1 (MOVE.1) regression techniques were used in TIBCO Spotfire S-PLUS™ (TIBCO Software Inc., 2008) to develop the relations between the partial-record site measurements (dependent variable) and daily mean streamflow from the potential index sites (independent variable) according to equation 1, after transforming all streamflow data to natural log scale:

$$\ln(Q_{PRS}) = \ln(a) + b\left(\ln\left(Q_I\right)\right) \quad (1)$$

where

Q_{PRS} is the synthetic or estimated daily mean streamflow at the partial-record site, in cubic feet per second;

ln is the natural log;

a is the regression intercept;

b is the regression coefficient corresponding to $\ln Q_I$; and

Q_I is the daily mean streamflow at the index site, in cubic feet per second.

Table 3. Streamgages evaluated as index sites for the development of synthetic streamflow records at partial-record sites, Owyhee Canyonlands Wilderness, Idaho, 2012.

[**Abbreviations:** mi^2, square miles; ft^3/s, cubic feet per second]

USGS site No.	Site name	Latitude	Longitude	Drainage area (mi^2)	Period of record used in analysis	Years of annual peak streamflows	Range of streamflows used in analysis (ft^3/s)
				Bruneau River Basin			
13161500	Bruneau River at Rowland, Nevada	41°56′00″	115°40′25″	382	June 1913 to September 1918; October 1966 to September 2012	57	1.7–2,140
13168500	Bruneau River near Hot Spring, Idaho	42°46′16″	115°43′13″	2,686	July 1909 to March 1915; October 1943 to September 2012	74	6.9–6,860
				Jarbidge River Basin			
13162225	Jarbidge River below Jarbidge, Nevada	41°53'26"	115°25'40"	30.6	April 1998 to October 2011; January 2012 to September 2012	15	1.0–633
				Little Humboldt River Basin			
10329500	Martin Creek near Paradise Valley, Nevada	41°32′05″	117°25′01″	175	October 1921 to September 2012	91	2.0–9,000
				Owyhee River Basin			
13175100	Owyhee River near Mountain City, Nevada	41°51′38″	115°59′18″	391	April 1991 to September 1995; May 1997 to September 2012	20	0.42–1,590
13181000	Owyhee River near Rome, Oregon	42°51′59″	117°38′57″	8,000	October 1949 to September 2012	63	42–55,700

The MOVE.1 regression technique was originally proposed by Hirsch (1982) as an improvement over traditional ordinary least squares (OLS) regression techniques, particularly when used to extend the streamflow record at a partial-record site. The MOVE.1 regression technique attempts to minimize errors in both the X and Y direction, whereas OLS minimizes errors only in the Y direction. Additionally, MOVE.1 preserves the variance of the observed record and has been shown to produce estimates that have much smaller bias than those generated using OLS, particularly when extending short streamflow records to estimate streamflow statistics for extreme streamflow conditions such as floods and droughts (Hirsch, 1982). Helsel and Hirsch (2002) stated that MOVE.1 regression techniques should be used to create synthetic or extended streamflow records when the probabilities of exceedance must be calculated or inferred. OLS regression techniques can underestimate variance in these cases because the variability of measured values around the resulting regression line is not considered (Hirsch, 1982). Other researchers (Stedinger and Thomas, 1985; Ries and Friesz, 2000; Parrett and others, 2010, among others) have since used MOVE.1 regression techniques for creating synthetic or extended streamflow records at partial-record sites based on comparisons with index sites. The most suitable index site for a particular partial-record site was initially selected using OLS regression techniques based on the best graphical fit of the data, highest coefficient of determination (R^2), lack of bias in regression residuals, statistical significance of the independent variable, and lowest root mean square error (RMSE). The final regression equations were then generated using MOVE.1 regression techniques.

Three partial-record sites had zero-flow observations: Big Jacks Creek at Al Sadie Ranch (July 27 and September 12, 2012), Wickahoney Creek (September 4, 2012), and Deep Creek (July 26–September 30, 2012 [from the CSA streamgage record]). Zero-flow observations were considered useful for representing the low streamflow conditions at the partial-record sites, but could not be easily incorporated into a natural log-transformed regression equation. As a result, left-censored linear regression techniques were used in TIBCO Spotfire S-PLUS™ (TIBCO Software Inc., 2008) to develop regression equations for partial-record sites with zero flow observations. Each zero flow observation was assigned a value of less than 0.01 ft^3/s, which is considered a reasonable perception threshold for streamflow on the basis of the operating limits of the instruments used to measure streamflow and USGS precision limits on published streamflow estimates (0.01 ft^3/s when streamflow is in the range 0.01 to 9.99 ft^3/s, as stated in Rantz and others, 1982). The left-censored linear regression technique in TIBCO Spotfire S-PLUS™ is a Tobit regression method, which is similar to OLS regression except that the regression equation intercept and coefficient are fit by maximum likelihood estimation techniques (Helsel and Hirsch, 2002). Tobit regression is considered appropriated for small (<20 percent) and moderate (20–50 percent) amounts of censored data (Helsel and Hirsch, 2002; Helsel, 1990). Left-censored regression techniques commonly are used when analyzing water-quality concentration datasets that include data points less than an analytical reporting limit, but also can be used to analyze streamflow measurement data.

Synthetic Streamflow Record

After the index site was selected, the developed regression equation was applied to the entire period of record of daily mean streamflows at the index site, creating a synthetic streamflow record at the partial-record site. A non-parametric bias correction factor (BCF), described in Duan (1983) and Risley and others (2008), was applied to the synthetic streamflow record to remove bias introduced during the retransformation of the data. The BCF was calculated according to equation 2 by averaging the mean of the transformed residuals from the regression equation between the partial-record and index site:

$$\mathrm{BCF} = \sum \exp\left(res_{1 \cdot\cdot N}\right)/N \tag{2}$$

where

BCF is the Duan bias correction factor (dimensionless);

exp is the exponent;

$res_{1 \cdot\cdot N}$ is the residual of each observation in the regression, or difference between the observation and estimated value from the partial-record and index site streamflows, in cubic feet per second;

$\sum \exp\left(res_{1 \cdot\cdot N}\right)$ is the sum of the transformed residuals from all observations used in the regression; and

N is the total number of observations used in the regression.

The final retransformed regression equation, with previously defined parameters, used to develop the synthetic streamflow record at each partial-record site is:

$$Q_{PRS} = \mathrm{BCF} \times aQ_I{}^b. \tag{3}$$

Given available data, the relation between measurements at the partial-record sites and daily mean streamflows at an index site was assumed to be roughly the same as the relation between annual peak streamflows at the two locations. Equation 3 also was used to create a synthetic record of annual peak streamflows at the partial-record sites from the record of annual peak streamflows at the index sites.

Drainage Area Ratio Method

The drainage area ratio method was used to create a synthetic streamflow record at the Sheep Creek monitoring site because relations between measurements and corresponding daily mean streamflow at potential index sites were extremely poor. As a result, the partial-record method could not be used. The drainage area ratio method allows for the estimation of streamflow at a point of interest by adjusting available streamflow data from streamgages elsewhere in the drainage basin using a ratio between the drainage area at the point of interest and at the streamgage. Two discontinued streamgages located in the Sheep Creek drainage basin were used for the analysis: USGS 13163000, Sheep Creek near Tindall, Idaho and USGS 13164000, Mary's Creek at Tindall, Idaho, which joins Sheep Creek at Tindall (fig. 3). Streamflow data were collected at these streamgages from 1910 to 1913, about a century before the data were collected for the study described in this report; more recent datasets were not available for the analysis at Sheep Creek.

The monitoring site (point of interest) on Sheep Creek (USGS 13164600) is downstream of the confluence of Sheep and Mary's Creeks, and the discontinued streamgage on Sheep Creek near Tindall is upstream of the confluence, so streamflow had to be estimated separately for Sheep and Mary's Creeks upstream of the confluence then adjusted on the basis of drainage area downstream to the monitoring site. Streamflow for the Sheep Creek upstream of the confluence was estimated according to equation 4:

$$Q_{SAC} = Q_{13163000} \times \left(DA_{SAC} / DA_{13163000} \right)^{a} \qquad (4)$$

where

Q_{SAC} is the daily mean streamflow estimated in Sheep Creek above the confluence with Mary's Creek, in cubic feet per second;

$Q_{13163000}$ is the daily mean streamflow measured at station 13163000, Sheep Creek near Tindall, Idaho, in cubic feet per second;

DA_{SAC} is the area of the drainage basin of Sheep Creek upstream of the confluence with Mary's Creek, in square miles;

$DA_{13163000}$ is the area of the drainage basin of Sheep Creek at station 13163000, in square miles; and

a is a unitless exponent representing a nonlinear relation in drainage area between stations, as described in Berenbrock (2002).

Similarly, streamflow for Mary's Creek upstream of the confluence with Sheep Creek was estimated according to equation 5:

$$Q_{MAC} = Q_{13164000} \times \left(DA_{MAC} / DA_{13164000} \right)^{a} \qquad (5)$$

where

Q_{MAC} is the daily mean streamflow estimated in Mary's Creek upstream of the confluence with Sheep Creek, in cubic feet per second;

$Q_{13164000}$ is the daily mean streamflow measured at station 13164000, Mary's Creek at Tindall, Idaho, in cubic feet per second;

DA_{MAC} is the area of the drainage basin of Mary's Creek above the confluence with Sheep Creek, in square miles;

$DA_{13164000}$ is the area of the drainage basin of Mary's Creek at station 13164000, in square miles; and

a is a unitless exponent representing a nonlinear relation in drainage area between stations, as described in Berenbrock (2002).

Drainage areas were obtained from streamgage records and by delineating basins using the USGS StreamStats program. These streamflow records were then combined and further adjusted to the monitoring site according to equation 6:

$$Q_{13164600} = \left[Q_{SAC} + Q_{MAC} \right] \times \left[DA_{13164600} / \left(DA_{SAC} + DA_{MAC} \right) \right]^{a} \qquad (6)$$

The drainage area method used for Sheep Creek does not account for travel time of streamflow from the discontinued monitoring sites, to the confluence of Sheep and Mary's Creeks, and ultimately to the site monitored during the study. An inherent assumption in the analysis is that the travel time is less than 1 day. Berenbrock (2002) assumed that the drainage-area ratio between gaged and ungaged sites was nonlinear in a regional frequency analysis of peak streamflows at ungaged sites in Idaho. He applied an exponent to a ratio that was computed on the basis of a regression between the logarithms of drainage area and the magnitude of floods with AEPs from 0.2 to 50 percent. The average exponent was 0.77 for the region that encompasses the study area. The exponent calculated by Berenbrock (2002) was assumed to be valid also for streamflow statistics described in this report and was applied in the Sheep Creek analysis. The drainage area ratio method was used to generate a synthetic record of daily mean streamflow for the period of record for the discontinued streamgages (1910–13), but was not used to create a synthetic record of annual peak streamflows because only 2 full years of streamflow data were available from the discontinued index sites.

Calculation of Bimonthly Streamflow Statistics

The record of daily mean streamflow from the current (2012) streamgage on the Jarbidge River, discontinued streamgages on Big Jacks (USGS 13169500) and Little Jacks (USGS 1317000) Creeks, and the synthetic record of daily mean streamflow at all other sites were divided into bimonthly periods to calculate bimonthly exceedance probabilities. The first bimonthly period was defined as the 1st through the 14th, and the second bimonthly period was defined as the 15th through the end of the month. Data from each of the 24 bimonthly periods were combined for all years in the period of record and were used to develop an exceedance probability curve for each period on the basis of the Weibull plotting position formula described in Helsel and Hirsch (2002) and Wanielista and others (1997). The Weibull formula commonly is used for the development of streamflow exceedance probability and flood frequency curves and is a standard procedure in Bulletin 17B, a well-recognized guidance manual for calculating flood frequency statistics in the United States (Interagency Advisory Committee on Water Data, 1982). Daily mean streamflow data were ranked in descending order, and exceedance probabilities were calculated for each value according to equation 7:

$$\text{Exceedance probability}_i \text{ (percent)} = \left[\text{Rank}Q_{dmi} / \left(n+1\right)\right] \times 100 \qquad (7)$$

where

i is the plotting position or rank,

$\text{Rank}Q_{dmi}$ is the i_{th} rank of the daily mean streamflow, in cubic feet per second, and,

n is the total number of daily mean streamflow values.

Daily mean streamflows corresponding to the 20-(Q_{20}), 50-(Q_{50}), and 80-(Q_{80}) percent exceedance probabilities then were extracted from the streamflow exceedance probability curves for each bimonthly period (fig. 10). The exceedance probability corresponds to the streamflow that is equaled or exceeded over a given period of time. For example, the daily mean streamflow corresponding to the Q_{20} for the bimonthly period May 1–14 is equaled or exceeded during 20 percent of the days during that period over the period of record. Q_{20} represents a high streamflow condition, Q_{50} represents a median streamflow condition, and Q_{80} represents a low streamflow condition. Annual values for Q_{20}, Q_{50}, and Q_{80} were also compiled because they were easily calculated and could be used by BLM for comparison with the bimonthly statistics.

Calculation of Bankfull Streamflow Statistics

The bankfull streamflow statistic, or 66.7-percent annual exceedance probability (AEP), is calculated using the record of annual peak streamflows for a site rather than the record of daily mean streamflows. Files containing annual peak streamflows were loaded into the USGS PeakFQ program described in Flynn and others (2006). The Bulletin 17B analysis option was used within the PeakFQ program to generate peak streamflow statistics. Bulletin 17B procedures, documented in Interagency Advisory Committee on Water Data (1982), involve fitting a Pearson Type III frequency distribution to the logarithms of annual peak streamflows using the method of moments. The accuracy of fitting a log Pearson Type III distribution to the dataset depends on the ability to represent the shape or skewness of the data distribution, which can be heavily influenced by very small or very large peak streamflows in the dataset (outliers). The PeakFQ program screens for high and low outliers and allows the use of a weighted skew that weights at-site station skew with a generalized, or regional, skew to improve the fit of the log Pearson Type III distribution. Weighted skew was used in the analysis for all sites except the East and South Fork Owyhee Rivers, which are affected by regulation and diversions to an unknown degree. The at-site skew was used for the East and South Fork Owyhee Rivers because regional characteristics may not be representative of conditions at the sites. The bankfull streamflow statistic for Jarbidge River, Big Jacks Creek, and Little Jacks Creek were computed using a flood frequency analysis of recorded peak streamflows because each site contained a long-term record of direct streamflow measurements. Bankfull streamflow statistics for each partial-record site were computed by doing a flood frequency analysis on the synthetic annual peak streamflows. The synthetic annual peak streamflows were estimated using a regression equation applied to the measured annual peak streamflows at the related index site. This file was created only for the period of record of the index site. The bankfull streamflow statistic for Sheep Creek was obtained from the USGS StreamStats program and was considered the best available estimate.

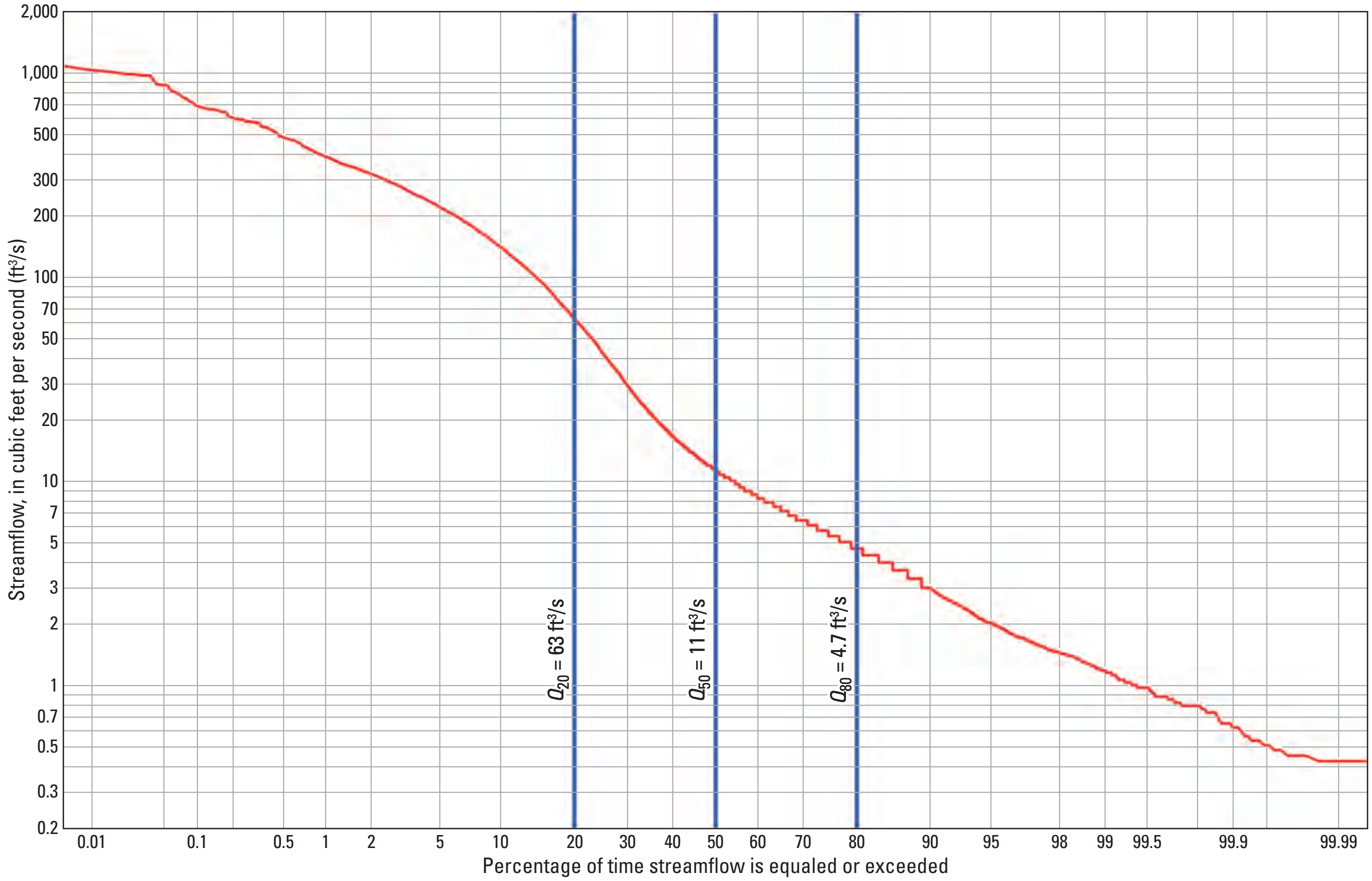

Figure 10. Example of determining 20-, 50-, and 80-percent exceedance probability streamflows from a streamflow exceedance probability curve.

The flood frequency statistics output by the PeakFQ program were slightly improved by computing a weighted average of the at-site flood quantile estimates with estimates from a regional regression equation developed from available streamgage records and basin characteristics. The regional regression equations for the bankfull streamflow statistic in the study area are published in Hortness and Berenbrock (2004) and are available in the USGS StreamStats program (U.S. Geological Survey, 2013). The USGS-developed Weighted Independent Estimate (WIE) program was used to calculate the weighted bankfull streamflow statistic on the basis of the site's basin characteristics, at-site flood quantile estimates, regional regression estimates, and variances of the respective estimates. Weighting by variance through use of a program such as WIE is required by the USGS Office of Surface Water (U.S. Geological Survey, 2010) when the basin characteristics of the site of interest are within the range of input variables for the regional regression model. For this analysis, characteristics of seven sites (Big Jacks Creek, Cottonwood Creek, Wickahoney Creek, Little Jacks Creek, North Fork Owyhee River, Battle Creek, and Deep Creek) were within the range of the regional regression model. Bankfull streamflow statistics for these sites were weighted using the WIE program. At-site statistics for the remaining four sites (West Fork Bruneau River, Jarbidge River, South Fork Owyhee River, and East Fork Owyhee River) were used and were not weighted with the regional regression estimates.

Method Validation

An example is presented to demonstrate and validate the partial-record method used in this study. For this example, five sites located in and near the Salmon River Basin were selected–one partial-record site, and four evaluated as index sites. The Salmon River Basin is not in the study area for this report, but was selected for validation of the method because it is the largest free-flowing (unregulated) river basin in Idaho and has several long-term streamgages scattered throughout the basin, including a few streamgages with more than 100 years of record (fig. 11). The partial-record site in figure 11 is the Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220). The site is a telemetered streamgage with daily mean and annual peak streamflow records extending to 1973, but for this study, was assumed to be a partial-record site for comparison with the long-term record and validation of the method. Streamflow measurements are made as part of the routine operation of the streamgage to maintain the long-term record. A total of 129 measurements were used in this example. Additionally, the last seven streamflow measurements from WY 2012 were used in a separate analysis to simulate a shorter period of record at a partial-record site. This analysis provided a comparison of results of the actual and estimated bimonthly and bankfull streamflows using the partial-record method using each of the four selected nearby streamgages as index sites.

The index sites selected for this example represent a wide range of streamflow and drainage areas and have periods of record ranging from 54 to 102 years. The first index site, the Salmon River at Salmon, Idaho (USGS 13302500), is upstream of the partial-record site. The second site, Johnson Creek at Yellow Pine, Idaho (USGS 13313000), is a tributary to the South Fork of the Salmon River. The third site, Salmon River at White Bird, Idaho (USGS 13317000), is downstream of the partial-record site on the main Salmon River. The Snake River near Anatone, Wash. (USGS 13334300) was the last site considered and was the only site not in the Salmon River Basin. The Snake River near Anatone, Wash., is the only site evaluated as an index site for the Salmon River that is affected by upstream regulation.

Each of the steps described in the Statistical Analysis section was applied to create synthetic streamflow records at the Middle Fork Salmon River site and to estimate the bimonthly and bankfull streamflows using each index site. Additionally, the bimonthly and bankfull statistics were calculated using the actual daily mean streamflow record at the Middle Fork Salmon River site to provide a quantitative comparison between the actual and synthetically generated bimonthly and bankfull streamflows. Two separate analyses were completed using (1) all 129 available measurements and (2) only 7 measurements made in WY 2012 to determine if uncertainty increases when fewer measurements are used in the regression. The results of analyses (1) and (2) are provided in tables 4 and 5, respectively. The Q_{20}, Q_{50}, and Q_{80} Absolute value Relative Percent Difference (ARPD) values in the tables represent the average absolute value of the percent difference between the statistics calculated using the partial-record method and those calculated from the full period of streamflow record for the streamgage. The average of all 24 bimonthly streamflow statistics was used for the calculation of ARPD. The ARPDs also are provided for the bankfull streamflow. Actual and estimated bimonthly streamflow statistics (Q_{20}) for the Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220) based on 129 and 7 partial-record site measurements are shown in figures 12 and 13, respectively.

Streamflows at the Johnson Creek index site (fig. 11) had the best relation with streamflows at the Middle Fork Salmon River site. The range of measured streamflows at the Middle Fork Salmon River site was most similar to streamflows for the Salmon River at Salmon index site for the full period of record among evaluated index sites, but drainage area and other basin characteristics are most similar to those at the Johnson Creek index site. Both the Middle Fork Salmon River and Johnson Creek sites drain mountainous, forested basins. The regression that yielded the lowest RMSE and BCF for all results also produced the lowest ARPD between the estimated streamflow statistic (on the basis of the regression between discrete streamflow measurements at the Middle Fork Salmon River and daily mean streamflows at an index site) and actual streamflow statistic (on the basis of the full period of record for the Middle Fork Salmon River streamgage). The Snake River index site had a poor correlation (tables 4 and 5; figs. 12 and 13) with the Middle Fork Salmon River site because of the degree of regulation and substantial differences in drainage basin characteristics. Although the Salmon River drains to the Snake River upstream of the index site near Anatone, Wash., the basin draining to the Snake River site has a lower mean basin elevation than the Salmon River Basin and is primarily semiarid, agricultural land.

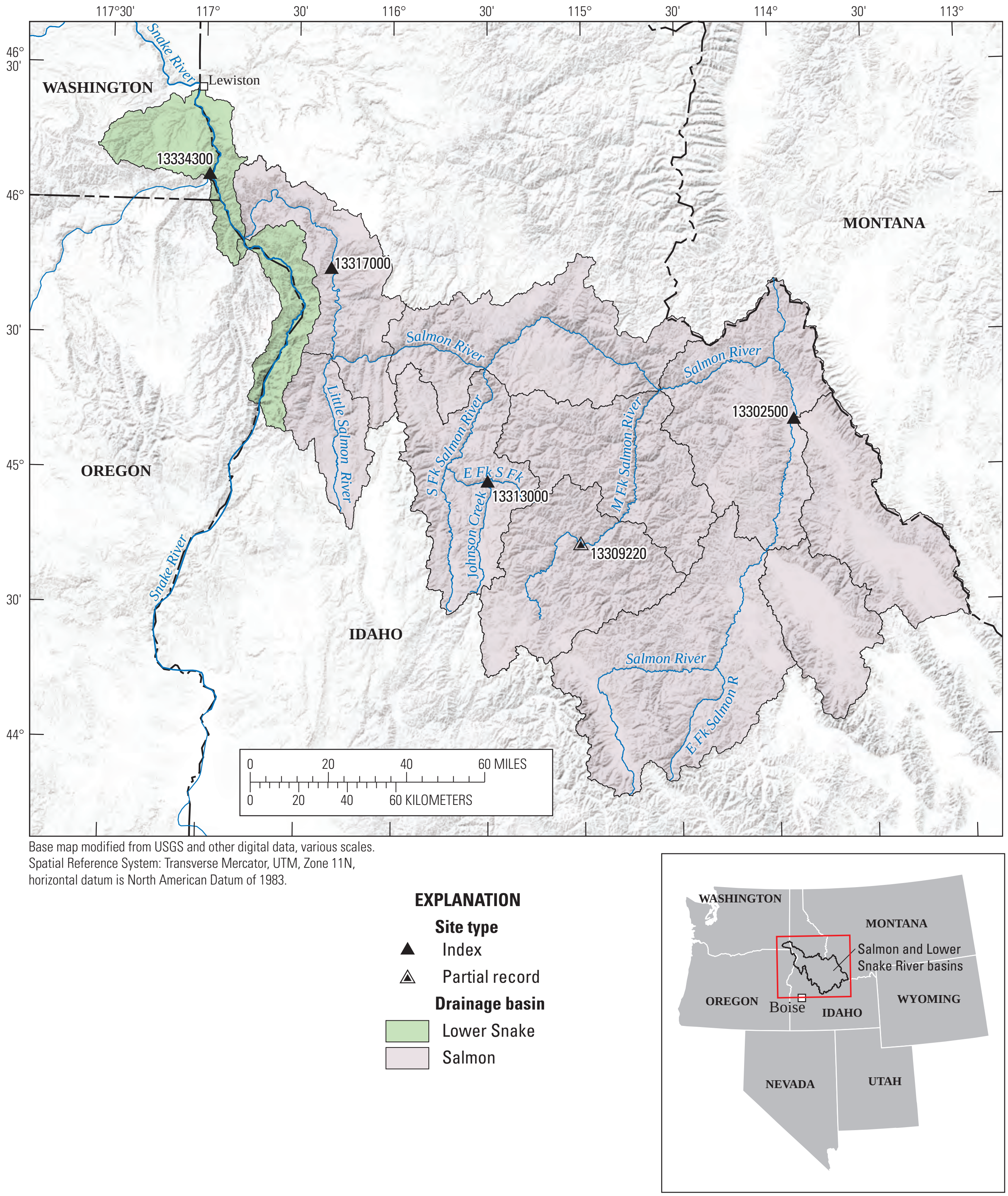

Figure 11. Location of streamgages in the Salmon River drainage basin selected for a verification of methods used to estimate streamflow statistics in the study area.

Table 4. Comparison of regressions and estimated and actual bimonthly and bankfull streamflow estimates using 129 measurements for the Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220).

[**Abbreviations:** USGS, U.S. Geological Survey; WY, water year (October 1–September 30); Q_{min}, minimum streamflow used in analysis; Q_{max}, maximum streamflow used in analysis; mi^2, square miles; R^2, coefficient of determination; RMSE, root-mean-square-error; BCF, Bias Correction Factor; ft^3/s, cubic feet per second; ARPD, average absolute value relative percent difference ([actual–estimated]/actual); Q_{20}, 20 percent bimonthly exceedance probability streamflow; Q_{50}, 50 percent bimonthly exceedance probability streamflow; Q_{80}, 80 percent bimonthly exceedance probability streamflow; –, not applicable]

Parameter	Partial record site	Index sites			
	Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220)	Salmon River at Salmon, Idaho (USGS 13302500)	Johnson Creek at Yellow Pine, Idaho (USGS 13313000)	Salmon River at White Bird, Idaho (USGS 13317000)	Snake River near Anatone, Washington (USGS 13334300)
Site characteristics of partial record and index sites					
Period of record (WY)	1973–2012	1912–2012	1928–2012	1910–2012	1958–2012
Q_{min} (ft^3/s)	304	242	21	1,000	6,010
Q_{max} (ft^3/s)	13,200	17,700	6,250	130,000	195,000
Drainage area (mi^2)	1,042	3,737	218	13,421	92,960
Regression statistics for partial record site against index sites					
Number of discrete streamflow measurements	–	129	129	129	129
R^2	–	0.86	0.97	0.94	0.63
RMSE (ft^3/s)	–	915	400	504	986
BCF	–	1.06	1.02	1.02	1.24
Streamflow statistics of partial record site based on index sites					
Bankfull streamflow–value (ft^3/s)	7,510	[1]7,000	[1]8,020	[1]6,750	[1]4,380
Bankfull streamflow–ARPD (percent)	–	6.8	6.8	10	42
Q_{20}–ARPD (percent)	–	31	8.0	8.3	99
Q_{50}–ARPD (percent)	–	26	6.7	8.7	54
Q_{80}–ARPD (percent)	–	23	9.6	10	33

[1] Bankfull streamflow statistics are calculated for the partial-record site (Middle Fork Salmon River, USGS 13309220) based on a regression with streamflows from each index site.

Table 5. Comparison of regressions and estimated and actual bimonthly and bankfull streamflow estimates using seven measurements made in 2012 for the Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220).

[**Abbreviations:** USGS, U.S. Geological Survey; WY, water year (October 1–September 30); Q_{min}, minimum streamflow used in analysis; Q_{max}, maximum streamflow used in analysis; mi^2, square miles; R^2, coefficient of determination; RMSE, root-mean-square-error; BCF, Bias Correction Factor; ft^3/s, cubic feet per second; ARPD, average absolute value relative percent difference ([actual–estimated]/actual); Q_{20}, 20 percent bimonthly exceedance probability streamflow; Q_{50}, 50 percent bimonthly exceedance probability streamflow; Q_{80}, 80 percent bimonthly exceedance probability streamflow; –, not applicable]

Parameter	Partial record site	Index sites			
	Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220)	Salmon River at Salmon, Idaho (USGS 13302500)	Johnson Creek at Yellow Pine, Idaho (USGS 13313000)	Salmon River at White Bird, Idaho (USGS 13317000)	Snake River near Anatone, Washington (USGS 13334300)
Site characteristics of partial record and index sites					
Period of record (WY)	1973–2012	1912–2012	1928–2012	1910–2012	1958–2012
Q_{min} (ft^3/s)	[1]490	242	21	1,000	6,010
Q_{max} (ft^3/s)	[1]5,240	17,700	6,250	130,000	195,000
Drainage area (mi^2)	1,042	3,737	218	13,421	92,960
Regression statistics for partial record site against index sites					
Number of discrete streamflow measurements	–	7	7	7	7
R^2	–	0.95	0.99	0.98	0.73
RMSE (ft^3/s)	–	615	164	311	1,630
BCF	–	1.02	1.01	1.01	1.17
Streamflow statistics of partial record site based on index sites					
Bankfull streamflow–value (ft^3/s)	7,510	[2]8,170	[2]8,170	[2]7,710	[2]7,930
Bankfull streamflow–ARPD (percent)	–	8.8	8.8	2.7	5.6
Q_{20}–ARPD (percent)	–	34	11	19	170
Q_{50}–ARPD (percent)	–	27	11	19	91
Q_{80}–ARPD (percent)	–	23	14	21	44

[1]For WY 2012.

[2]Bankfull streamflow statistics are calculated for the partial-record site (Middle Fork Salmon River, USGS 13309220) based on a regression with streamflows from each index site.

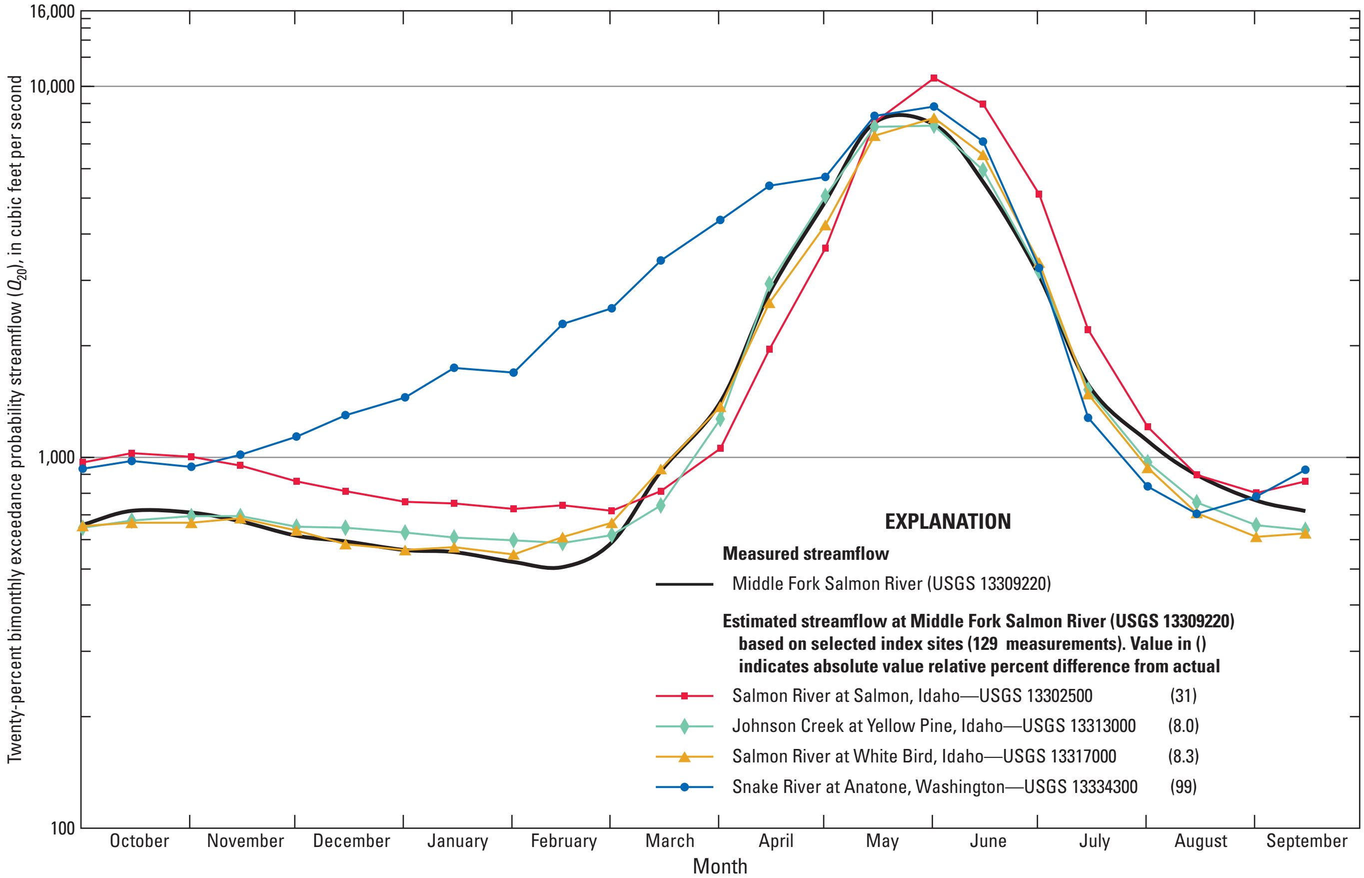

Figure 12. Twenty-percent bimonthly exceedance probability streamflow (Q_{20}) for the Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220) based on 129 measurements.

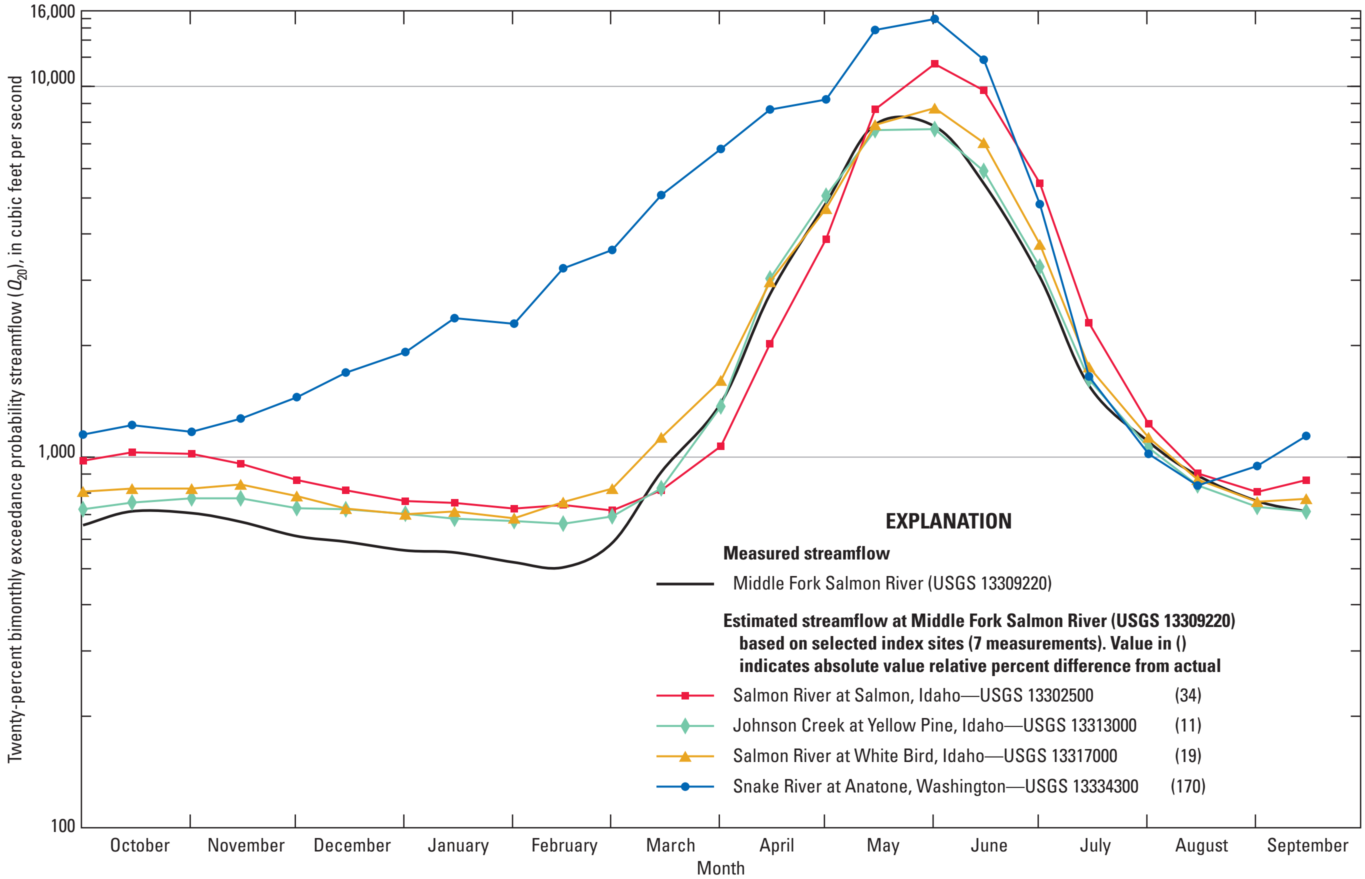

Figure 13. Twenty-percent bimonthly exceedance probability streamflow (Q_{20}) for the Middle Fork Salmon River at Middle Fork Lodge near Yellow Pine, Idaho (USGS 13309220) based on seven measurements made in 2012.

Using all 129 discrete streamflow measurements, the estimated record using the Johnson Creek index site produced a bankfull streamflow statistic within 6.8 percent of the “true” statistic calculated from the full period of daily mean streamflows measured at the Middle Fork Salmon River streamgage (table 4). Using only the seven discrete streamflow measurements from WY 2012, the estimated record using the Johnson Creek index site produced a bankfull streamflow statistic within 8.8 percent of the “true” statistic. The estimated record produced bimonthly exceedance probability statistics within 6.7 to 9.6 percent of the true statistic for the analysis on the basis of 129 measurements and 11 to 14 percent of the true statistic for the analysis using only 7 measurements in WY 2012. These results show that the partial-record method can produce reasonable estimates of the streamflow statistics if the full period of streamflow record had not been available at the Middle Fork Salmon River site. The regression fit, in terms of R^2 and RMSE, was better for the dataset with only the 7 WY 2012 measurements compared with the full dataset with 129 measurements, likely because of a smaller range of streamflows measured in WY 2012 compared to the full range of streamflow measured over the period of record. The ARPDs were larger, but not substantially different, for the results calculated using 7 discrete measurements in WY 2012 compared with the results calculated using all 129 available measurements. Assuming the range of streamflows is reasonably represented by discrete measurements, the partial-record method seems to produce results with reasonable certainty as long as the partial-record and index sites have somewhat similar drainage basin characteristics. The certainty is greater for results generated for the Middle Fork Salmon River than results generated for sites in the Owyhee Canyonlands Wilderness because of a greater number and range of streamflow measurements available for the Middle Fork Salmon River; however, this analysis is presented as a demonstration and validation of the partial-record concept.

Streamflow Monitoring

The total number of measurements at partial-record sites used to develop the regression between the partial-record and index site varied from as few as 4 to as many as 19. A summary of measurements made in WY 2012 is provided in table 6, and a table of all measurements is provided in appendix A. Sites with limited access typically were measured fewer times because of the logistical challenges associated with accessing the sites. Sites with the most limited access included Cottonwood, Wickahoney, Sheep, Battle, and Deep Creeks. These sites were visited only 4 to 5 times, and had no previous or historical measurements. Although only five measurements were made at Battle and Deep Creeks, the CSA gage data and developed stage-discharge rating allowed the calculation of 201 daily mean streamflows at Battle Creek and 200 daily mean streamflows at Deep Creek. A complete table of daily mean streamflows for both CSA streamgages is available in appendix B. Sites with measurements made prior to WY 2012 (North Fork, East Fork, and South Fork Owyhee Rivers and West Fork Bruneau River) each had between 8 and 19 total measurements. Measurements prior to WY 2012 at the North Fork Owyhee River monitoring site were made specifically to capture low streamflow conditions and did not substantially improve the range of streamflows used to develop the regression with an index site. Big Jacks Creek (USGS 13169450) was measured only three times in WY 2012, before going dry for the remainder of the year. Streamflow observed and measured on May 18, 2012, upstream near the wilderness boundary, indicated that streamflow may be perennial in the wilderness area. Little Jacks Creek (USGS 13169800) was measured seven times, and a quantifiable amount of streamflow was documented at each site visit. No streamflow was observed during any of the monthly visits to the selected measurement sites at the discontinued streamgages on Big Jacks (USGS 13169500) and Little Jacks (USGS 13170000) Creeks.

Measurements at some sites represented a diverse range of streamflows (West Fork Bruneau, South Fork Owyhee, East Fork Owyhee, and North Fork Owyhee Rivers, and Battle Creek and Deep Creeks). Measurements at other sites indicated a limited range of streamflows (Big Jacks, Little Jacks, Cottonwood, Wickahoney, and Sheep Creeks). No evidence of high water marks or defined floodplains was found at Big Jacks, Little Jacks, Cottonwood, and Wickahoney Creeks during field reconnaissance, indicating that streamflow in these creeks may not have greatly exceeded the range measured in WY 2012 in the recent past and that streamflow might be dominated by groundwater inflows. The percentage of actual streamflows represented by the measurements cannot be determined without continuous streamflow monitoring at the sites. Streamflow variability and comparisons of hydrologic conditions measured at the monitoring sites in WY 2012 cannot be fully understood by the limited number of measurements; however, comparisons to historical conditions can be inferred on the basis of conditions observed at the index sites. The annual mean streamflows measured at the index sites in WY 2012 all were less than one-half of the corresponding annual mean streamflow calculated for each site’s full period of record, meaning that WY 2012 was a drier than normal year. Use of only values from this drier than normal year can result in large uncertainty when extrapolating the regressions developed between the monitoring and index site streamflows to years with higher streamflows. However, the available measurements likely allowed the calculation of streamflow statistics with greater certainty than was previously available.

Table 6. Summary of discrete streamflow measurements made at monitoring sites, Owyhee Canyonlands Wilderness, Idaho.

[**Total**: Includes zero flow observations in WY 2012, which were assigned a value of "<0.01" in regression analyses for partial-record sites. **Abbreviations:** USGS, U.S. Geological Survey; WY, water year (October 1–September 30); Q_{min}, minimum streamflow measurement; Q_{max}, maximum streamflow measurement; ft^3/s, cubic feet per second; <, less than]

USGS site No.	Site name	Number of discrete streamflow measurements				Q_{min} (ft^3/s)	Q_{max} (ft^3/s)
		Pre-WY 2012	WY 2012	Zero flow observations WY 2012	Total		
	Big Jacks Creek Basin						
13169450	Big Jacks Creek at Al Sadie Ranch near Bruneau, Idaho	0	3	3	6	0	2.67
13169500	Big Jacks Creek near Bruneau, Idaho	192	0	6	198	0	230
13169420	Cottonwood Creek near Harvey Point near Bruneau, Idaho	0	4	0	4	1.14	2.45
13169400	Wickahoney Creek near Grasmere, Idaho	0	3	1	4	0	0.47
	Bruneau River Basin						
13162050	West Fork Bruneau River above Jarbidge River near Grasmere, Idaho	3	6	0	9	9.91	244
13164600	Sheep Creek above Mouth near Grasmere, Idaho	0	3	1	4	0	68.9
	Jarbidge River Basin						
13162225	Jarbidge River below Jarbidge, Nevada	170	10	0	180	2.81	567
	Little Jacks Creek Basin						
13169800	Little Jacks Creek above Wilderness Road near Bruneau, Idaho	0	7	0	7	1.35	3.29
13170000	Little Jacks Creek near Bruneau, Idaho	36	0	7	43	0	908
	Owyhee River Basin						
13177845	South Fork Owyhee River below Little Owyhee River near Crutcher Crossing, Idaho	3	5	0	8	14.5	164
13176400	East Fork Owyhee River at Crutcher Crossing, Idaho	13	6	0	19	14.1	763
13177910	North Fork Owyhee River near Fairylawn, Idaho	11	8	0	19	0.77	145
13176195	Battle Creek above Mouth near Riddle, Idaho	0	5	0	5	3.47	184
13176305	Deep Creek above Mouth near Riddle, Idaho	0	5	1	6	0	962

Correlations with Index Sites

The selected index site, regression equation, and selected regression statistics for each partial-record site are shown in table 7. Four streamgages in Idaho, Nevada, and Oregon were selected as index sites for all of the partial-record sites. The telemetered streamgage in the Big Jacks Creek Basin at Al Sadie Ranch (USGS 13169450), not shown in table 7, went dry in May 2012. The partial-record method was first attempted for the Big Jacks Creek streamgage by relating 54 available daily mean streamflow values to available index sites, but resulting regressions were poor because of the limited range (0–2.7 ft^3/s) in measured streamflows. Data from the discontinued streamgage (USGS 13169500), located downstream of the monitoring site at Al Sadie Ranch, were instead used to calculate the streamflow statistics. Martin Creek near Paradise Valley, Nev. (USGS 10329500), a high-elevation and arid drainage basin located in the Santa Rosa Range of northern Nevada (fig. 1), was selected as the index site for Little Jacks Creek (USGS 13169800). Although Martin Creek is outside the study area, Little Jacks Creek and Martin Creek share similar runoff characteristics, and the regression between the sites had the lowest RMSE and BCF of any site in the study. Low streamflows during the late summer and autumn are dominated by spring inflows in Little Jacks and Martin Creeks. The Bruneau River near Hot Spring, Idaho (USGS 13168500) was the best index site for Cottonwood and Wickahoney Creeks and the West Fork Bruneau River. Sites

Table 7. Regression equations used to create synthetic streamflow records at partial-record sites, Owyhee Canyonlands Wilderness, Idaho, 2012.

[**Selected index site**: See table 3. **R^2**: coefficient of determination. **RMSE**: Root mean square error. **BCF**: Bias correction factor. A**bbreviations:** USGS, U.S. Geological Survey; Q_{site}, estimated streamflow at monitoring site; Q_{index}, measured streamflow at index site]

USGS site No.	Site name	Selected index site	Regression equation	Number of measurements used	R^2	RMSE (ft^3/s)	BCF
			Big Jacks Creek Basin				
13169420	Cottonwood Creek near Harvey Point near Bruneau, Idaho	13168500	$Q_{site} = 1.00 \times (3.62E\text{-}01 \times Q_{index}^{0.33})$	4	0.89	0.21	1.00
13169400	Wickahoney Creek near Grasmere, Idaho[1]	13168500	$Q_{site} = 1.11 \times (1.88E\text{-}05 \times Q_{index}^{1.72})$	4	0.74	0.21	1.11
			Bruneau River Basin				
13162050	West Fork Bruneau River above Jarbidge River near Grasmere, Idaho	13168500	$Q_{site} = 1.01 \times (1.99E\text{-}01 \times Q_{index}^{1.09})$	9	0.98	26.1	1.01
			Little Jacks Creek Basin				
13169800	Little Jacks Creek above Wilderness Road near Bruneau, Idaho	10329500	$Q_{site} = 1.00 \times (9.28E\text{-}01 \times Q_{index}^{0.32})$	7	0.95	0.15	1.00
			Owyhee River Basin				
13177845	South Fork Owyhee River below Little Owyhee River near Crutcher Crossing, Idaho	13181000	$Q_{site} = 1.04 \times (2.45E\text{-}01 \times Q_{index}^{0.995})$	8	0.85	8.55	1.04
13176400	East Fork Owyhee River at Crutcher Crossing, Idaho	13181000	$Q_{site} =1.03 \times (1.07E\text{-}01 \times Q_{index}^{1.18})$	19	0.96	40.0	1.03
13177910	North Fork Owyhee River near Fairylawn, Idaho	13161500	$Q_{site} = 1.07 \times (2.58E\text{-}01 \times Q_{index}^{1.10})$	19	0.94	17.1	1.07
13176195	Battle Creek above Mouth near Riddle, Idaho	13181000	$Q_{site} =1.07 \times (3.14E\text{-}02 \times Q_{index}^{1.05})$	[2]201	0.86	17.5	1.07
13176305	Deep Creek above Mouth near Riddle, Idaho[1]	13161500	$Q_{site} = 0.96 \times (1.06E\text{-}04 \times Q_{index}^{2.72})$	[2]200	0.98	90.5	0.96

[1] Regression equations for Wickahoney and Deep Creeks were developed using left-censored regression techniques because of the inclusion of 0 streamflow measurements. All other regression equations were developed using MOVE.1 regression techniques.

[2] Number of computed daily streamflow values from the continuous record at the continuous slope area streamgage used to develop regression with index site.

located within the Owyhee River Basin, except the North Fork Owyhee River and Deep Creek, were indexed to the Owyhee River near Rome, Oreg. (USGS 13181000), which is near the downstream end of the Owyhee River Basin. The North Fork Owyhee River and Deep Creek sites did not index well with the downstream streamgage because their runoff patterns are dominated by snowmelt runoff from high elevations in the basin, which occurs in late spring. Peak streamflow at the Owyhee River near Rome, Oreg., index site typically occurs in early spring because most runoff comes from low elevation areas. The Bruneau River at Rowland, Nev. streamgage (USGS 13161500) was determined to be the best index site for the North Fork Owyhee River and Deep Creek, even though it is outside the Owyhee River Basin, because of similarities in runoff timing and basin characteristics.

Streamflow Statistics at Monitoring Sites

Annual and bimonthly streamflow exceedance and bankfull streamflow statistics were estimated for 12 sites in the study area (tables 8 and 9). For comparison, bankfull streamflow statistics generated using the USGS StreamStats program are presented in table 9 alongside the estimates generated using the methods described in this report. The bankfull streamflow estimates generated using procedures described in this report were within the prediction intervals identified for the StreamStats estimate for four sites: Little Jacks Creek, North Fork Owyhee River, Battle Creek, and Deep Creek. Deviations in estimates from the StreamStats prediction intervals for some sites made sense because the unique hydrologic conditions at those sites (such as groundwater-surface water interactions) were not well-represented by regional regression models and are best represented through the collection of site-specific data. Bankfull streamflow estimates could not be compared to StreamStats prediction intervals for three sites (West Fork Bruneau River, South Fork Owyhee River, and East Fork Owyhee River) because their basin characteristics were outside the range of basin characteristics of streamgages used to develop the regional regression models nor for the Jarbidge River because StreamStats was not available in Nevada to calculate a bankfull streamflow statistic.

An annual hydrograph showing calculated streamflow statistics for the Jarbidge River is presented as an example in figure 14. The Jarbidge River site was selected as an example because of its long, directly measured streamflow record, and the high confidence in computed statistics. Annual hydrographs of statistics are presented for all other sites in appendix C. Figures in appendix C display the minimum and maximum streamflow measurements made at a monitoring site and associated ranges in streamflows that are considered extrapolations beyond the range of currently (2012) available measurements.

Big Jacks Creek Basin

Bimonthly and bankfull streamflow statistics for Big Jacks Creek were estimated using the streamflow record from the discontinued streamgage (USGS 13169500) located about 3 mi downstream of the streamgage installed at Al Sadie Ranch in WY 2012 (USGS 13169450) (fig. 2). The streamflow record at Al Sadie Ranch (USGS 13169450) recorded only 54 daily mean values before going dry in late May for the remainder of the water year. The bimonthly streamflow record at the discontinued streamgage (USGS 13169500) showed that peak streamflow typically occurred in early- to mid-March. Daily mean streamflow at the Al Sadie Ranch streamgage decreased over the period of record (March 29–May 30, 2012), indicating that the peak streamflow likely occurred prior to installation of the streamgage. The range of streamflow values (0–2.7 ft^3/s) recorded at Al Sadie Ranch was small, whereas the range at the discontinued streamgage was much larger (0–1,210 ft^3/s) and represented 65 years of data collected in 1939–2004. On the basis of the long period of record and wide range of measured streamflows, the discontinued streamgage (USGS 13169500) was thought to provide a better estimate of the streamflow statistics in the WSR segment on Big Jacks Creek than the Al Sadie Ranch streamgage (USGS 13169450). Field observations of Big Jacks Creek at the discontinued streamgage determined that the creek is dry for most of the year. The calculated bimonthly streamflow statistics supported this because the Q_{80} was zero for all bimonthly periods. The Q_{50} was greater than zero for only 2 months, but the Q_{20} was greater than zero for all bimonthly periods. The estimated bimonthly streamflow statistics are representative of the discontinued streamgage location (USGS 13169500), which does not account for surface water and groundwater interactions between the WSR segment boundary and the discontinued streamgage. However, the estimates calculated using the discontinued streamgage data (USGS 13169500) are more reasonable and likely more representative of conditions in the WSR segment than those calculated using the available Al Sadie Ranch streamgage (USGS 13169450) data. The bankfull estimate at Big Jacks Creek was calculated using the record of annual peak streamflow at the discontinued streamgage (USGS 13169500) and is likely similar to what might be expected upstream at the current (2012) streamgage (USGS 13169450) and WSR segment boundary. Streamgage 13169500 was discontinued in 2004 because of a lack of streamflow, however, so it may not serve as a valid long-term monitoring site for streamflows in the WSR segment. The streamgage installed in WY 2012 at Al Sadie Ranch (USGS 13169450) may produce streamflow statistics that are more representative of conditions in the WSR segment when more data are collected over a range of hydrologic and climatic conditions. Overall, uncertainty is high in estimates for Big Jacks Creek because of the unknown degree of interaction between groundwater and surface water along the reach.

Table 8. Annual and bimonthly streamflow exceedance probability statistics calculated from actual and synthetic streamflow records at monitoring sites, Owyhee Canyonlands Wilderness, Idaho, 2012.

[**Abbreviations:** USGS, U.S. Geological Survey; ft³/s, cubic feet per second; Q_{20}, 20 percent exceedance probability streamflow; Q_{50}, 50 percent exceedance probability streamflow; Q_{80}, 80 percent exceedance probability streamflow]

Creek or river	Record computation method	Streamflow statistic	Streamflow (ft³/s)								
			Annual	January		February		March		April	
				Days 1–14	Days 15–31	Days 1–14	Days 15–29	Days 1–14	Days 15–31	Days 1–14	Days 15–30
Big Jacks Creek Basin											
Big Jacks Creek[1]	Direct	Q_{20}	3.80	0.50	1.10	2.60	7.36	14.0	35.0	27.0	14.0
		Q_{50}	0.00	0.00	0.00	0.00	0.00	0.00	3.40	3.50	1.65
		Q_{80}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottonwood Creek	Partial-record	Q_{20}	2.93	1.91	2.04	2.09	2.30	2.49	3.08	3.54	3.91
		Q_{50}	1.86	1.72	1.78	1.84	1.91	2.06	2.41	2.87	3.26
		Q_{80}	1.56	1.56	1.62	1.68	1.75	1.82	1.99	2.32	2.68
Wickahoney Creek	Partial-record	Q_{20}	1.14	0.12	0.17	0.19	0.32	0.49	1.46	3.01	5.05
		Q_{50}	0.11	0.07	0.08	0.10	0.12	0.18	0.41	1.02	1.97
		Q_{80}	0.04	0.04	0.05	0.06	0.08	0.09	0.15	0.33	0.71
Bruneau River Basin											
West Fork Bruneau River	Partial-record	Q_{20}	202	49.0	60.4	66.1	90.9	118	237	374	519
		Q_{50}	44.6	34.4	38.5	43.6	49.0	62.5	105	188	285
		Q_{80}	24.8	24.8	28.1	31.7	36.8	41.5	56.0	92.7	150
Sheep Creek	Drainage area ratio	Q_{20}	262	26.3	38.0	96.8	38.7	191	730	638	602
		Q_{50}	26.4	15.2	18.4	18.2	27.6	66.5	181	378	402
		Q_{80}	12.2	10.9	14.8	15.3	18.2	25.5	52.2	229	282
Jarbidge River Basin											
Jarbidge River	Direct	Q_{20}	45.4	7.34	9.30	9.02	9.70	14.0	27.4	55.2	86.6
		Q_{50}	8.30	6.10	6.50	6.90	7.80	9.25	15.0	30.5	56.0
		Q_{80}	5.20	5.10	5.20	5.60	5.70	6.78	11.0	15.0	39.0
Little Jacks Creek Basin											
Little Jacks Creek[2]	Partial-record	Q_{20}	3.10	2.04	2.19	2.50	2.86	3.31	4.02	4.19	4.46
		Q_{50}	1.93	1.91	1.93	2.04	2.19	2.40	2.94	3.34	3.62
		Q_{80}	1.68	1.75	1.79	1.87	1.93	2.09	2.32	2.70	2.86
Owyhee River Basin											
South Fork Owyhee River	Partial-record	Q_{20}	268	93.9	186	225	361	601	1,150	1,120	878
		Q_{50}	56.5	50.9	63.3	90.5	139	214	421	503	491
		Q_{80}	34.6	40.2	42.7	49.1	70.3	84.9	142	159	133
East Fork Owyhee River	Partial-record	Q_{20}	423	122	274	343	601	1,110	2,380	2,310	1,730
		Q_{50}	66.8	58.9	76.4	117	194	324	723	891	866
		Q_{80}	37.2	44.6	47.8	56.5	86.5	108	199	229	184
North Fork Owyhee River	Partial-record	Q_{20}	70.9	16.3	23.1	22.2	30.5	55.8	148	222	285
		Q_{50}	12.9	9.94	10.8	13.8	17.1	29.6	62.9	103	136
		Q_{80}	5.43	5.83	7.45	8.27	11.2	15.6	28.6	46.7	65.8
Battle Creek	Partial-record	Q_{20}	52.0	17.2	35.3	43.1	71.0	122	242	236	182
		Q_{50}	10.0	8.99	11.3	16.5	26.0	41.0	83.7	101	98.3
		Q_{80}	5.98	7.02	7.47	8.67	12.7	15.4	26.6	30.0	24.8
Deep Creek	Partial-record	Q_{20}	96.4	2.56	6.04	5.47	12.0	53.5	589	1,630	3,020
		Q_{50}	1.43	0.75	0.92	1.68	2.86	11.1	71.6	244	486
		Q_{80}	0.17	0.20	0.37	0.48	1.01	2.29	10.2	34.5	80.4

Table 8. Annual and bimonthly streamflow exceedance probability statistics calculated from actual and synthetic streamflow records at monitoring sites, Owyhee Canyonlands Wilderness, Idaho, 2012.—Continued

Creek or river	Record computation method	Streamflow statistic	Streamflow (ft³/s)							
			May		June		July		August	
			Days 1–14	Days 15–31	Days 1–14	Days 15–30	Days 1–14	Days 15–31	Days 1–14	Days 15–31
Big Jacks Creek Basin										
Big Jacks Creek[1]	Direct	Q_{20}	12.0	9.10	6.82	3.80	2.90	1.50	0.97	0.97
		Q_{50}	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Q_{80}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottonwood Creek	Partial-record	Q_{20}	4.16	4.36	4.17	3.70	2.94	2.23	1.86	1.66
		Q_{50}	3.61	3.77	3.57	3.05	2.35	1.87	1.62	1.50
		Q_{80}	2.91	3.06	3.03	2.42	1.86	1.55	1.37	1.35
Wickahoney Creek	Partial-record	Q_{20}	6.93	8.88	7.14	3.79	1.14	0.27	0.11	0.06
		Q_{50}	3.33	4.19	3.17	1.39	0.36	0.11	0.05	0.04
		Q_{80}	1.10	1.42	1.34	0.43	0.11	0.04	0.02	0.02
Bruneau River Basin										
West Fork Bruneau River	Partial-record	Q_{20}	636	745	646	435	203	81.9	44.6	30.8
		Q_{50}	399	461	387	229	97.5	45.6	28.4	22.2
		Q_{80}	197	231	223	107	44.9	24.5	16.6	15.5
Sheep Creek	Drainage area ratio	Q_{20}	1,080	1,150	814	225	66.3	33.1	15.7	4.51
		Q_{50}	372	319	228	118	31.6	17.0	8.44	1.34
		Q_{80}	272	237	149	70.2	15.8	15.8	4.58	0.90
Jarbidge River Basin										
Jarbidge River	Direct	Q_{20}	156	283	238	161	45.0	16.0	9.92	6.32
		Q_{50}	94.0	152	148	66.0	19.0	9.90	6.90	5.05
		Q_{80}	60.8	92.0	56.0	20.0	10.0	6.48	4.80	3.70
Little Jacks Creek Basin										
Little Jacks Creek[2]	Partial-record	Q_{20}	4.66	4.65	4.13	3.25	2.47	1.91	1.72	1.68
		Q_{50}	3.89	3.81	3.32	2.61	1.98	1.68	1.60	1.60
		Q_{80}	3.06	2.99	2.64	2.04	1.65	1.55	1.54	1.54
Owyhee River Basin										
South Fork Owyhee River	Partial-record	Q_{20}	751	580	397	208	102	61.0	50.4	43.5
		Q_{50}	408	298	169	92.3	56.0	43.0	35.5	32.1
		Q_{80}	108	73.4	62.8	43.9	29.9	25.4	23.0	19.9
East Fork Owyhee River	Partial-record	Q_{20}	1,440	1,050	674	313	134	73.1	58.2	48.9
		Q_{50}	695	479	244	119	66.1	48.2	38.5	34.1
		Q_{80}	144	90.9	75.6	49.5	31.3	25.8	23.0	19.4
North Fork Owyhee River	Partial-record	Q_{20}	300	292	199	111	43.8	18.6	9.52	6.23
		Q_{50}	178	145	101	51.3	18.2	9.10	5.03	3.86
		Q_{80}	64.5	68.5	52.5	18.7	6.63	3.12	2.02	1.76
Battle Creek	Partial-record	Q_{20}	154	117	78.7	39.8	18.6	10.9	8.90	7.61
		Q_{50}	80.8	58.0	31.9	16.9	9.96	7.52	6.16	5.53
		Q_{80}	19.9	13.3	11.2	7.70	5.12	4.32	3.89	3.35
Deep Creek	Partial-record	Q_{20}	3,420	3,200	1,240	294	29.3	3.54	0.67	0.24
		Q_{50}	939	570	232	43.3	3.33	0.60	0.14	0.07
		Q_{80}	76.5	88.7	45.9	3.58	0.28	0.04	0.01	0.01

Table 8. Annual and bimonthly streamflow exceedance probability statistics calculated from actual and synthetic streamflow records at monitoring sites, Owyhee Canyonlands Wilderness, Idaho, 2012.—Continued

Creek or river	Record computation method	Streamflow statistic	Streamflow (ft³/s)							
			September		October		November		December	
			Days 1–14	Days 15–30	Days 1–14	Days 15–31	Days 1–14	Days 15–30	Days 1–14	Days 15–31
Big Jacks Creek Basin										
Big Jacks Creek[1]	Direct	Q_{20}	0.93	0.93	0.97	1.20	1.40	1.40	1.00	0.01
		Q_{50}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Q_{80}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottonwood Creek	Partial-record	Q_{20}	1.62	1.65	1.75	1.79	1.84	1.88	1.88	1.90
		Q_{50}	1.46	1.48	1.55	1.64	1.70	1.73	1.70	1.70
		Q_{80}	1.30	1.35	1.39	1.46	1.55	1.55	1.54	1.52
Wickahoney Creek	Partial-record	Q_{20}	0.05	0.06	0.08	0.09	0.10	0.11	0.11	0.12
		Q_{50}	0.03	0.03	0.04	0.06	0.07	0.07	0.07	0.07
		Q_{80}	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04
Bruneau River Basin										
West Fork Bruneau River	Partial-record	Q_{20}	28.4	30.1	36.8	39.1	43.2	46.6	46.6	48.0
		Q_{50}	20.3	21.3	24.5	29.8	33.1	35.4	33.4	32.9
		Q_{80}	13.7	15.9	17.1	20.3	24.5	24.5	24.2	23.2
Sheep Creek	Drainage area ratio	Q_{20}	8.26	8.79	23.6	20.2	256	50.6	25.6	22.9
		Q_{50}	4.58	6.07	18.4	18.8	33.2	22.2	17.1	15.8
		Q_{80}	0.90	1.95	5.63	8.26	10.5	13.5	13.5	13.3
Jarbidge River Basin										
Jarbidge River	Direct	Q_{20}	5.52	5.70	6.80	8.22	9.20	8.84	6.92	7.76
		Q_{50}	4.40	4.40	5.60	5.70	6.80	6.30	6.00	5.70
		Q_{80}	3.60	3.50	4.10	4.50	4.88	5.18	5.10	5.00
Little Jacks Creek Basin										
Little Jacks Creek[2]	Partial-record	Q_{20}	1.69	1.72	1.79	1.89	1.93	1.98	2.04	2.04
		Q_{50}	1.62	1.66	1.72	1.79	1.85	1.87	1.88	1.87
		Q_{80}	1.56	1.60	1.64	1.70	1.77	1.75	1.74	1.75
Owyhee River Basin										
South Fork Owyhee River	Partial-record	Q_{20}	41.9	45.9	45.4	48.4	52.6	63.0	77.7	90.8
		Q_{50}	30.1	29.9	33.6	37.6	42.2	45.2	47.2	49.6
		Q_{80}	19.7	22.2	26.1	30.1	33.6	36.0	37.3	38.7
East Fork Owyhee River	Partial-record	Q_{20}	46.8	52.2	51.4	55.5	61.3	75.8	97.3	117
		Q_{50}	31.6	31.3	36.0	41.3	47.2	51.2	53.8	57.2
		Q_{80}	19.1	22.0	26.7	31.6	36.1	39.1	40.7	42.6
North Fork Owyhee River	Partial-record	Q_{20}	6.23	7.86	10.4	12.1	13.4	13.8	13.8	14.7
		Q_{50}	3.48	4.64	5.83	7.45	8.69	9.10	9.10	9.10
		Q_{80}	1.91	2.25	2.92	4.25	5.83	5.91	6.23	5.83
Battle Creek	Partial-record	Q_{20}	7.33	8.07	7.97	8.53	9.31	11.3	14.1	16.6
		Q_{50}	5.17	5.12	5.80	6.55	7.38	7.93	8.30	8.76
		Q_{80}	3.30	3.74	4.45	5.17	5.81	6.25	6.47	6.74
Deep Creek	Partial-record	Q_{20}	0.24	0.42	0.83	1.21	1.56	1.68	1.68	1.96
		Q_{50}	0.06	0.11	0.20	0.37	0.54	0.60	0.60	0.60
		Q_{80}	0.01	0.02	0.04	0.09	0.20	0.21	0.24	0.20

[1] Statistics were not estimated for the streamgage on Big Jacks Creek at Al Sadie Ranch (USGS 13169450) because an adequate regression could not be developed with an index site. Statistics presented for Big Jacks Creek are based on the discontinued USGS streamgage near Bruneau, Idaho (USGS 13169500) and are considered the best estimate for the designated Wild and Scenic River (WSR) segment on Big Jacks Creek given available data.

[2] Statistics were estimated using the USGS monitoring site above Wilderness Road near Bruneau, Idaho (USGS 13169800). Statistics generated using data from the discontinued streamgage (USGS 13170000) are not fully representative of bimonthly exceedance probability streamflows in the WSR segment due to surface-water to groundwater loss zones along the stream reach.

Table 9. Bankfull streamflow statistics calculated from actual and synthetic streamflow records at monitoring sites and comparison with USGS StreamStats estimates, Owyhee Canyonlands Wilderness, Idaho, 2012.

[The bankfull statistic is defined as the streamflow with a 66.7 percent annual exceedance probability, or the streamflow that has a 66.7 percent chance of occurring at any time in a given year (1.5-year recurrence interval). **Estimates generated using StreamStats**: From U.S. Geological Survey (2013). **Abbreviations:** PeakFQ, USGS Peak Flow Analysis program using the Bulletin 17B analysis option (Interagency Advisory Committee on Water Data, 1982); WIE, USGS Weighted Independent Estimates program; USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; NA, not applicable/could not be calculated]

Creek or river	Estimates generated using PeakFQ (with weighting using WIE where applicable)	Estimates generated using StreamStats			Final selected estimates	
			90 percent prediction intervals			
	Bankfull streamflow (ft^3/s)	Bankfull streamflow (ft^3/s)	Lower	Upper	Bankfull streamflow (ft^3/s)	Source
Big Jacks Creek Basin						
Big Jacks Creek[1]	83.4	331	104	1,050	83.4	PeakFQ, WIE
Cottonwood Creek	4.14	36	11.5	113	4.14	PeakFQ, WIE
Wickahoney Creek	7.53	111	35.4	350	7.53	PeakFQ, WIE
Bruneau River Basin						
West Fork Bruneau River	625	799	NA	NA	625	PeakFQ[2]
Sheep Creek	NA	735	NA	NA	735	StreamStats
Jarbidge River Basin						
Jarbidge River	375	NA[3]	NA	NA	375	PeakFQ[2]
Little Jacks Creek Basin						
Little Jacks Creek[4]	98.0	167	52.7	531	98.0	PeakFQ, WIE
Owyhee River Basin						
South Fork Owyhee River	1,810	1,730	NA	NA	1,810	PeakFQ[2]
East Fork Owyhee River	4,060	1,960	NA	NA	4,060	PeakFQ[2]
North Fork Owyhee River	242	191	61.1	596	242	PeakFQ, WIE
Battle Creek	389	397	126	1,260	389	PeakFQ, WIE
Deep Creek	1,650	570	178	1,820	1,650	PeakFQ, WIE

[1] Statistics were not estimated for the streamgage on Big Jacks Creek at Al Sadie Ranch (USGS 13169450) because an adequate regression could not be developed with an index site. Statistics presented for Big Jacks Creek are based on the discontinued USGS streamgage near Bruneau, Idaho (USGS 13169500) and are considered the best estimate for the designated Wild and Scenic River (WSR) segment on Big Jacks Creek given available data.

[2] PeakFQ estimates were not weighted using WIE because the basin characteristics of the site were outside the range of input variables used to create the regional streamflow regression equations.

[3] StreamStats estimates could not be generated at the streamgage location because the StreamStats program is not yet available in Nevada.

[4] Statistics shown are for the USGS discontinued streamgage on Little Jacks Creek near Bruneau, Idaho (USGS 1317000).

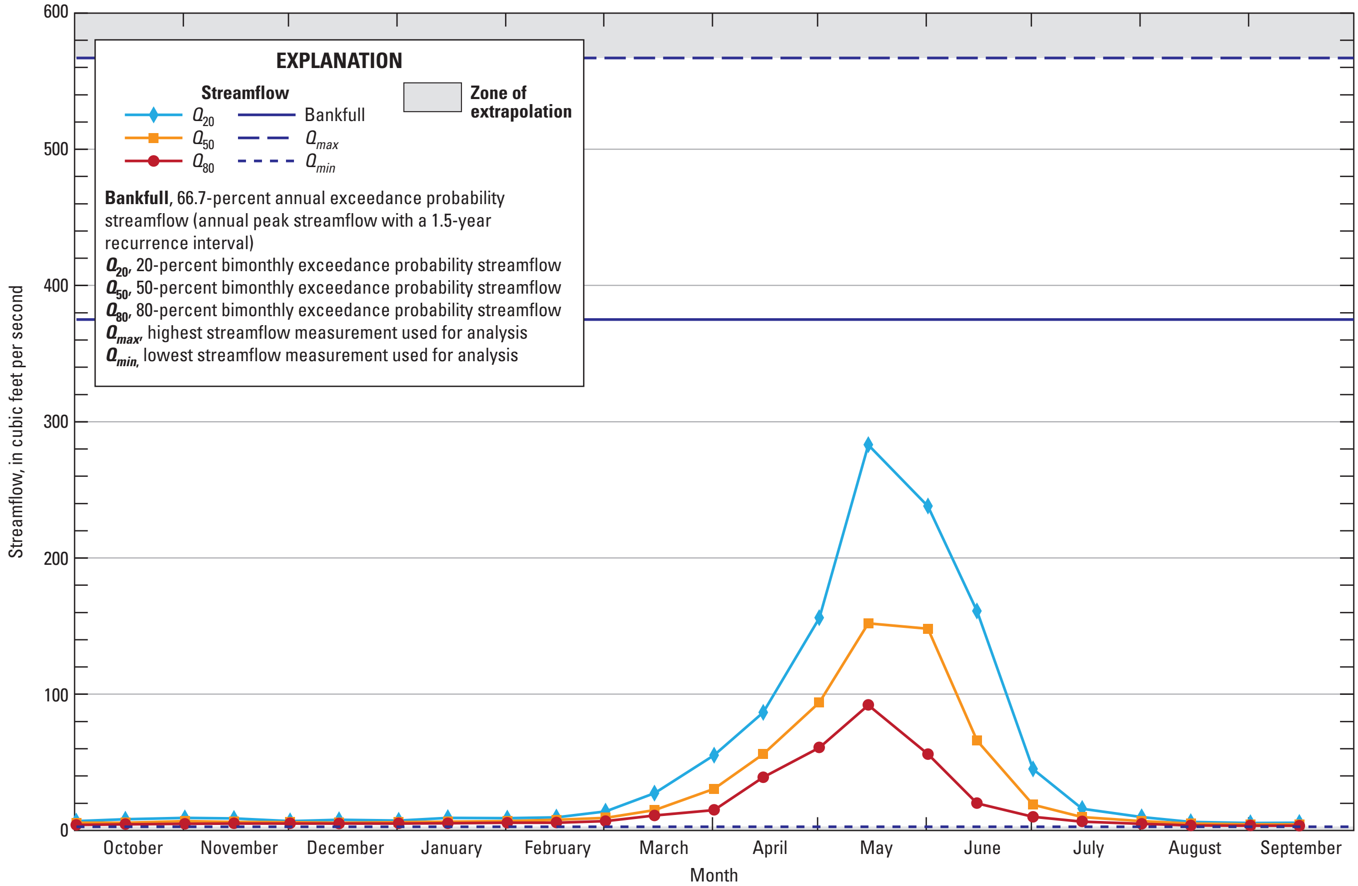

Figure 14. Bimonthly exceedance probability and bankfull streamflow statistics calculated for the Jarbidge River below Jarbidge, Nevada (USGS 13162225), 2012.

Streamflow statistics for both Cottonwood and Wickahoney Creeks were developed based on only a few measurements with a small range in streamflow. The R^2 for the index relation developed for Cottonwood Creek was misleadingly high (0.89; table 7) because the regression line joined two clusters of data at about 1 and 2 ft^3/s, which might not be representative of the distribution and range of streamflows in Cottonwood Creek. The bimonthly data showed that highest streamflows occur toward the end of May, which does not match the pattern measured in the discrete streamflow measurements. The difference in timing is likely the result of the index site having peak streamflows later in spring than is probably typical for Cottonwood Creek. Cottonwood Creek had the smallest drainage area and bankfull streamflow of any monitoring site in the study. The drainage basin for Wickahoney Creek is nearly five times larger than Cottonwood Creek, but streamflow statistics between the sites were not proportional. Streamflows measured at Wickahoney Creek were less than streamflows measured at Cottonwood Creek. Highest streamflow statistics occurred around the middle of May, similar to Cottonwood Creek, which also was probably a function of runoff patterns at the index site, and did not match patterns in WY 2012 streamflow measurements. Similar to Big Jacks Creek, uncertainty is high for the streamflow statistics calculated for Cottonwood and Wickahoney Creeks. The small range in measured streamflows may be representative of true conditions, indicating that interactions with groundwater dominate streamflow patterns, although this assumption cannot be verified without additional measurements or continuous monitoring. The bankfull streamflow statistics for Big Jacks, Cottonwood, and Wickahoney Creeks were outside the 90 percent prediction intervals for estimates generated in StreamStats (table 9), which indicates that site conditions are unique and that streamflow patterns are not well-represented by the regional regression models currently available in StreamStats.

Bruneau River Basin

The West Fork Bruneau River monitoring site was located between two telemetered streamgages, which allowed the best comparison with index sites of all of the partial-record sites. The regression was developed using nine measurements, including three measurements made prior to WY 2012, which represented a wide range of streamflow. Estimated bankfull streamflow was 625 ft^3/s, which is about 2.5 times larger than the highest streamflow measured in WY 2012; but, because the mean annual streamflow in WY 2012 at the selected index site was only about 50 percent of the mean annual streamflow over the period of record, the bankfull streamflow estimate seems to be a reasonable estimate. Highest streamflows were measured at the site in WY 2012 at about the end of April. The highest bimonthly percent exceedance streamflows were between the end of April through the beginning of June, which is reasonable for the site on the basis of streamflow patterns observed at the upstream and downstream streamgages.

Uncertainty in computed streamflow statistics is high for the Sheep Creek monitoring site because of the limited number of streamflow measurements and the method used to generate streamflow statistics, but the results are reasonable in comparison with results from the nearby West Fork Bruneau River site. Sheep Creek and the West Fork Bruneau River have similar drainage areas (Sheep Creek is slightly larger), but Sheep Creek receives about 6 in. less precipitation per year (table 2). Highest bimonthly streamflow statistics for Sheep Creek are slightly larger and occur around the same time as those for the West Fork Bruneau River. However, the bimonthly Q_{50} streamflow at Sheep Creek is less than 50 percent of the bimonthly Q_{50} streamflow for the West Fork Bruneau River during low streamflow periods, which is expected given the more arid climate within the Sheep Creek drainage basin. Some small peaks in the bimonthly Q_{20} values were noted at Sheep Creek prior to the maximum values in late May and early June (fig. C5), a phenomenon that was not noted at other sites. The small peaks are probably due to a limited number of years (2) of streamflow record used in the exceedance probability analysis and to actual hydrologic conditions in the basin during the short period of analysis (1910–13).

Jarbidge River Basin

The Jarbidge River below Jarbidge, Nev., was the only monitoring site with a long-term streamgage that was operating during the study in WY 2012. The streamflow statistics are based on 14 years of daily mean and annual peak streamflow records. The Jarbidge River has the second smallest drainage area among monitoring sites in the study, but it had the 7th largest estimate of bankfull streamflow of monitoring sites presented in table 9. The larger than average bankfull value is reasonable, considering that most of the peak streamflow at the site is derived from snowmelt in upstream, high elevation areas. Confidence is high for the computed bimonthly statistics (fig. 14) because of the availability of direct streamflow records, but actual streamflow statistics in the WSR segment are likely higher than those computed at the streamgage, because the streamgage is several miles upstream of the upstream boundary of the WSR segment (fig. 1).

Little Jacks Creek Basin

Streamflow statistics were estimated for the Little Jacks Creek within the WSR segment boundary (USGS 13169800), and also for the discontinued streamgage located downstream (USGS 13170000) (fig. 2), which was operated in 1938–49. Lowest bimonthly streamflows within the WSR segment boundary occurred in the second half of August, and highest bimonthly streamflows occurred in the first half of May. Estimates for the discontinued streamgage were considerably lower than the upstream site, and 88 percent of the computed bimonthly streamflow statistics at the discontinued streamgage were zero. The highest bimonthly streamflow at the discontinued streamgage, in the second half of March, was slightly larger and occurred about 2 months earlier than was estimated for the upstream monitoring site. The bimonthly streamflow statistics estimated at the upstream monitoring site (USGS 13169800) probably are more representative of conditions with the WSR segment than those at the discontinued streamgage (USGS 13170000) because Little Jacks Creek was observed to be a perennial stream at the WSR segment boundary in WY2012. However, uncertainty is high in the timing of the bimonthly streamflow statistics at the upstream monitoring site because it is driven by streamflow patterns at the index site, which might not align with the timing of streamflows at the WSR segment boundary.

Bankfull estimates were significantly different between the two monitoring sites on Little Jacks Creek. The bankfull streamflow estimate at the upstream site was about 95 percent less than the bankfull streamflow for the discontinued streamgage. Possible causes of this discrepancy are the lack of high streamflow measurements at the upstream monitoring site and variable interactions between groundwater and surface water along the reach. Similar to monitoring sites in the Big Jacks Creek Basin, the limited range of streamflows measured in WY 2012 might be representative of current conditions, again indicating that groundwater dominates streamflow patterns at these monitoring sites. The highest measured streamflow in WY 2012 at the upstream site was 3.29 ft^3/s, but the highest measured streamflow over the period of record at the discontinued streamgage was 908 ft^3/s, based on an indirect measurement of streamflow in 1943 using a series of high water marks. USGS field personnel did not observe any recent evidence of high streamflows along the reach in WY 2012, but streamflows greater than 100 ft^3/s were measured on four dates in the 11-year period of record (1938–49) for the discontinued streamgage—in 1939, 1941, 1942, and 1943. The bankfull streamflow generated using data from the discontinued streamgage (98.0 ft^3/s; table 9) is considered a reasonable estimate for the WSR segment, but a longer period of monitoring at the upstream monitoring site, within the WSR segment, is needed to verify this assumption.

Owyhee River Basin

Streamflow statistics were estimated at five sites in the Owyhee River Basin, which is regulated by reservoirs and irrigation diversions throughout the basin. The South Fork and East Fork Owyhee Rivers are affected to an unknown degree by regulation, which introduces uncertainty in the regression with index sites because of varying effects and timing of the regulation at the monitoring and index sites. The Owyhee River near Rome, Oreg. (USGS 13181000; fig. 1) was the selected index site for each of the South Fork and East Fork Owyhee Rivers. The Bruneau River at Rowland, Nev. (USGS 13161500) was selected as the index site for the North Fork Owyhee River because of similarities in runoff characteristics. The Owyhee River near Rome (USGS 13181000) was not selected as the index site for the unregulated North Fork Owyhee River because of the potential effect of regulation in the South Fork and East Fork Owyhee Rivers on streamflows at the Owyhee River near Rome (USGS 13181000). Although different index sites were used for the three forks of the Owyhee River monitored in WY 2012, the streamflow statistics were compared to statistics computed from the long-term streamflow record at the downstream Owyhee River near Rome, Oreg., streamgage (USGS 13181000) for verification. The drainage areas for the three forks of the river encompass about 50 percent of the total drainage area of the Owyhee River near Rome, Oreg. (USGS 13181000). The sum of each bimonthly streamflow statistic for the three forks was about 60 percent of the streamflow statistic computed for the Owyhee River near Rome (USGS 13181000). The total streamflow contribution from the three forks is slightly higher than expected at the Rome streamgage (USGS 13181000) based only on drainage area, but the discrepancy is logical because a larger portion of total runoff in the Owyhee River drainage basin is probably generated from precipitation and snowmelt in high elevations of the drainage basin rather than from the lower-elevation, more arid areas between the monitoring sites on the three forks and at the Rome streamgage (USGS 13181000).

Streamflow statistics generated for the South Fork of the Owyhee River have the highest uncertainty among evaluated sites in the Owyhee River Basin, because of a limited range in measured streamflow compared to the range in statistics. Peak streamflows during spring runoff at this site might have occurred prior to the start of data collection in WY 2012. The three pre-WY 2012 measurements were made in September during lower streamflow conditions. Discrete measurements during mid- to late September, including those made in WY 2012, ranged from 14.5 to 43.6 ft^3/s (appendix A, table A1), which are within the range in computed bimonthly streamflow statistics for this same period (table 8). The estimated bankfull streamflow (1,810 ft^3/s; table 9) for the South Fork Owyhee River was nearly 11 times larger than the highest measured streamflow (164 ft^3/s) (appendix C), but is considered possible on the basis of the size of the drainage area.

The regression developed for the East Fork Owyhee River monitoring site had the highest R^2 and BCF closest to 1.0 among sites in the Owyhee River Basin, which was likely the result of the relatively high number and range of available streamflow measurements. Highest bimonthly streamflow statistics occurred from mid-March to mid-April, which matches the pattern in discrete measurements made at the site. Similar to the South Fork Owyhee River, the bimonthly streamflow statistics at the East Fork Owyhee River increased steadily beginning in early autumn, which could be due to the cessation of upstream streamflow regulation around this time of the year. The estimated bankfull value (4,060 ft^3/s) was about five times larger than the highest streamflow measured at the site, but is considered possible on the basis of drainage area and site conditions. The bankfull value differed substantially from the StreamStats estimate, but the drainage area for the East Fork Owyhee River is about four times larger than the maximum drainage area of streamgages used to develop the regional regression equations. Again, the use of site-specific streamflow data likely provides more accurate estimates of streamflow statistics than are possible using the currently-available regional regression equations.

Several measurements were available for the analysis in the North Fork Owyhee River, but nearly two-thirds of the measurements were made during low streamflow conditions in late August or September. The overall quality of the developed regression was acceptable, but the measurements are clustered somewhat into low and high streamflow conditions. Additionally, streamflow conditions between October and March are not represented in the regression because no streamflow measurements were made during that period. The highest estimated bimonthly streamflow statistics occurred toward the end of April through May, likely the result of snowmelt in the higher elevations of the drainage area.

Monitoring sites on Battle and Deep Creeks are close to each other, but the estimated streamflow statistics varied greatly between sites. Regressions for each site were developed using daily mean streamflow values computed from the stage-discharge relation developed at the CSA streamgages in WY 2012, but different index sites were used for the two sites because the basin and runoff characteristics were different. The selected index sites were the Owyhee River near Rome, Oreg. (USGS 13180000) for Battle Creek and the Bruneau River near Rowland, Nev. (USGS 13161500) for Deep Creek. High regression uncertainty for Battle and Deep Creeks is likely the result of poor correlations between the index and monitoring site at high streamflows which may have been caused by localized storm events that occurred at either the index or monitoring site, but not both. Additionally, the Deep Creek regression showed poor correlations with the index site at low streamflows before the monitoring site went dry in late July. The bimonthly streamflow statistics for Battle Creek were highest in late to early April, which was expected based on the more arid climate and lower basin elevations than most other sites in the study area. The bimonthly streamflow statistics were considerably larger for Deep Creek than for Battle Creek. The Q_{20} bimonthly streamflows for Deep Creek during the spring months were higher than expected because they far exceeded the corresponding Q_{20} bimonthly streamflows for the East Fork Owyhee River, which is downstream of Deep Creek. One likely cause for this discrepancy is the difference in selected index sites, but another suspected cause is the high uncertainty in the regression for Deep Creek. The bankfull streamflow for Deep Creek is about twice as high as the peak streamflow recorded at the CSA streamgage in WY 2012, but is considered a reasonable estimate on the basis of basin characteristics and lower than average streamflow conditions in WY 2012.

Limitations and Uncertainty

The methods selected for this study and the resulting streamflow statistics have inherent uncertainties because of the limited availability of long-term streamflow records in the area and a limited window of time to collect additional data. Although the results presented in this report are considered the best available for the study area, many of the techniques used are non-standard and result in large and not fully quantifiable uncertainty in the estimated streamflow statistics.

Index Site Location and Number of Measurements

The locations of the selected index sites varied widely in this study. Index sites selected for five of the partial-record sites were located in a drainage basin different from the partial-record site. Differences in basin characteristics and timing of runoff between the monitoring and index sites can lead to uncertainties in the estimated streamflow statistics. In some cases, regressions generated using index sites either upstream or downstream from a monitoring site resulted in very different streamflow statistics for the monitoring site. One example where this occurred was the West Fork Bruneau River monitoring site. Diagnostics for the regression developed between the monitoring site and the upstream index site (USGS 13161500) were better than for the regressions with other index sites, but the daily mean streamflows generated using the regression did not seem reasonable relative to the streamflows measured at other index sites along the reach. For example, the resulting annual peak streamflow estimates at the monitoring site were less than (as much as half) the annual peak streamflows measured at the upstream index site. As a result, the index site downstream (USGS 13168500) from the monitoring site was selected for the regression because it produced more reasonable results. Streamflow statistics for most other sites in the analysis could not be verified in this way because there were no upstream or downstream index sites, and as a result, uncertainty is higher for those estimates than for the West Fork Bruneau River.

Regression diagnostics for sites with few measurements may be misleading, because the full range of streamflows and seasonal and inter-annual differences may not be well represented. An example is the regression equation for Wickahoney Creek (USGS 13169400). In comparison with the regression equation for the East Fork Owyhee River (USGS 13176400), which was developed using 19 streamflow measurements over a reasonable range of streamflows (fig. 15*A*), the regression equation for Wickahoney Creek was developed using only four streamflow measurements (fig. 15*B*), one of which was censored as less than 0.01 ft^3/s. For Wickahoney Creek, the coefficient of determination of the regression (0.74) implies that 74 percent of the variability in streamflow is represented by mean daily streamflows at the Bruneau River near Hot Spring, Idaho, index site (USGS 13168500), but uncertainty in computed streamflows at Wickahoney Creek is high due to the limited number and range of streamflow measurements. Streamflow estimates outside of the range of measured streamflows at the monitoring sites could have substantial error, but are considered the best available data for the study area. Some additional uncertainty was introduced in the analysis by estimating streamflow statistics for increments of time smaller than the frequency of the measurements (for example, bimonthly streamflow statistics when measurements were made approximately every month).

Upstream Regulation and Diversion

Streamflows in the East Fork and South Fork Owyhee Rivers are regulated to an unknown degree by small upstream reservoirs and irrigation diversions. The timing and quantity of the regulation and diversion are being studied by BLM. The streamflow statistics presented in this report were generated using measurements made primarily during an expected period of regulation (except for the March 2012 measurements). Additional analysis is needed to determine the effect of regulation on streamflows in the WSR segments, and separate statistics should ideally be calculated using measurements made during regulated and non-regulated periods.

Analysis Assumptions

Several assumptions were made in the development of a consistent method for estimating synthetic streamflow records at partial-record sites. These assumptions, which are potential sources of error and uncertainty, are:

- The regressions developed for partial-record sites were used to create synthetic records of daily mean streamflow based on the relation between the discrete measurements at a monitoring site and daily mean streamflow at an index site. The discrete measurements were assumed to be approximately equal to the daily mean streamflow at the monitoring site where they were made. Errors in the analysis as a result of this assumption are likely greatest for the highest streamflow measurements made in spring 2012, when streamflow was driven by spring runoff or rain-on-snow events. Streamflow measurements during this period were dependent on field personnel’s ability to access the sites and not necessarily timed to represent an average condition for a particular day.
- The regressions developed between discrete measurements at monitoring sites and daily mean streamflow at index sites were assumed to be representative of the relation between annual peak streamflows at the sites. This assumption was made because no record existed of annual peak streamflows at the partial-record sites for the calculation of bankfull streamflow statistics, and because the hydrologic conditions that control the relation in daily mean streamflows between sites are expected to also control the relation in peak streamflows. Uncertainty exists in the calculation of bankfull streamflow statistics because of this assumption.
- The bankfull streamflow statistical analysis was based on an actual or synthetic record of one peak streamflow per year. The occurrence of streamflows that correspond with bankfull conditions at a site might be more frequent than the 66.7-percent AEP implies, because in years when the annual peak streamflow is higher than the 66.7-percent AEP, secondary peaks equal to or greater than bankfull level may have occurred. In this case, the frequency of bankfull streamflows may not be accurately represented in the record of annual peak streamflows.
- Simple linear regressions were created and assumed to represent all streamflows values for partial-record sites. For some sites, multiple linear regressions or compound linear regressions with slope breakpoints may be more appropriate for representing the range of streamflows at partial-record sites. Regression techniques more complex than simple linear were deemed inappropriate for this analysis given the limited dataset, but might improve the accuracy of streamflow statistics if more streamflow data are available in the future.
- An inherent assumption in the analysis was that the hydrologic conditions in WY 2012 were close to average, compared to historical conditions, for the days when measurements were made. On the basis of hydrologic conditions at the index sites, which have long-term streamflow records, streamflow in the study area in WY 2012 appeared to be below average. As a result, the computed streamflow statistics are probably biased low but are the best available estimates without long-term continuous monitoring in the study area.

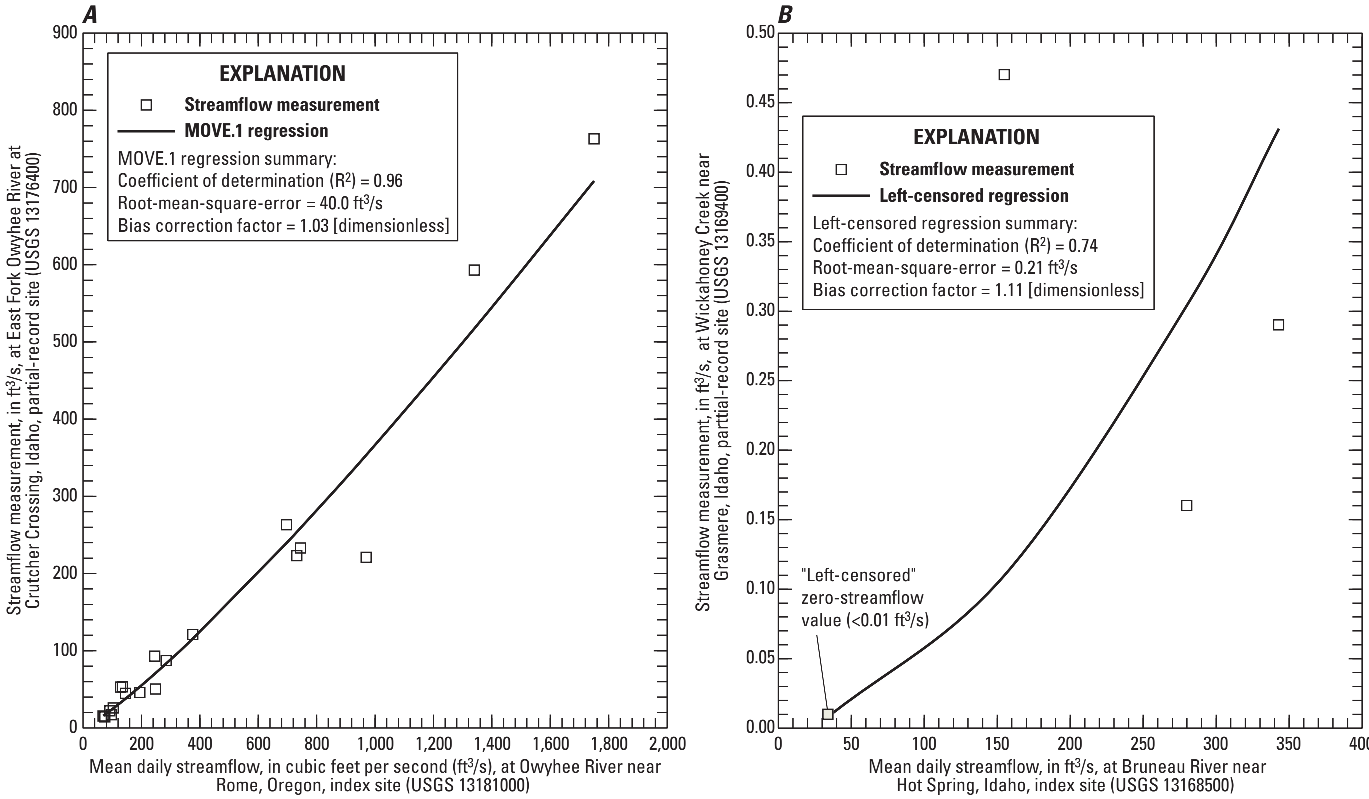

Figure 15. Regressions between partial-record and index sites for example sites with (*A*) a reasonable number and range of measurements, East Fork Owyhee River at Crutcher Crossing, Idaho (USGS 13176400), and (*B*) a limited number and range of measurements, Wickahoney Creek near Grasmere, Idaho (USGS 13169400).

Benefit of Long-Term Streamgages

Long-term streamflow records collected using consistent data-collection methods are important for ensuring that water is appropriately allocated and accounted for among water rights holders. Most of the statistics presented in this report were calculated based on only 6–8 months of streamflow measurements over 1 year, applied through regression to the long-term record from a USGS streamgage to produce a “synthetic” record of streamflow data at the point of interest. The methods presented would not have been possible without the availability of data from long-term streamgages, but many of these streamgages are far away from the WSR segments. Additionally, the period of data collection at the discrete monitoring sites near the WSR segments represents a limited range of hydrologic conditions. The accuracy of the presented statistics would be improved through long-term data collection or streamgaging over a range of hydrologic conditions at or near the WSR segments. The availability of long-term streamflow records decreases the uncertainty of streamflow statistics. For example, Kiang and others (2013) determined that increasing record length from 10 to 100 years at streamgages in southern Idaho decreased standard error for estimates of a 10-percent AEP flood (10-year recurrence interval) from less than or equal to 50 percent to less than or equal to 20 percent. Surprisingly, Kiang and others (2013) also determined that only a minimum record length of 6 years was required for streamgages in the Pacific Northwest to be able to estimate mean annual streamflows within an average standard error of 10 percent. The USGS typically calculates streamflow statistics only when the streamgage record length is at least 10 years.

Long-term data collection is needed to evaluate and track changes in streamflows in the WSR segments in response to changes in climate and upstream land use. To this end, the BLM funded a telemetered streamgage on the East Fork Owyhee River at Crutcher Crossing, Idaho (USGS 13176400), installed in December 2012 after the primary data-collection period, because of a lack of streamgages near the WSR segments in the Owyhee River Basin. This streamgage will be valuable for long-term monitoring and trend analysis in the basin.

Potential Areas for Further Study

The synthetic streamflow records and statistics presented in this report were calculated based on only 6–8 months of streamflow measurements within 1 year. Streamflow measurements over a wider range of hydrologic and climatic conditions would help improve the relations between data from monitoring and index sites. Furthermore, the accuracy of streamflow statistics would probably substantially improve for streams that had poor correlations with all evaluated index sites, such as Cottonwood, Little Jacks, Sheep, and Wickahoney Creeks, by installing additional telemetered streamgages in two or more of these basins to serve as future index sites. Additionally, although the selected streamflow statistics are intended to be an estimate of the streamflows needed to sustain ORVs in the WSR segments, field surveys would help determine site-specific streamflow needs and would provide confirmation whether selected streamflows are appropriate. Examples of such field surveys include physical measurements of stream pool and riffle sequences and water depths required for fish passage, mapping of fish habitat and spawning areas, monitoring vegetation type and extent in riparian areas, and written or verbal surveys of boaters and anglers regarding their experience on the rivers at specific streamflows.

Future streamflow monitoring efforts could be made more cost effective by measuring at locations with improved site access, perhaps not at but within reasonable proximity of the WSR segment boundary, which will serve as the point of quantification and compliance for the water right claim. Although this might result in slight differences in results between the measurement site and point of interest (downstream boundary of WSR segment), improved site access likely would result in more measurements, an improved relation in streamflows between the monitoring and index sites, and reduced uncertainty in the synthetic streamflow record. The drainage area ratio method could be used to adjust streamflow measurements and estimate the difference in streamflow between the measurement site and the downstream boundary of the WSR segment. Some periodic comparison measurements made at both locations could be used to verify whether a drainage area ratio adjustment is appropriate. The relations would be further improved by measurements made no less than twice per month, where possible, and by additional efforts to capture peak and low streamflows over a range of climate conditions. Measuring twice per month would allow for calculation of bimonthly statistics using the approach described in Riggs (1969), which might produce more accurate results. Additionally, the estimates of bankfull streamflow statistics would be improved by field observations and targeted measurements when the streamflow is truly bankfull, but still confined to the main channel. Calculation of bankfull streamflow statistics could be further enhanced through the installation of crest-stage gages (CSGs) at all monitoring sites. CSGs are non-mechanical, non-recording devices used to monitor the elevation of the highest water level at a site since the CSG was last visited and serviced. CSGs would be useful for capturing the annual peak stream elevation, which could be used to determine annual peak streamflow by developing a rating between stream elevation and streamflow through a series of measurements. The at-site estimates of annual peak streamflow could then be used to directly calculate the AEP distribution and bankfull streamflow.

The selection process for index sites could be made more robust and comprehensive through the use of the map correlation method proposed in Archfield and Vogel (2010). The map correlation method has been evaluated primarily in the northeastern United States, but the techniques might also be applicable to the more arid western United States. The method involves estimating streamflow quantiles at an ungaged location based on regional regression equations between streamflows at USGS streamgages and basin characteristics. Correlation maps are then developed for every combination of an ungaged location, or site of interest, and a streamgage in the study area using a geostatistical kriging technique. The correlation maps are examined to determine which streamgage has the best correlation with the ungaged location. The timing of streamflows at the streamgage is then used to create a synthetic hydrograph of streamflows at the ungaged location. The map correlation method could potentially produce results that are more robust than those described in this report because it is a more objective approach for determining the best index site for an ungaged location, and could allow a more rapid evaluation of index gages in a much wider study area than could be evaluated in this report. The map correlation method also could be used to generate synthetic hydrographs in regulated streams. Archfield and others (2010) developed the Sustainable-Yield Estimator tool, on the basis of the map correlation method, as a decision-support tool to model water availability at ungaged locations in Massachusetts under various regulation and water withdrawal scenarios. The development of a similar tool for the Owyhee Canyonlands Wilderness could be useful for predicting streamflow changes in the WSR segments in response to changes in upstream withdrawals or regulation.

The apparent upstream migration of streamflow loss zones in the Big Jacks and Little Jacks Creeks warrants further investigation to better understand the cause, whether it is climatic or indicative of a long-term decrease in groundwater contributions to stream base flow in the area. Such a decrease, if real, could be detrimental to streamflows and associated ORVs in the WSR segments. Additional streamflow measurements, long-term observations of the point at which all streamflow is lost to groundwater, and streamside piezometers could be useful for quantifying long-term trends.

Because streamflows in the East Fork and South Fork Owyhee Rivers were affected to an unknown degree by small upstream reservoirs and irrigation diversions, the timing and magnitude of these controls could be monitored, and separate data collection efforts could be planned for regulated and unregulated periods. Such an evaluation would probably result in more accurate and representative streamflow statistics, which would better facilitate management of streamflows and ORVs in these basins.

Summary

The U.S. Geological Survey (USGS) collected streamflow data at 14 monitoring sites during February–September 2012 and estimated streamflow statistics for selected National Wild and Scenic Rivers in the Owyhee Canyonlands Wilderness in Idaho. Two sites were equipped with telemetered streamgaging equipment. Synthetic streamflow records were created for 11 of the 14 monitoring sites using a partial-record method or drainage area ratio method. Streamflow records were directly obtained from a long-term streamgage at the monitoring site on the Jarbidge River in Nevada and two discontinued streamgages located on Big Jacks and Little Jacks Creeks in Idaho. For the 10 sites analyzed using the partial-record method, discrete measurements were related to daily mean streamflow at a nearby, telemetered “index” streamgage. Four streamgages in Idaho, Nevada, and Oregon were selected as index sites for all the partial-record sites. Four to 19 streamflow measurements per site were used in the analysis. Continuous slope area streamgages at Battle and Deep Creeks in Idaho provided 201 and 200 daily mean streamflow values, respectively, to compare with index sites. Resulting regression equations were used to estimate daily mean and annual peak streamflow at the monitoring sites during the full period of record for the index sites. Assumptions of the regression analyses included (1) the discrete measurements were representative of the daily mean streamflow at monitoring sites, and (2) the regressions could be extrapolated and applied to the record of annual peak streamflows with acceptable error. A synthetic streamflow record for Sheep Creek was developed using a drainage area ratio method, because measured streamflows did not relate well enough to any index site to allow use of the partial-record method. In the drainage area ratio method, available streamflow data from discontinued streamgages in a drainage basin are adjusted to a downstream site using a ratio between drainage areas of the two locations. The synthetic and actual daily mean streamflow records were used to estimate the daily mean streamflows that were exceeded 80, 50, and 20 percent of the time for bimonthly (80-, 50-, and 20-percent bimonthly streamflow exceedances) and annual periods. Bankfull streamflow statistics were calculated by fitting the synthetic and actual annual peak streamflow records to a log Pearson Type III distribution using methods described in Bulletin 17B in the USGS PeakFQ program and weighting at-site flood quantile estimates with the regional regression estimates using the WIE program.

The coefficients of determination (R^2) for the regressions between the monitoring and index sites ranged from 0.74 for Wickahoney Creek to 0.98 for the West Fork Bruneau River and Deep Creek. Temporal patterns in the bimonthly exceedance statistics were dictated primarily by patterns in the streamflow records at the selected index sites, but the timing of high streamflows matched what was expected at most sites on the basis of the regional hydrology, basin characteristics, and WY 2012 measurements. Deviations in expected patterns for Cottonwood and Wickahoney Creeks probably are the result of a limited range of streamflows measured in WY 2012 and resulting errors in the regressions with index sites. Determining whether the bankfull streamflow statistic was reasonable for a given site was difficult because most sites were measured during only one water year with below-average streamflow conditions. However, the bankfull streamflow statistics are considered plausible and reasonable given the knowledge of site hydrology and basin characteristics.

Confidence in computed streamflow statistics is highest for the East Fork Owyhee River and West Fork Bruneau River on the basis of regression statistics, visual fit of the related data, and the range and number of streamflow measurements and for the Jarbidge River, because of the availability of a directly-measured, long-term record of streamflow. Sites with streamflow statistics with greatest uncertainty include Big Jacks and Little Jacks Creeks, because of observed losses of surface water to groundwater along stream reaches; Cottonwood and Wickahoney Creeks, because of a limited range in measured streamflows; and Sheep Creek, because streamflow was estimated using a drainage area ratio method with century-old discontinued streamgage data. The degree and effect of streamflow regulation in the East Fork and South Fork Owyhee Rivers is unknown, but could contribute to errors in the relation between measurements and index sites in these basins. Uncertainty exists in the computed streamflow statistics because of the distance of index sites relative to monitoring sites, relatively low streamflow conditions measured during the study, and limited number and range of streamflow measurements. However, the computed streamflow statistics are considered the best possible estimates for the study area given available datasets and are reasonable given current (2012) knowledge of monitoring site characteristics and area hydrology. Estimates of bankfull streamflow computed for this report compared reasonably well with estimates from the USGS StreamStats program for some sites. At other sites, deviations in bankfull streamflow estimates from the StreamStats prediction intervals made sense because the unique hydrologic conditions at those sites (such as groundwater-surface water interactions, runoff from large drainage areas) are not well-represented by regional regression models and are best represented through the collection of site-specific data and the methods described in this report.

More frequent streamflow measurements over a wider range of hydrologic and climatic conditions are needed to improve the relations between data from monitoring and index sites. Long-term data collection would be useful for tracking changes in streamflows in the Wild and Scenic River segments in response to changes in climate and upstream land use. Future streamflow monitoring efforts could be made more cost effective by measuring at sites with better access than some sites selected for this study, perhaps not at but within reasonable proximity of the Wild and Scenic River segment boundary. Field surveys also are needed to verify whether the streamflows selected for the water rights claims are sufficient for maintaining outstanding remarkable values in the Wild and Scenic Rivers reviewed in this study.

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Appendix A. Discrete Streamflow Measurements at Monitoring Sites, Owyhee Canyonlands Wilderness, Idaho

Table A1. Discrete streamflow measurements used for development of synthetic streamflow records at monitoring sites, Owyhee Canyonlands Wilderness, Idaho.

[**Abbreviations**: USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; –, no data]

USGS site No.	Site name	Date	Time	Streamflow (ft^3/s)	Remarks
		Big Jacks Creek Basin			
13169450	Big Jacks Creek at Al Sadie Ranch, near Bruneau, Idaho	03-16-12	0800	2.54	–
		03-29-12	1342	2.67	–
		05-07-12	1515	0.86	–
		05-18-12	–	0.17	Zero flow at measurement site, measurement made upstream at the wilderness boundary
		07-27-12	–	0	Zero flow observed, no time recorded
		09-12-12	–	0	Zero flow observed, no time recorded
13169420	Cottonwood Creek near Harvey Point, near Bruneau, Idaho	02-09-12	1231	2.23	–
		04-10-12	1129	2.45	–
		05-30-12	1346	2.06	–
		09-04-12	1141	1.14	–
13169400	Wickahoney Creek near Grasmere, Idaho	02-09-12	1034	0.47	–
		04-10-12	1443	0.29	–
		05-30-12	1621	0.16	–
		09-04-12	–	0	Zero flow observed, no time recorded
		Bruneau River Basin			
13162050	West Fork Bruneau River above Jarbidge River, near Grasmere, Idaho	08-07-86	1312	29.5	–
		09-21-88	1306	15.7	–
		08-14-89	1305	18	–
		02-14-12	1241	45.8	–
		04-18-12	1213	162	–
		04-26-12	1210	244	–
		05-30-12	1225	81.3	–
		07-31-12	1313	11.2	–
		09-06-12	1248	9.91	–
13164600	Sheep Creek above mouth, near Grasmere, Idaho	03-01-12	1222	25.3	–
		04-10-12	1235	68.9	–
		05-31-12	1430	24.4	–
		09-07-12	–	0	Zero flow observed, no time recorded
		Little Jacks Creek Basin			
13169800	Little Jacks Creek above Wilderness Road, near Bruneau, Idaho	03-16-12	0934	3.29	–
		05-07-12	1249	2.88	–
		05-18-12	1037	2.4	–
		06-27-12	1332	1.79	–
		07-27-12	0934	1.35	–
		08-22-12	1025	1.57	–
		09-12-12	0920	1.67	–

Table A1. Discrete streamflow measurements used for development of synthetic streamflow records at monitoring sites, Owyhee Canyonlands Wilderness, Idaho.—Continued

[**Abbreviations**: USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; –, no data]

USGS site No.	Site name	Date	Time	Streamflow (ft^3/s)	Remarks
		Owyhee River Basin			
13177845	South Fork Owyhee River below Little Owyhee River, near Crutcher Crossing, Idaho	09-28-89	2004	43.6	–
		09-27-90	0950	27.3	–
		09-16-92	1444	14.5	–
		04-10-12	1715	164	–
		05-10-12	1042	41.5	–
		06-25-12	1650	28.9	–
		08-09-12	1436	15.3	–
		09-13-12	1351	31.1	–
13176400	East Fork Owyhee River at Crutcher Crossing, Idaho	06-16-55	–	87.2	Time unknown
		06-17-56	–	121	Time unknown
		06-21-58	–	233	Time unknown
		06-17-59	–	53	Time unknown
		06-10-60	–	50.3	Time unknown
		06-13-61	–	45.8	Time unknown
		06-12-62	–	223	Time unknown
		06-23-64	–	593	Time unknown
		06-29-65	–	221	Time unknown
		09-28-89	1306	44.8	–
		09-27-90	1400	25.8	–
		09-19-91	0955	17	–
		09-16-92	1108	15.4	–
		03-17-12	1450	763	–
		04-10-12	1440	263	–
		05-10-12	843	93	–
		06-25-12	1446	52.9	–
		08-09-12	1231	22.1	–
		09-13-12	1203	14.1	–
13177910	North Fork Owyhee River near Fairylawn, Idaho	09-27-89	1257	2.45	–
		09-17-91	1230	2.61	–
		09-27-93	1115	4.86	–
		09-11-01	1400	1.28	–
		09-17-03	1400	1.54	–
		09-28-04	1230	2.72	–
		09-15-05	1500	2.7	–
		08-31-06	1320	2.68	–
		09-10-07	550	0.77	–
		09-19-08	1224	2.21	–
		09-15-10	1052	3.47	–
		04-03-12	1034	145	–
		04-16-12	1150	81.4	–
		04-23-12	1212	70.1	–
		05-30-12	1105	12.8	–
		06-25-12	1248	4.54	–
		07-30-12	1100	1.78	–
		08-21-12	1118	1.8	–
		09-05-12	1120	1.38	–

Table A1. Discrete streamflow measurements used for development of synthetic streamflow records at monitoring sites, Owyhee Canyonlands Wilderness, Idaho.—Continued

[**Abbreviations**: USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; –, no data]

USGS site No.	Site name	Date	Time	Streamflow (ft^3/s)	Remarks
Owyhee River Basin—Continued					
13176195	Battle Creek above mouth, near Riddle, Idaho	03-13-12	1544	184	–
		04-01-12	1110	75.3	–
		04-01-12	1745	67.4	–
		06-06-12	2011	10.2	–
		08-14-12	0909	3.47	–
13176305	Deep Creek above mouth, near Riddle, Idaho	03-14-12	1628	533	–
		03-15-12	1130	962	–
		04-02-12	1800	245	–
		04-03-12	1010	190	–
		06-07-12	1832	6.89	–
		08-14-12	–	0	Zero flow observed, no time recorded

Appendix B. Daily Mean Streamflows at Continuous Slope Area Streamgages, Owyhee Canyonlands Wilderness, Idaho, 2012

Table B1. Computed daily mean streamflows at continuous slope area streamgages on Battle and Deep Creeks, Owyhee Canyonlands Wilderness, Idaho, 2012.

[**Abbreviations:** USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; –, no data]

Date	Daily mean streamflow (ft^3/s)	
	Battle Creek above mouth, near Riddle, Idaho (USGS 13176195)	Deep Creek above mouth, near Riddle, Idaho (USGS 13176305)
03-14-12	134	–
03-15-12	139	432
03-16-12	128	594
03-17-12	167	592
03-18-12	185	515
03-19-12	95	267
03-20-12	61	263
03-21-12	47	261
03-22-12	133	557
03-23-12	100	364
03-24-12	63	272
03-25-12	45	261
03-26-12	38	277
03-27-12	34	258
03-28-12	32	253
03-29-12	30	250
03-30-12	83	322
03-31-12	141	745
04-01-12	72	379
04-02-12	46	250
04-03-12	35	195
04-04-12	31	174
04-05-12	27	156
04-06-12	26	136
04-07-12	24	116
04-08-12	22	104
04-09-12	21	102
04-10-12	20	109
04-11-12	19	111
04-12-12	19	115
04-13-12	18	104
04-14-12	20	98
04-15-12	19	93
04-16-12	19	87
04-17-12	19	83
04-18-12	19	82
04-19-12	19	81
04-20-12	18	80
04-21-12	18	78
04-22-12	17	74
04-23-12	16	68
04-24-12	16	63
04-25-12	16	59
04-26-12	19	61
04-27-12	21	123
04-28-12	25	125
04-29-12	25	88
04-30-12	21	70
05-01-12	19	61
05-02-12	18	54
05-03-12	16	48
05-04-12	16	44
05-05-12	16	43
05-06-12	15	39
05-07-12	15	36
05-08-12	14	33
05-09-12	14	30
05-10-12	14	28
05-11-12	13	25
05-12-12	12	23
05-13-12	12	22
05-14-12	12	20
05-15-12	11	18
05-16-12	11	17
05-17-12	11	17
05-18-12	11	16
05-19-12	11	15
05-20-12	11	14
05-21-12	10	13
05-22-12	10	12
05-23-12	11	12
05-24-12	11	12
05-25-12	13	13
05-26-12	15	14
05-27-12	25	17
05-28-12	39	16
05-29-12	26	16
05-30-12	19	14
05-31-12	16	12
06-01-12	13	10
06-02-12	11	8.9
06-03-12	11	8.3
06-04-12	10	7.3
06-05-12	11	7.3
06-06-12	11	7.0
06-07-12	10	7.0
06-08-12	9.5	7.5
06-09-12	9.9	7.9
06-10-12	9.3	7.1
06-11-12	9.1	6.6
06-12-12	8.4	6.2
06-13-12	8.1	5.8
06-14-12	7.8	5.0
06-15-12	7.3	4.2
06-16-12	6.5	3.6

Table B1. Computed daily mean streamflows at continuous slope area streamgages on Battle and Deep Creeks, Owyhee Canyonlands Wilderness, Idaho, 2012.—Continued

[**Abbreviations:** USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; –, no data]

Date	Daily mean streamflow (ft^3/s)	
	Battle Creek above mouth, near Riddle, Idaho (USGS 13176195)	Deep Creek above mouth, near Riddle, Idaho (USGS 13176305)
06-17-12	5.6	3.0
06-18-12	5.4	2.6
06-19-12	5.5	2.7
06-20-12	5.1	2.2
06-21-12	4.6	1.7
06-22-12	4.0	1.3
06-23-12	4.0	1.3
06-24-12	3.9	1.2
06-25-12	3.8	1.1
06-26-12	4.0	0.82
06-27-12	4.0	0.69
06-28-12	3.8	0.57
06-29-12	3.6	0.55
06-30-12	3.5	0.45
07-01-12	3.3	0.38
07-02-12	3.3	0.33
07-03-12	3.1	0.28
07-04-12	3.2	0.21
07-05-12	3.1	0.17
07-06-12	3.0	0.14
07-07-12	3.2	0.14
07-08-12	3.1	0.10
07-09-12	3.0	0.06
07-10-12	3.0	0.05
07-11-12	3.3	0.03
07-12-12	3.2	0.03
07-13-12	3.0	0.01
07-14-12	3.2	0.01
07-15-12	3.2	0.02
07-16-12	3.4	0.01
07-17-12	3.5	0.02
07-18-12	3.4	0.03
07-19-12	3.1	0.03
07-20-12	3.0	0.02
07-21-12	2.9	0.02
07-22-12	3.0	0.01
07-23-12	3.0	0.01
07-24-12	3.3	0.01
07-25-12	3.6	0.01
07-26-12	3.4	0.00
07-27-12	2.9	0.00
07-28-12	2.9	0.00
07-29-12	2.9	0.00
07-30-12	2.8	0.00
07-31-12	2.9	0.00
08-01-12	2.8	0.00
08-02-12	2.8	0.00
08-03-12	3.0	0.00
08-04-12	3.2	0.00
08-05-12	3.0	0.00
08-06-12	3.3	0.00
08-07-12	3.2	0.00
08-08-12	3.1	0.00
08-09-12	3.2	0.00
08-10-12	3.2	0.00
08-11-12	3.2	0.00
08-12-12	3.2	0.00
08-13-12	3.1	0.00
08-14-12	3.2	0.00
08-15-12	3.3	0.00
08-16-12	3.4	0.00
08-17-12	3.4	0.00
08-18-12	3.5	0.00
08-19-12	3.4	0.00
08-20-12	3.9	0.00
08-21-12	3.6	0.00
08-22-12	3.6	0.00
08-23-12	3.6	0.00
08-24-12	3.7	0.00
08-25-12	3.7	0.00
08-26-12	3.6	0.00
08-27-12	3.5	0.00
08-28-12	3.7	0.00
08-29-12	3.8	0.00
08-30-12	3.8	0.00
08-31-12	3.9	0.00
09-01-12	4.1	0.00
09-02-12	4.2	0.00
09-03-12	4.2	0.00
09-04-12	3.9	0.00
09-05-12	3.9	0.00
09-06-12	4.2	0.00
09-07-12	4.6	0.00
09-08-12	4.3	0.00
09-09-12	4.0	0.00
09-10-12	4.2	0.00
09-11-12	4.4	0.00
09-12-12	4.3	0.00
09-13-12	4.3	0.00
09-14-12	4.2	0.00
09-15-12	4.2	0.00
09-16-12	4.2	0.00
09-17-12	4.3	0.00
09-18-12	4.5	0.00
09-19-12	4.3	0.00
09-20-12	4.4	0.00
09-21-12	4.4	0.00
09-22-12	4.5	0.00
09-23-12	4.7	0.00
09-24-12	5.2	0.00
09-25-12	5.3	0.00
09-26-12	5.2	0.00
09-27-12	4.8	0.00
09-28-12	4.7	0.00
09-29-12	4.6	0.00
09-30-12	4.6	0.00

Appendix C. Bimonthly Exceedance Probability and Bankfull Streamflow Statistics and Zones of Extrapolation Above and Below Discrete Streamflow Measurements for Monitoring Sites, Owyhee Canyonlands Wilderness, Idaho, 2012

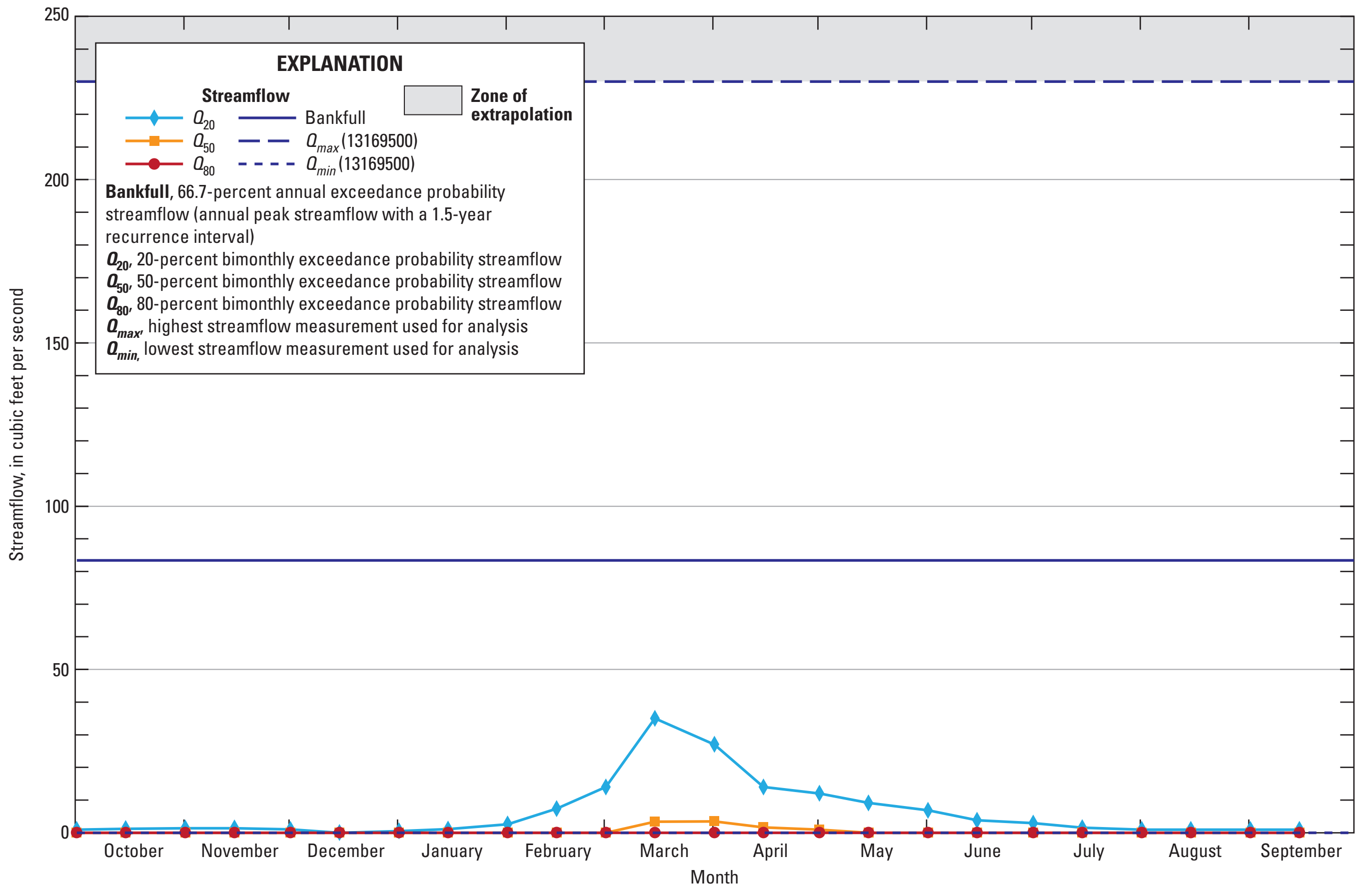

Figure C1. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Big Jacks Creek near Bruneau, Idaho (USGS 13169500).

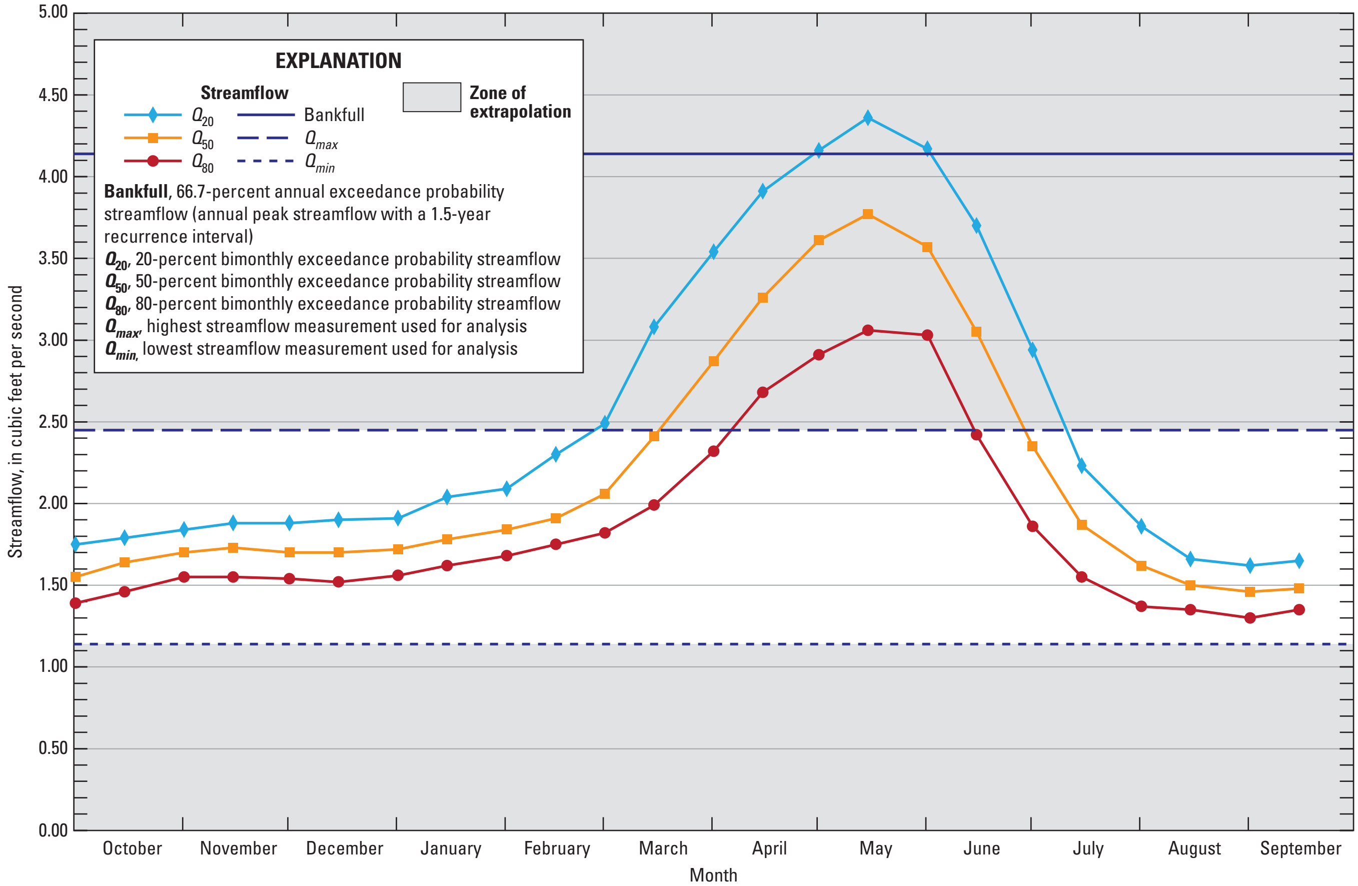

Figure C2. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Cottonwood Creek near Harvey Point near Bruneau, Idaho (USGS 13169420).

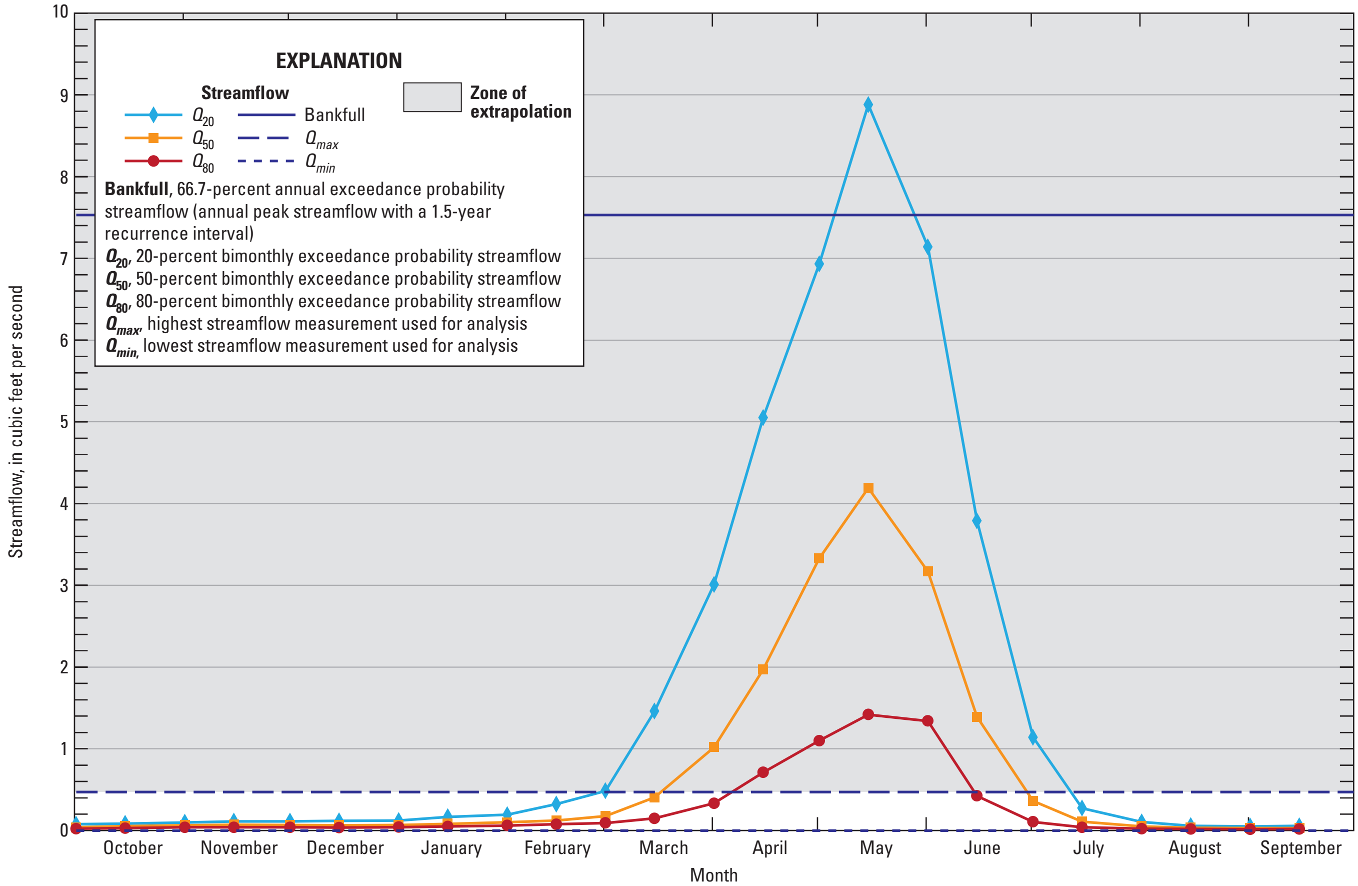

Figure C3. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Wickahoney Creek near Grasmere, Idaho (USGS 13169400).

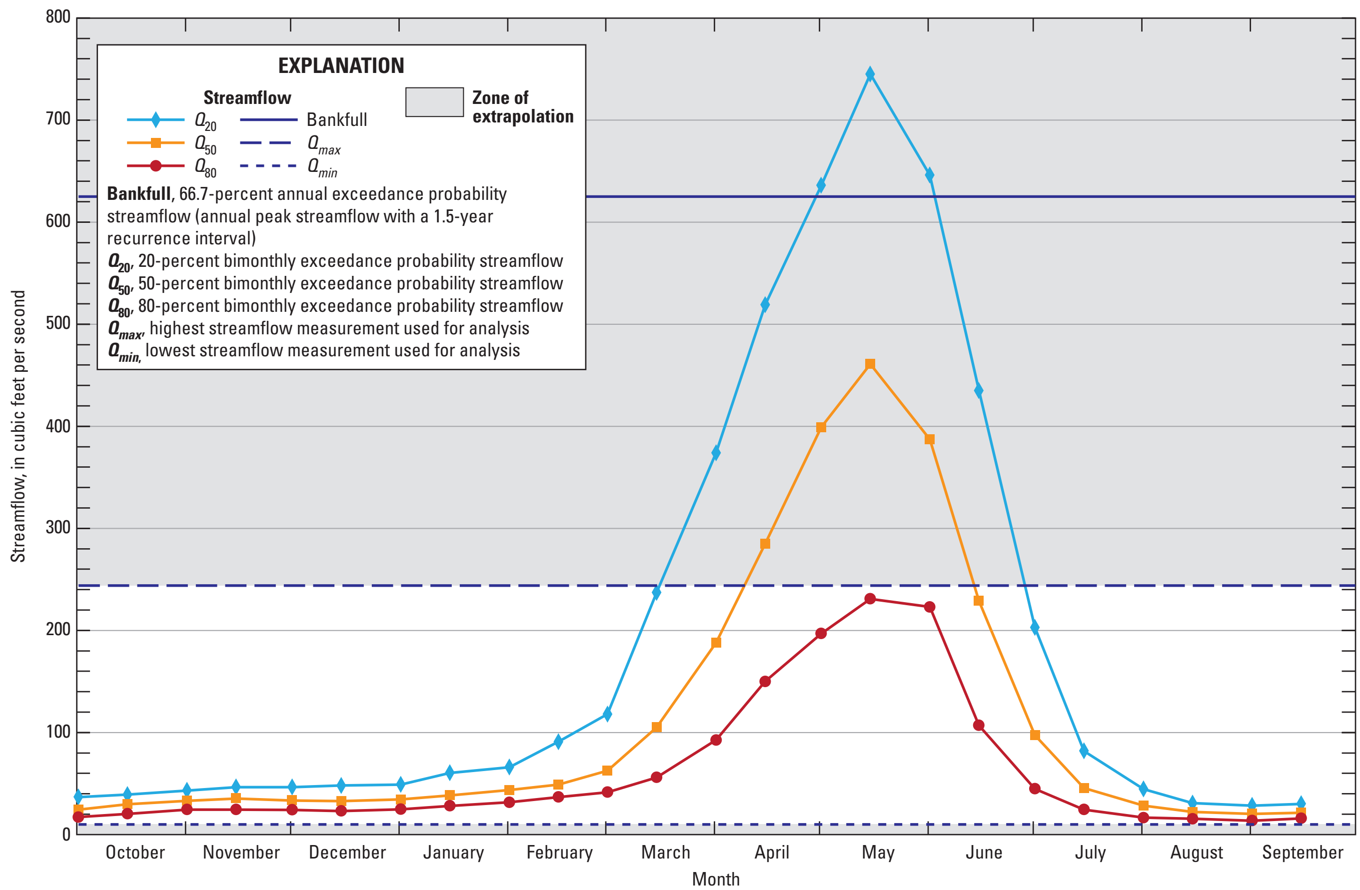

Figure C4. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at West Fork Bruneau River above Jarbidge River near Grasmere, Idaho (USGS 13162050).

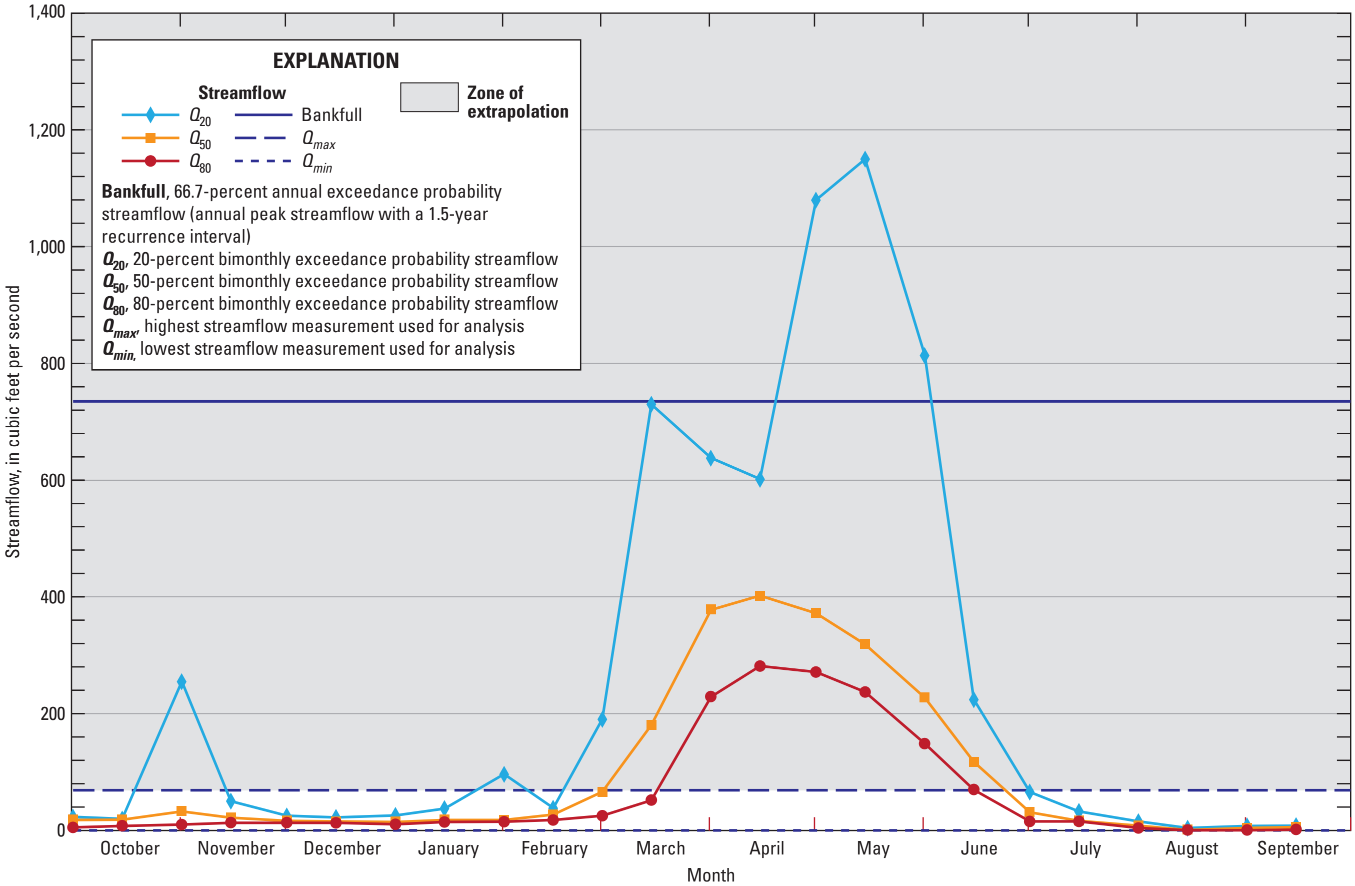

Figure C5. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Sheep Creek above Mouth near Grasmere, Idaho (USGS 13164600).

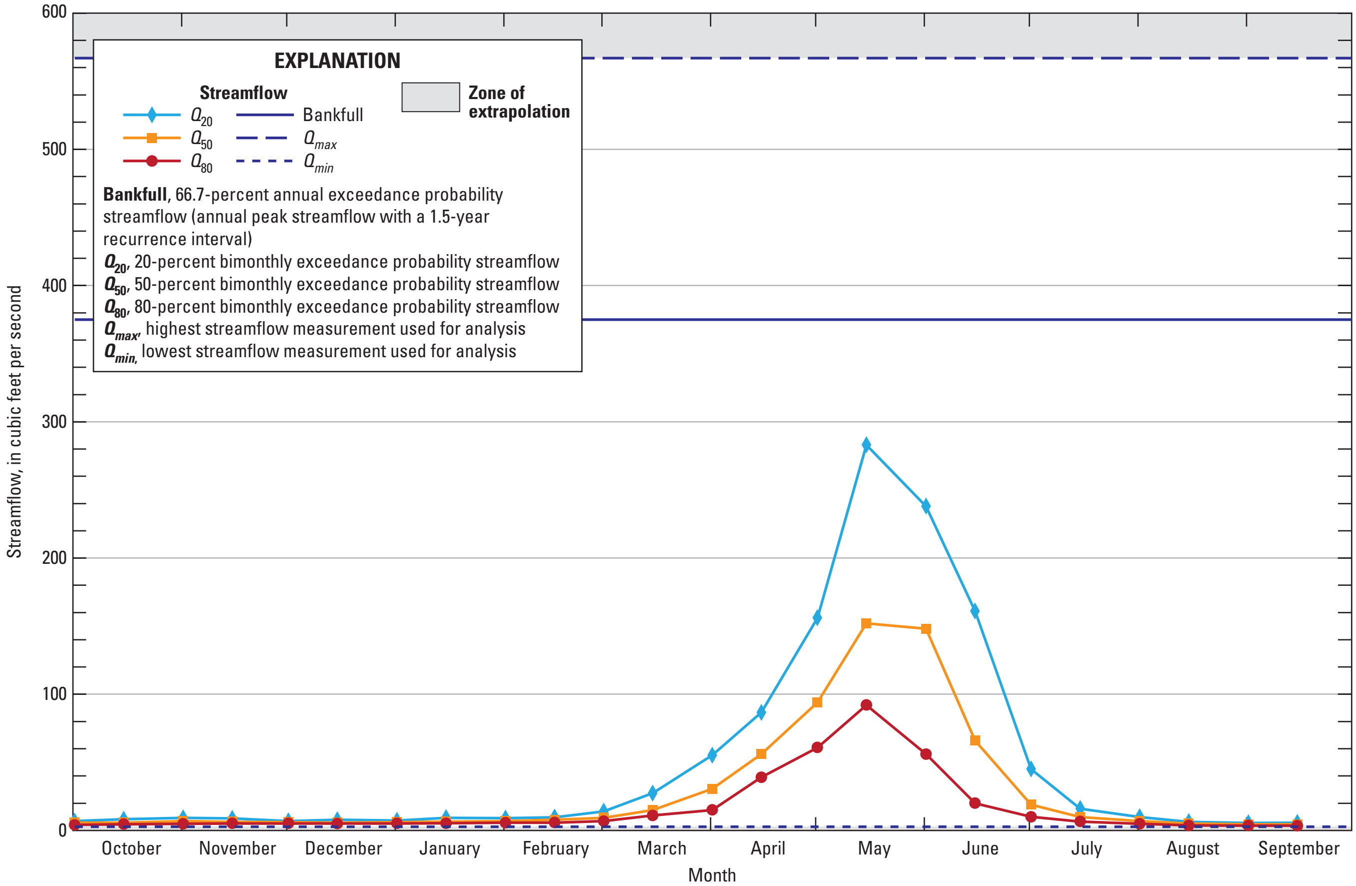

Figure C6. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Jarbidge River below Jarbidge, Nevada (USGS 13162225).

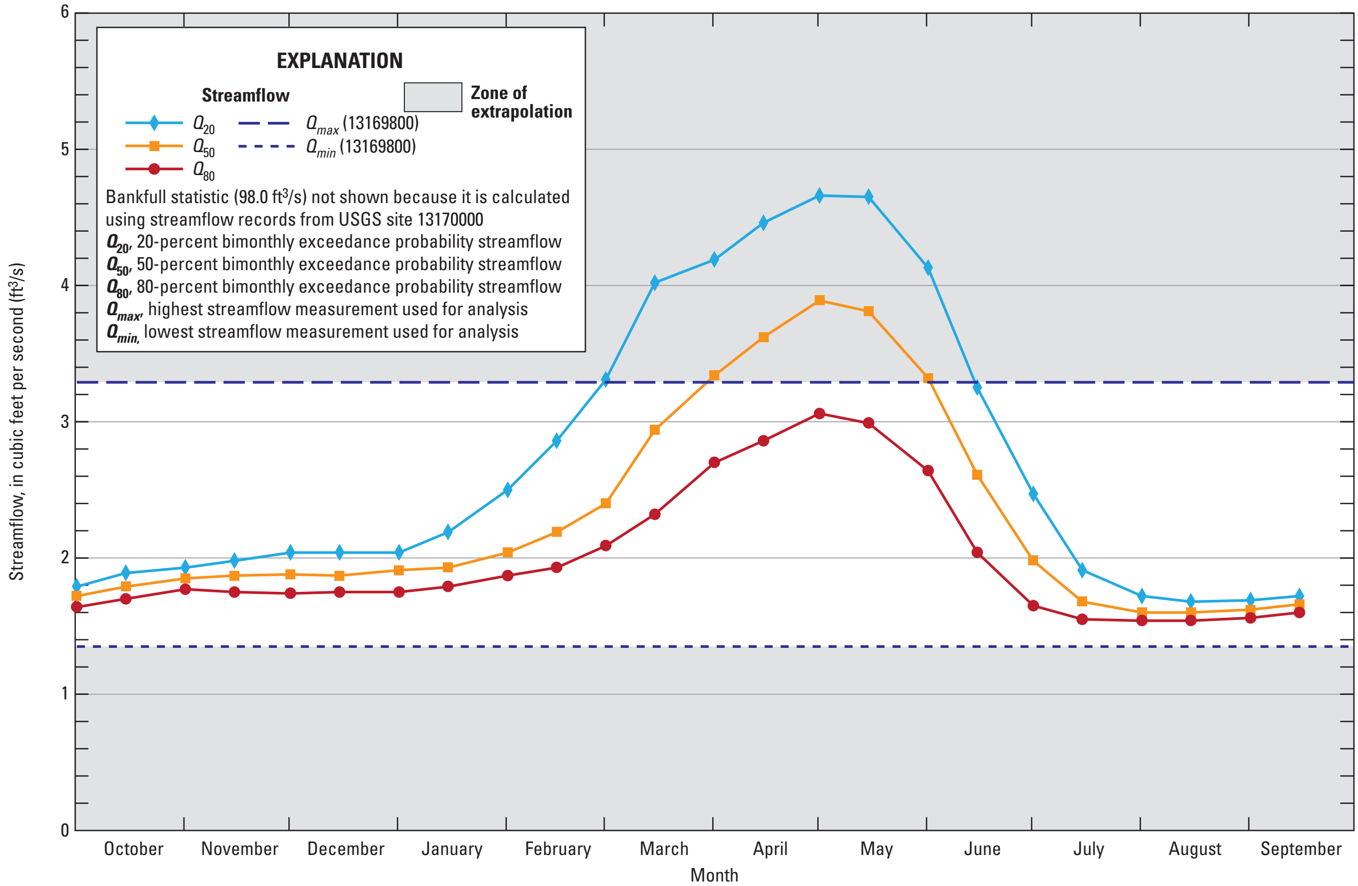

Figure C7. Bimonthly exceedance probability streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Little Jacks Creek above Wilderness Road near Bruneau, Idaho (USGS 13169800).

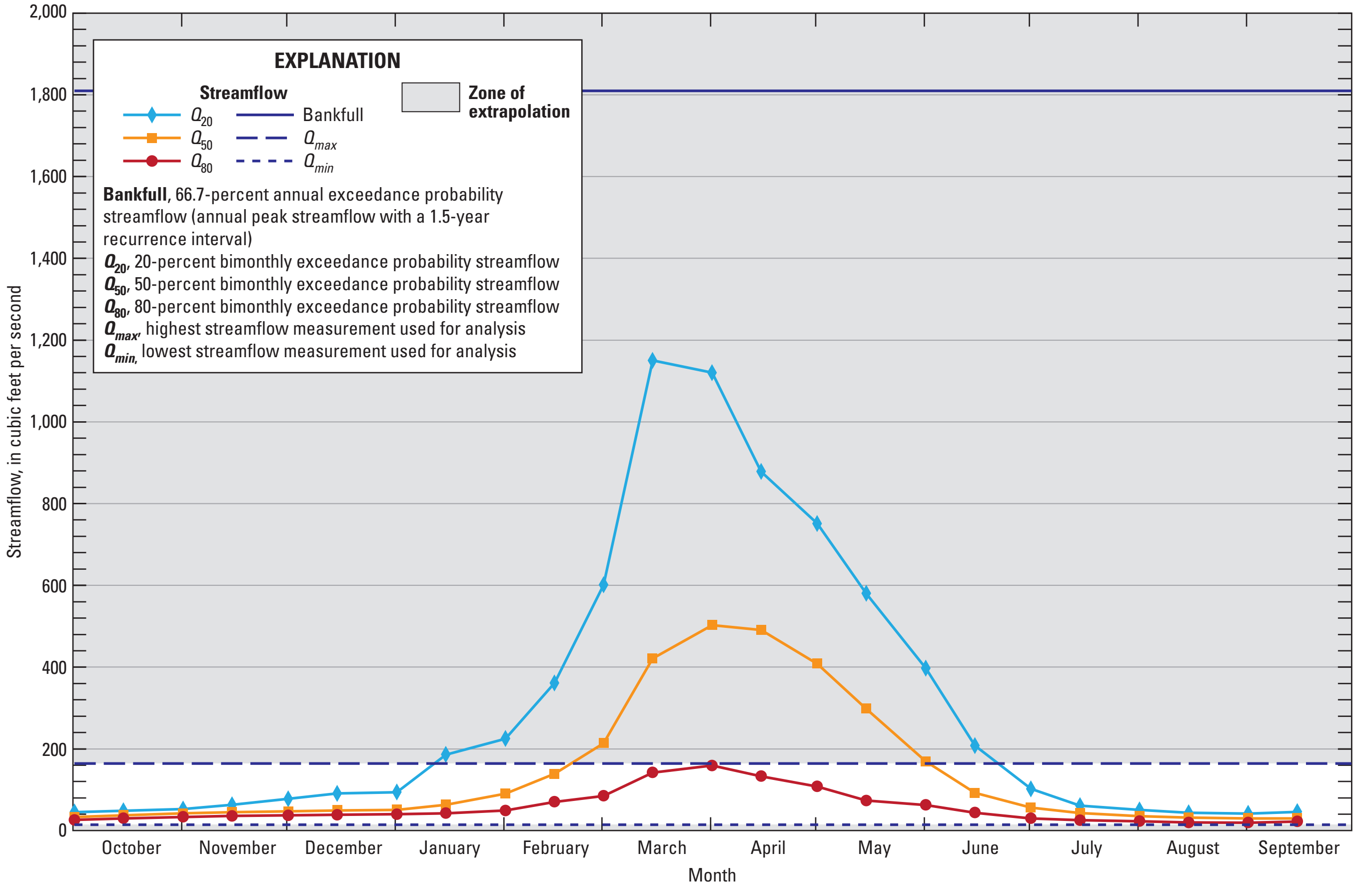

Figure C8. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at South Fork Owyhee River below Little Owyhee River near Crutcher Crossing, Idaho (USGS 13177845).

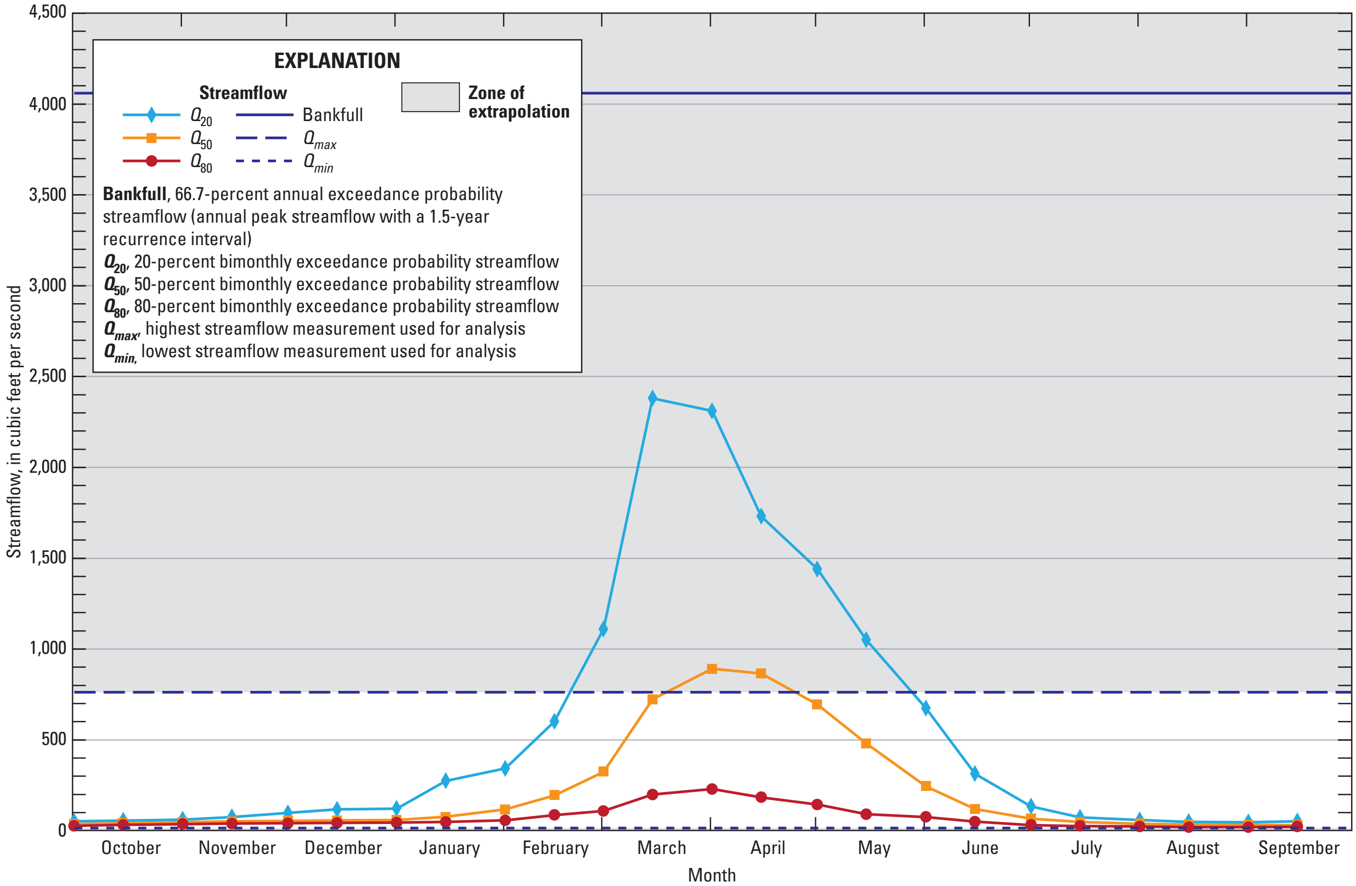

Figure C9. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at East Fork Owyhee River at Crutcher Crossing, Idaho (USGS 13176400).

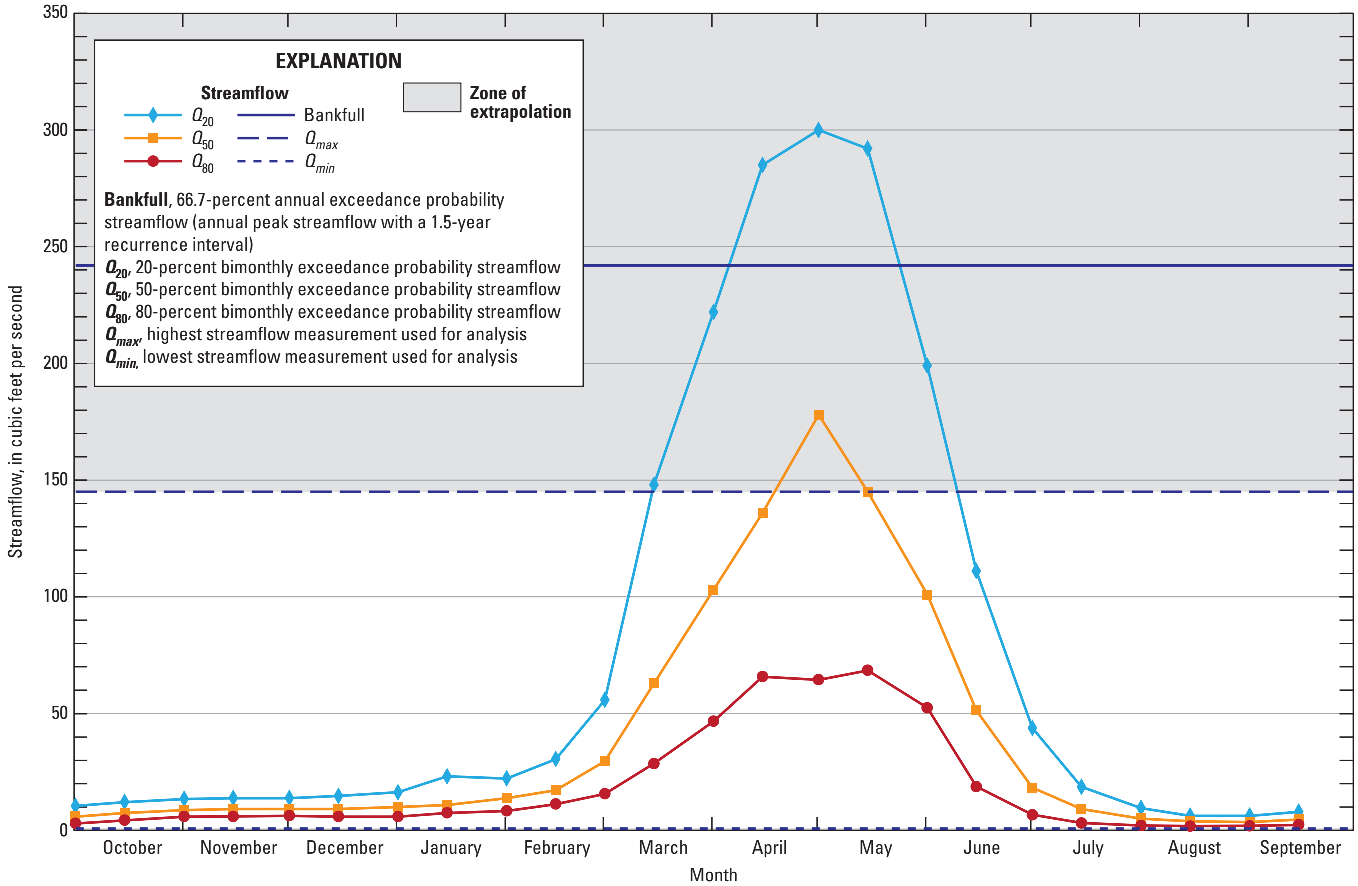

Figure C10. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at North Fork Owyhee River near Fairylawn, Idaho (USGS 13177910).

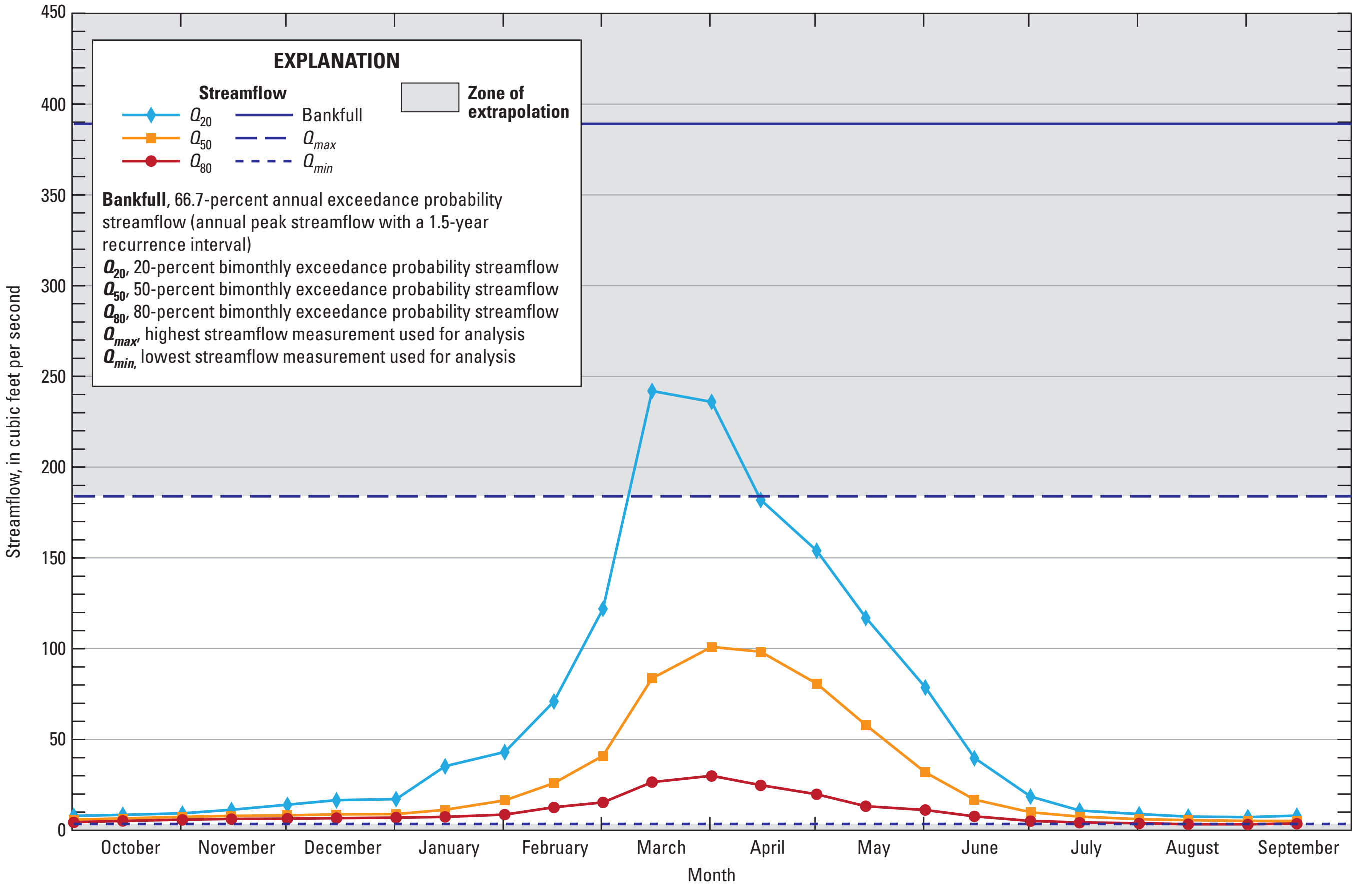

Figure C11. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Battle Creek above Mouth near Riddle, Idaho (USGS 13176195).

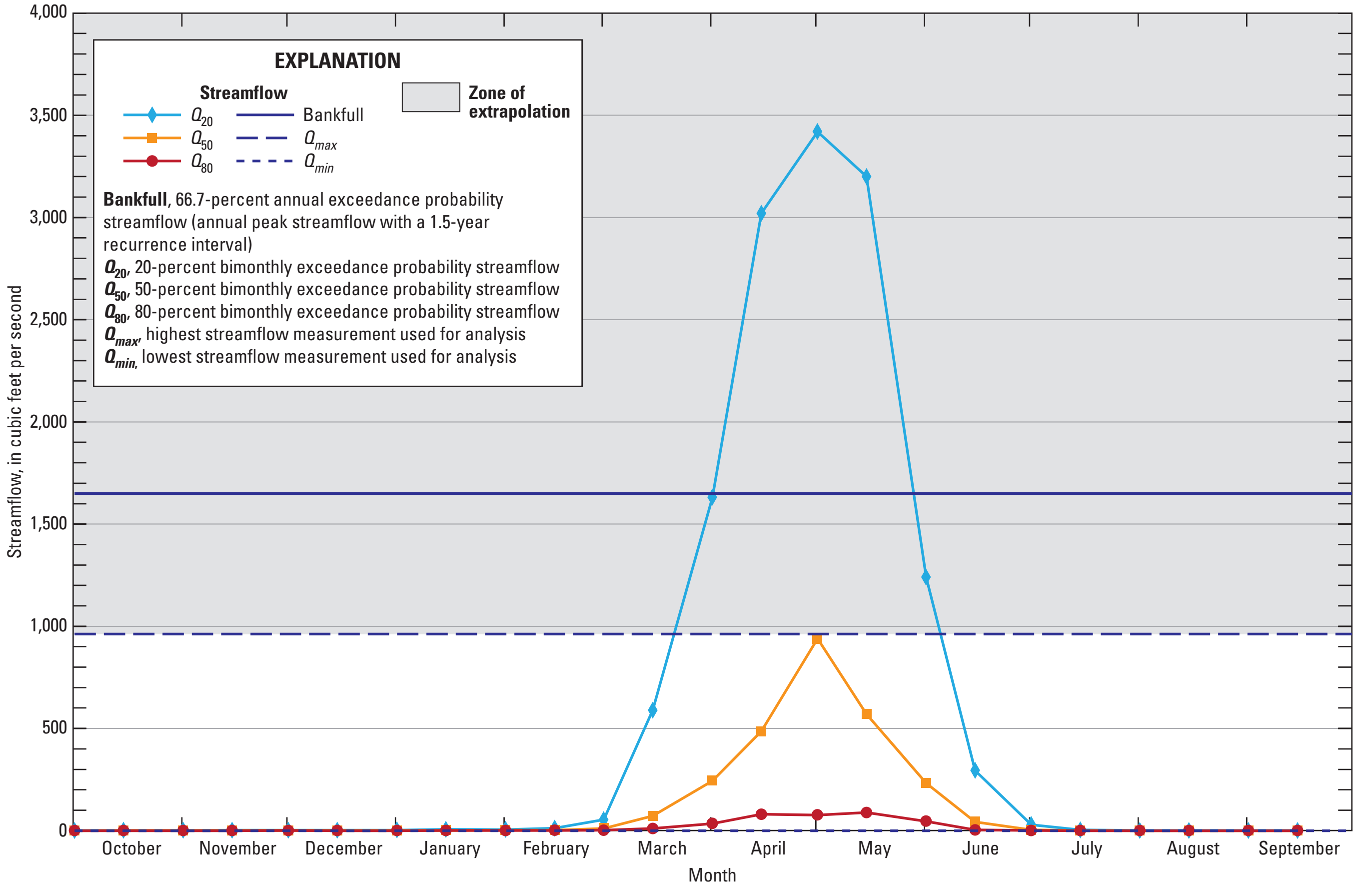

Figure C12. Bimonthly exceedance probability and bankfull streamflow statistics and zones of extrapolation above and below discrete streamflow measurements at Deep Creek above Mouth near Riddle, Idaho (USGS 13176305).

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For more information concerning the research in this report, contact the
Director, Idaho Water Science Center
U.S. Geological Survey
230 Collins Road
Boise, Idaho 83702
http://id.water.usgs.gov

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