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Estimation of Streamflow Characteristics for Charles M. Russell National Wildlife Refuge, Northeastern Montana

Scientific Investigations Report 2009–5009

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

Cover photograph: Hell Creek upstream from Hart Creek near Charles M. Russell National Wildlife Refuge. Photograph by Martha Kaufmann, World Wildlife Fund, taken June 2007. Published with permission by Martha Kaufmann.

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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	0.4047	hectare (ha)
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)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

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

$$°C=(°F-32)/1.8$$

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

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

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

Water year is the 12-month period from October 1 through September 30 of the following calendar year. The water year is designated by the calendar year in which it ends. For example, water year 2008 is the period from October 1, 2007, through September 30, 2008.

Acronyms

BLM	Bureau of Land Management
CMR	Charles M. Russell National Wildlife Refuge
EYR	equivalent years of record—the number of years of record at a gaged site that would be needed to provide the same reliability as the regression estimate
FWS	U.S. Fish and Wildlife Service
GIS	geographic information system
GLS	generalized least squares
NHDPlus	National Hydrography Dataset Plus
OLS	ordinary least squares

PK1.5	1.5-year recurrence interval peak flow
PK2	2-year recurrence interval peak flow
PK2.33	2.33-year recurrence interval peak flow
PKM	mean of annual peak flows for specified period of years
p-value	significance level or probability of obtaining a value of a test statistic at least as extreme as the one observed given that the null hypothesis is true
Q.90	90-percent exceedance streamflow
Q.80	80-percent exceedance streamflow
Q.50	50-percent exceedance streamflow
Q.20	20-percent exceedance streamflow
QM	mean streamflow
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAR	Regional Adjustment Relationship
SEE	average standard error of estimate (also sometimes referred to as the root mean square error or the standard deviation of the residuals)
SEP	average standard error of prediction
USGS	U.S. Geological Survey
WLS	weighted least squares

Definitions for Streamflow Terminology

annual mean streamflow	arithmetic mean of all daily mean streamflows for a single specified year
annual peak flow	maximum instantaneous streamflow that occurred during a single specified year
daily mean streamflow	mean streamflow for a single specified day
mean annual streamflow	arithmetic mean of all annual mean streamflows for the period of record or for a specific period of multiple years
mean daily streamflow	arithmetic mean of all daily mean streamflows for a specified day for the period of record or for a specific period of multiple years
mean monthly streamflow	arithmetic mean of all monthly mean streamflows for a specified month for the period of record or for a specific period of multiple years
mean peak flow	arithmetic mean of all annual peak flows for the period of record or for a specific period of multiple years
monthly mean streamflow	arithmetic mean of all daily mean streamflows for a single specified month in a single specified year
T-year peak flow	peak flow determined by statistical analysis of annual peak flows for the period of record or for a specific period of multiple years to occur on average once every *T* years

Estimation of Streamflow Characteristics for Charles M. Russell National Wildlife Refuge, Northeastern Montana

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Abstract

Charles M. Russell National Wildlife Refuge (CMR) encompasses about 1.1 million acres (including Fort Peck Reservoir on the Missouri River) in northeastern Montana. To ensure that sufficient streamflow remains in the tributary streams to maintain the riparian corridors, the U.S. Fish and Wildlife Service is negotiating water-rights issues with the Reserved Water Rights Compact Commission of Montana. The U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, conducted a study to gage, for a short period, selected streams that cross CMR, and analyze data to estimate long-term streamflow characteristics for CMR. The long-term streamflow characteristics of primary interest include the monthly and annual 90-, 80-, 50-, and 20-percent exceedance streamflows and mean streamflows (Q.90, Q.80, Q.50, Q.20, and QM, respectively), and the 1.5-, 2-, and 2.33-year peak flows (PK1.5, PK2, and PK2.33, respectively).

The Regional Adjustment Relationship (RAR) was investigated for estimating the monthly and annual Q.90, Q.80, Q.50, Q.20, and QM, and the PK1.5, PK2, and PK2.33 for the short-term CMR gaging stations (hereinafter referred to as CMR stations). The RAR was determined to provide acceptable results for estimating the long-term Q.90, Q.80, Q.50, Q.20, and QM on a monthly basis for the months of March through June, and also on an annual basis. For the months of September through January, the RAR regression equations did not provide acceptable results for any long-term streamflow characteristic. For the month of February, the RAR regression equations provided acceptable results for the long-term Q.50 and QM, but poor results for the long-term Q.90, Q.80, and Q.20. For the months of July and August, the RAR provided acceptable results for the long-term Q.50, Q.20, and QM, but poor results for the long-term Q.90 and Q.80. Estimation coefficients were developed for estimating the long-term streamflow characteristics for which the RAR did not provide acceptable results. The RAR also was determined to provide acceptable results for estimating the PK1.5., PK2, and PK2.33 for the three CMR stations that lacked suitable peak-flow records.

Methods for estimating streamflow characteristics at ungaged sites also were derived. Regression analyses that relate individual streamflow characteristics to various basin and climatic characteristics for gaging stations were performed to develop regression equations to estimate streamflow characteristics at ungaged sites. Final equations for the annual Q.50, Q.20, and QM are reported. Acceptable equations also were developed for estimating QM for the months of February, March, April, June, and July, and Q.50, Q.20, and QM on an annual basis. However, equations for QM for the months of February, March, April, June, and July were determined to be less consistent and reliable than the use of estimation coefficients applied to the regression equation results for the annual QM. Acceptable regression equations also were developed for the PK1.5, PK2, and PK2.33.

Introduction

Charles M. Russell National Wildlife Refuge (CMR) encompasses about 1.1 million acres (including Fort Peck Reservoir on the Missouri River) in northeastern Montana. CMR consists of rugged land bordering the Missouri River, generally termed the Missouri River Breaks. The Missouri River Breaks provides important habitat, including riparian corridors along Missouri River tributary streams, for numerous animals and plants in CMR. To ensure that sufficient streamflow remains in the tributary streams to maintain the riparian corridors, the U.S. Fish and Wildlife Service (FWS) is negotiating water-rights issues with the Reserved Water Rights Compact Commission of Montana. These negotiations require accurate information about current and long-term streamflow characteristics for Missouri River tributary streams that cross CMR. However, there is very little long-term streamflow data for these streams. Thus, the U.S. Geological Survey (USGS), in cooperation with the FWS, conducted a study to gage, for a short period, selected streams that cross CMR, and analyze data to estimate long-term streamflow characteristics for CMR.

Purpose and Scope

The purpose of this report is to describe methods to estimate streamflow characteristics for CMR. The report presents (1) methods and results of analyses to estimate long-term streamflow characteristics for short-term gaging stations and (2) methods and results of analyses to develop regional regression equations that estimate long-term streamflow characteristics at ungaged sites in or near CMR.

Acknowledgments

Special thanks are given to Patricia J. Fiedler, Danielle L. Kepford, and Megan A. Estep of the U.S. Fish and Wildlife Service for their support of this study. Technical reviews by Daniel G. Driscoll and Charles Parrett of the U.S. Geological survey are greatly appreciated.

Description of Study Area

The study area (fig. 1) is defined by the drainage boundary of the Missouri River between the points where the river enters and exits CMR; the study area does not include the drainage area of the Musselshell River upstream from where this river enters CMR. The study area encompasses about 8,260 mi^2 and includes parts of Fergus, Phillips, Petroleum, Garfield, Valley, McCone, Prairie, Custer, and Rosebud Counties in northeastern Montana.

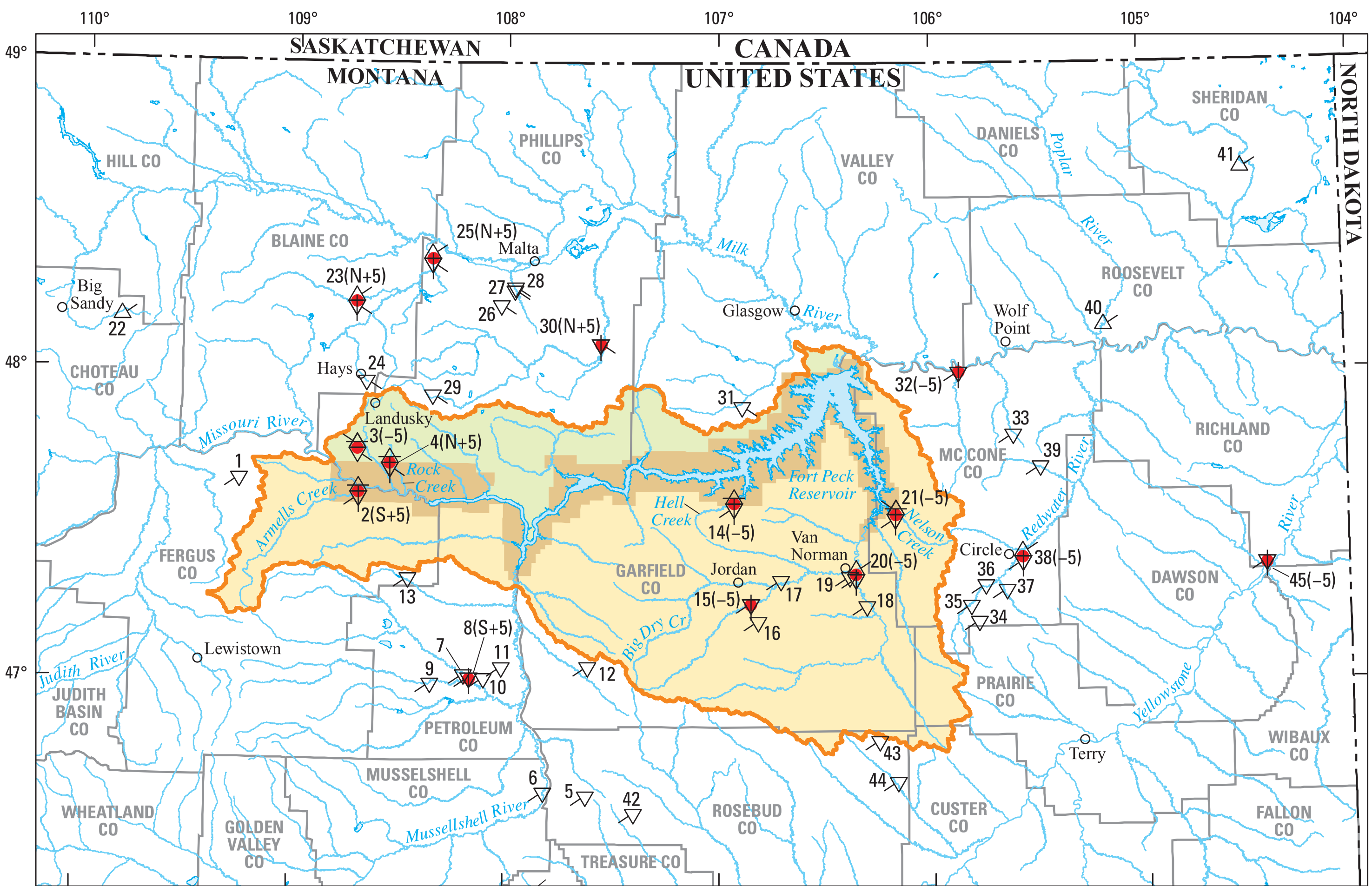
CMR (originally designated as the Fort Peck Game Range) was established by an executive order in 1936 that withdrew about 1.1 million acres (including the 245,000-acre Fort Peck Reservoir) from the public domain (U.S. Fish and Wildlife Service, 2006). Tributary streams that cross CMR that are of primary interest in this study are those identified by solid lines in the 1:100,000-scale National Hydrography Dataset (U.S. Geological Survey, 2007), but excluding the Musselshell River. The watersheds of these streams are within the Northwestern Great Plains and/or Northwestern Glaciated Plains ecoregions described by Woods and others (2002) and range in area from 58 to 2,830 mi^2. CMR itself is almost entirely within "river breaks" topography adjacent to major stream channels and characterized by very highly dissected terrain, steep slopes, erodible clayey soils, and high runoff potential.

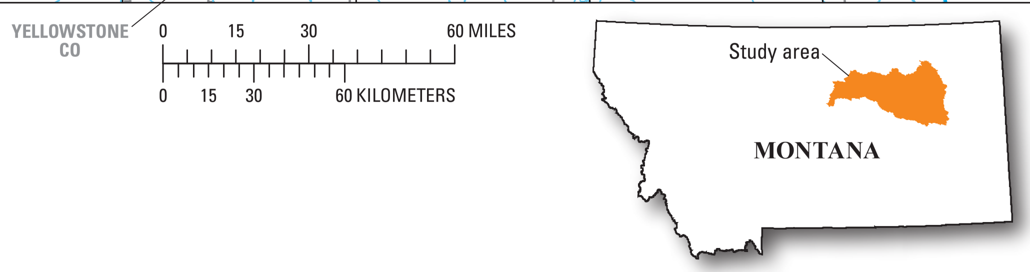
Predominant vegetation in CMR includes native grasses (including grama, needle grass, western wheatgrass, and buffalo grass), several shrub species (including sagebrush, greasewood, buffaloberry, and chokecherry), and coniferous trees (including juniper, ponderosa pine, and Douglas fir) that occur in scattered patches of woodland. Wildlife is abundant and includes mule and white-tailed deer, elk, bighorn sheep, antelope, coyote, bobcat, beaver, sharp-tailed and sage grouse, and numerous other species (U.S. Fish and Wildlife Service, 2006).

About 1,720 mi^2 of the 8,260 mi^2 study area lies within CMR where land use predominantly is shrub and mixed rangeland managed for wildlife habitat. Cattle grazing is allowed but is strictly regulated to prevent degradation of wildlife habitat. Land use for most of the study area outside of CMR is grazed grass, shrub, or mixed rangeland; relatively small areas are cropland, pasture, or mixed forest.

The geology of the study area is dominated by shale, siltstone, and sandstone. Most of the study area is underlain by the Tertiary Fort Union Formation and the Upper Cretaceous Hell Creek Formation, Fox Hills Sandstone, and Bearpaw Shale. The Fort Union Formation crops out over about 39 percent of the study area and consists of sandstone, siltstone, and shale interbedded with thick continuous coal beds (Frahme, 1979). The Hell Creek Formation crops out over about 20 percent of the study area and predominantly is soft claystone but varies in composition from shale to medium-grained sandstone and also has intermittent concretions (Jensen and Varnes, 1964). The Fox Hills Sandstone crops out over about 4 percent of the study area and ranges from soft claystone to fine sandstone. Cementation is variable but more pronounced in the upper part of this formation resulting in relatively erosion-resistant rimrock features (Jensen and Varnes, 1964) in some areas of exposure. The Bearpaw Shale crops out over about 33 percent of the study area and is dark grey marine shale with discontinuous interbedded silt and sand layers, and concretions (Jensen and Varnes, 1964). Where exposed at the surface, the Bearpaw Shale generally is highly erodible. The geologic characteristics of the study area contribute to the river breaks topography in areas where highly erodible shales occur at the surface and badlands topography in areas where materials with more variable erosive characteristics occur. Soil characteristics in the study area also are profoundly influenced by the bedrock from which the soils are derived. In general, soils within the study area are very fine grained (ranging from clays to silty clay loam) and poorly drained (Frahme, 1979).

The general climate of the study area is semiarid continental and characterized by relatively low precipitation, cold winters, hot summers, and extreme variations in both precipitation and temperatures. Monthly (1971–2000) precipitation and temperature characteristics for Jordan, Mont., located within the study area south of CMR (fig. 1) are presented in figure 2 (Western Regional Climate Center, 2006). Average annual temperature at Jordan is 44.0°F. On average, coldest temperatures occur in January (mean monthly temperature of 14.1°F) and warmest temperatures occur in July (mean monthly temperature of 71.4°F). Average annual precipitation is 12.9 in.; about 70 percent occurs as rainfall during the months of May through September, and about 50 percent occurs during May through July. Cooper and Jean (2001) noted that although precipitation decreases in late summer in the CMR area, July through September precipitation in the area averages about 0.5 to 1.0 in. more than sites in western Montana that have about the same average annual precipitation. They also indicated that convective thunderstorms generally account for more of the late summer precipitation than frontal systems.





Base map from U.S. Census Bureau TIGER digital data, 1993–2001, 1:100,000; Montana State Library, 2003, 1:100,000; and Montana Natural Heritage Program, 2002, 1:100,000
Albers Equal-Area Conic projection
Standard parallels 29°30′N and 45°30′N, central meridian 107°00′W
North American Datum of 1983 (NAD 83)

Note: Gaging stations not centered on stream lines are on small drainages with stream channels too short to be appropriately displayed at the map scale.

EXPLANATION

- Charles M. Russell National Wildlife Refuge (CMR)
- North Region of study area (includes parts of CMR)
- South Region of study area (includes parts of CMR)
- Study area boundary
- 41 Site number (see table 1)
- Gaging station used to develop estimation ratios for monthly streamflow characteristics for watersheds. N+5 in parentheses indicates station on the north side of the Missouri River with maximum elevation greater than about 5,000 feet above North American Vertical Datum of 1988 (NAVD 88); S+5 in parentheses indicates station on the south side of the Missouri River with maximum elevation greater than about 5,000 feet (above NAVD 88); –5 in parentheses indicates station with maximum elevation less than about 5,000 feet (above NAVD 88)
- Long-term gaging station used in regression analysis for estimation of peak-flow characteristics at ungaged sites (South Region)
- Long-term gaging station used in regression analysis for estimation of peak-flow characteristics at ungaged sites (North Region)
- Long-term continuous-record gaging station used in regression analysis for estimation of monthly and annual streamflow characteristics at ungaged sites
- Long-term gaging station used in Regional Adjustment Relationship analysis for estimation of peak-flow characteristics for short-term gaging stations
- Long-term continuous-record gaging station used in Regional Adjustment Relationship analysis for estimation of both monthly and annual streamflow characteristics for short-term gaging stations
- Short-term continuous-record gaging station on Charles M. Russell National Wildlife Refuge gaged during study period (2000–2004)

Figure 1. Locations of study area, gaging stations used in various analyses, and Charles M. Russell National Wildlife Refuge, northeastern Montana.

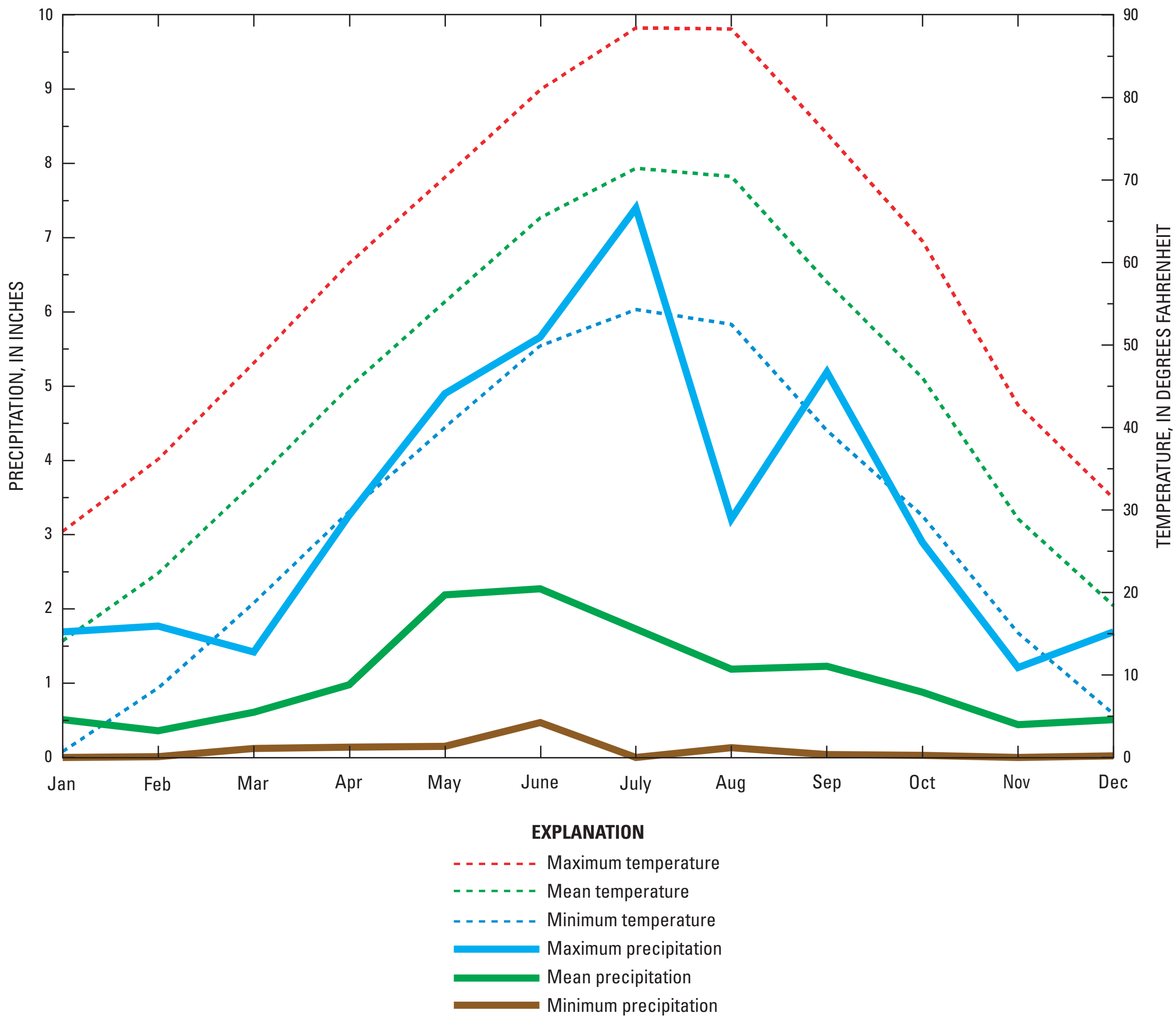


Figure 2. Monthly precipitation and temperature characteristics (1971–2000) for Jordan, Mont. Data from Western Regional Climate Center (2006).

Previous Studies

Omang and Parrett (1984) developed ordinary least squares (OLS) regression equations that relate mean annual streamflow to various basin and climatic characteristics for estimating mean annual streamflow at ungaged sites in central and eastern Montana. These regression equations covered a larger area than the study area of this report, used streamflow data through water year 1982, and were developed by using manually determined basin characteristics. Omang and Parrett (1984) described the reliability of the regression equations that they developed by using the average standard error of estimate (SEE, also referred to as the root mean square error or the standard deviation of the residuals). The SEE is a measure of the overall reliability of regression equations, and smaller values of SEE generally indicate better reliability of regression equations than do larger values. The study area described in this report falls within two regions defined in Omang and Parrett (1984): Region 1 (north of the Missouri River) and Region 2 (south of the Missouri River). For Region 1, Omang and Parrett (1984) considered 17 gaging stations and developed a regression equation for mean annual streamflow with an SEE of 31 percent. For Region 2, Omang and Parrett (1984) considered 27 gaging stations and developed a three-variable regression equation for mean annual streamflow with an SEE of 51 percent, a two-variable regression equation with an SEE of 62 percent, and a 1-variable equation with an SEE of 64 percent. The regression equations developed by Omang and Parrett (1984) require manual determination of basin characteristics (which is labor intensive), were developed from data only through water year 1982, and did not specifically address streams in CMR. Thus, the methods described in the following sections of this report are more conveniently applied and are considered to provide more consistent and reliable results than the methods described by Omang and Parrett (1984).

Parrett and Johnson (2003) developed generalized least squares (GLS) regression equations that relate peak-flow characteristics to various basin and climatic characteristics for estimating peak flows having recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years (*T*-year peak flows) at ungaged sites for all of Montana. Methods for estimating only the 2-year peak flow are most relevant to the specific objectives of this study of streamflow characteristics for CMR. The Parrett and Johnson (2003) regression equations covered a larger area than the study area of this report, used streamflow data through water year 1998, and were developed by using manually determined basin characteristics. Parrett and Johnson (2003) described the reliability of the regression equations that they developed by using the average standard error of prediction (SEP), which generally is similar to the SEE. However, the SEP incorporates time-sampling error (accounted for in the more rigorous GLS regression), which is not incorporated in the SEE. Smaller values of SEP generally indicate better reliability of regression equations than do larger values. The study area described in this report falls within two regions defined in Parrett and Johnson (2003): Northeast Plains Region and East-Central Plains Region. For the Northeast Plains Region, Parrett and Johnson (2003) considered 57 gaging stations and developed a regression equation for the 2-year peak flow with an average SEP of 91.0 percent. For the East-Central Plains Region, Parrett and Johnson (2003) considered 85 gaging stations and developed a regression equation for the 2-year peak flow with an average SEP of 99.9 percent. The regression equations developed by Parrett and Johnson (2003) require manual determination of basin characteristics (which is labor intensive), were developed from data only through water year 1998, and did not specifically address streams in CMR. Thus, the methods described in the following sections of this report are more conveniently applied and are considered to provide more consistent and reliable results than the methods described by Parrett and Johnson (2003).

Estimation of Streamflow Characteristics

To address the need for streamflow information in CMR, a three-phased approach was used that involved (1) collecting continuous records of daily mean streamflow for a 5-year period (water years 2000–2004, hereinafter referred to as the study period) for five streams that cross CMR, (2) estimating long-term streamflow characteristics for the five gaging stations by using relations between study-period streamflow characteristics and long-term streamflow characteristics for nearby long-term gaging stations to adjust recorded study-period streamflow characteristics, and (3) developing regional regression equations to relate streamflow characteristics to basin characteristics. The long-term streamflow characteristics of primary interest include the monthly and annual 90-, 80-, 50-, and 20-percent exceedance streamflows and mean streamflows (Q.90, Q.80, Q.50, Q.20, and QM, respectively), and the 1.5-, 2-, and 2.33-year peak flows (PK1.5, PK2, and PK2.33, respectively). Q.50 is equivalent to the long-term median streamflow.

Estimates of Monthly and Annual Streamflow Characteristics for Short-Term Gaging Stations

Five continuous-record gaging stations were installed on five tributaries to the Missouri River that cross CMR (sites 2, 3, 4, 14, and 21; table 1 and fig. 1). The gaging stations were installed between November 1999 and February 2000 and were operated through September 2004. Procedures used for measuring streamflow and operating the gaging stations are described by Rantz and others (1982).

The 5-year period during which the CMR streams were gaged was characterized by unusually dry conditions. Streamflow records for long-term gaging stations in or near CMR show that, on a regional basis, annual mean streamflows during the study period were among the lowest for any consecutive 5-year period since the start of streamflow-record collection (fig. 3). The very low streamflows that occurred during the study period complicated the use of typical procedures for estimating long-term streamflow characteristics by using short-term streamflow records. During the study period, variability in streamflow was much less than average and for months that typically have low streamflows (that is, September through January), streamflows for the gaged CMR streams generally were extremely low or equal to zero. Some methods for extending streamflow characteristics for short-term gaging stations (for example, the mixed-station procedure described by Alley and Burns, 1983) use correlation between concurrent streamflows of the short-term gaging stations and nearby long-term gaging stations that are hydrologically similar. Use of concurrent-correlation methods were investigated but were found to perform poorly because the small streamflow variability during the study period resulted in poor correlations between streamflows of the short-term gaging stations and those of the long-term gaging stations. Concurrent-correlation methods might have performed acceptably if more typical streamflow conditions had occurred during the study period.

The Regional Adjustment Relationship (RAR; Bakke and others, 1999) provides an alternative to concurrent-correlation methods. The conceptual basis of the RAR is that at individual stream sites the correlation between a streamflow characteristic for a short period of record and long-term streamflow characteristics is consistent over a somewhat broad and climatically homogeneous region. OLS regressions are used to relate a streamflow characteristic for the short-term period to long-term streamflow characteristics for many long-term

Table 1. Site information for selected gaging stations, northeastern Montana.

[Abbreviations: CMRG, short-term gaging station in or near Charles M. Russell National Wildlife Refuge operated during study period (water years 2000–2004); ERAT1, gaging station used for developing monthly estimation coefficients for watersheds with maximum elevations less than about 5,000 feet (above the North American Vertical Datum of 1988); ERAT2, gaging station used for developing monthly estimation coefficients for watersheds south of the Missouri River with maximum elevations greater than about 5,000 feet; ERAT3, gaging station used for developing monthly estimation coefficients for watersheds north of the Missouri River with maximum elevations greater than about 5,000 feet; RAR1, long-term index gaging station used in Regional Adjustment Relationship for estimating long-term monthly and annual streamflow characteristics for short-term gaging stations; RAR2, long-term index gaging station used in Regional Adjustment Relationship for estimating peak-flow characteristics for short-term gaging stations; REGR1, gaging station used for developing regression equations for estimating long-term monthly and annual streamflow characteristics for ungaged sites on the basis of basin characteristics; REGR2N, gaging station used for developing regression equations for estimating peak-flow characteristics for ungaged sites on the basis of basin characteristics in North Region; REGR2S, gaging station used for developing regression equations for estimating peak-flow characteristics for ungaged sites on the basis of basin characteristics in South Region. Symbol: --, no data]

Site number (fig. 1)	Station number	Station name	Type of gaging station or use of gaging-station records	Drainage area, in square miles	Period of daily mean streamflow records through 2005, water years	Period of annual peak-flow records through 2005, water years
1	06114900	Taffy Creek tributary near Winifred	REGR2S	3.0	--	1974–2002
2	06115270	Armells Creek near Landusky	CMRG, ERAT2, REGR1, REGR2S	397	2000–2004	2000–2004
3	06115300	Duval Creek near Landusky	CMRG, RAR2, ERAT1, REGR2N	3.3	2000–2004	1963–2005
4	06115350	Rock Creek near Landusky	CMRG, ERAT3, REGR1, REGR2N	75	2000–2004	2000–2004
5	06127520	Home Creek near Sumatra	REGR2S	2.0	--	1973–2005
6	06127570	Butts Coulee near Melstone	REGR2S	6.7	--	1963–2005
7	06128900	Box Elder Creek tributary near Winnett	REGR2S	16	--	1955–73
8	06129000	Box Elder Creek near Winnett	ERAT2, REGR1, REGR2S	684	1930–33, 1934–36, 1958–72	1931–32, 1934–38, 1959–65, 1967–71, 1978
9	06129500	McDonald Creek at Winnett	REGR2S	421	1930–32, 1934–45, 1953–56	1931–32, 1934–45, 1953–73, 1975
10	06129700	Gorman Coulee near Cat Creek	REGR2S	2.3	--	1955–59, 1962–73, 1977, 1980, 1991–2005
11	06130600	Cat Creek near Cat Creek	REGR2S	37	--	1958–73, 1977, 1980
12	06130610	Bair Coulee near Mosby	REGR2S	1.8	--	1974–2005
13	06130620	Blood Creek tributary near Valentine	REGR2S	2.0	--	1974–2005
14	06130650	Hell Creek near Jordan	CMRG, ERAT1, REGR1, REGR2S	71	2000–2004	2000–2004
15	06130700	Sand Creek near Jordan	ERAT1, REGR1, REGR2S	317	1957–67	1958–67, 1986
16	06130850	Second Creek tributary No. 2 near Jordan	REGR2S	2.1	--	1958–90
17	06130915	Russian Coulee near Jordan	REGR2S	3.5	--	1974–2005

Table 1. Site information for selected gaging stations, northeastern Montana.—Continued

[Abbreviations: CMRG, short-term gaging station in or near Charles M. Russell National Wildlife Refuge operated during study period (water years 2000–2004); ERAT1, gaging station used for developing monthly estimation coefficients for watersheds with maximum elevations less than about 5,000 feet (above the North American Vertical Datum of 1988); ERAT2, gaging station used for developing monthly estimation coefficients for watersheds south of the Missouri River with maximum elevations greater than about 5,000 feet; ERAT3, gaging station used for developing monthly estimation coefficients for watersheds north of the Missouri River with maximum elevations greater than about 5,000 feet; RAR1, long-term index gaging station used in Regional Adjustment Relationship for estimating long-term monthly and annual streamflow characteristics for short-term gaging stations; RAR2, long-term index gaging station used in Regional Adjustment Relationship for estimating peak-flow characteristics for short-term gaging stations; REGR1, gaging station used for developing regression equations for estimating long-term monthly and annual streamflow characteristics for ungaged sites on the basis of basin characteristics; REGR2N, gaging station used for developing regression equations for estimating peak-flow characteristics for ungaged sites on the basis of basin characteristics in North Region; REGR2S, gaging station used for developing regression equations for estimating peak-flow characteristics for ungaged sites on the basis of basin characteristics in South Region. Symbol: --, no data]

Site number (fig. 1)	Station number	Station name	Type of gaging station or use of gaging-station records	Drainage area, in square miles	Period of daily mean streamflow records through 2005, water years	Period of annual peak-flow records through 2005, water years
18	06130940	Spring Creek tributary near Van Norman	REGR2S	1.4	--	1974–2005
19	06130950	Little Dry Creek near Van Norman	REGR2S	1,224	1980	1958–75, 1986, 1995
20	06131000	Big Dry Creek near Van Norman	RAR1, RAR2, , ERAT1, REGR1, REGR2S	2,554	1939–2005	1940–2005
21	06131200	Nelson Creek near Van Norman	CMRG, RAR2, ERAT1, REGR1, REGR2S	100	1976–85, 2000–2004	1976–85, 1991, 2000–2005
22	06137400	Big Sandy Creek at reservation boundary, near Rocky Boy	RAR1, RAR2	25	1982–2005	1982–2005
23	06154400	Peoples Creek near Hays	RAR1, RAR2, , ERAT3, REGR1, REGR2N	220	1966–2005	1967–2005
24	06154410	Little Peoples Creek near Hays	REGR2N	13	1973–2005	1973–2005
25	06154550	Peoples Creek below Kuhr Coulee, near Dodson	RAR1, RAR2, ERAT3, REGR1, REGR2N	675	1951–73, 1982–2005	1952–66, 1968–73, 1982–2005
26	06155100	Black Coulee near Malta	REGR2N	6.6	--	1956–67, 1986
27	06155200	Alkali Creek near Malta	REGR2N	162	--	1956–59, 1961–73, 1986
28	06155300	Disjardin Coulee near Malta	REGR2N	4.8	--	1956–2002
29	06164600	Beaver Creek tributary near Zortman	REGR2N	3.9	--	1974–2005
30	06164800	Beaver Creek above Dix Creek, near Malta	ERAT3, REGR1, REGR2N	929	1967–69, 1976–82	1967–69, 1974, 1976–82, 1986
31	06173300	Willow Creek tributary near Fort Peck	REGR2N	.9	--	1972, 1974–91
32	06175540	Prairie Elk Creek near Oswego	ERAT1, REGR1, REGR2S	352	1975–85	1976–85
33	06175550	East Fork Sand Creek near Vida	REGR2S	8.5	--	1963–77
34	06177050	East Fork Duck Creek near Brockway	REGR2S	12	--	1955–2002
35	06177100	Duck Creek near Brockway	REGR2S	54	--	1957–73

Table 1. Site information for selected gaging stations, northeastern Montana.—Continued

[Abbreviations: CMRG, short-term gaging station in or near Charles M. Russell National Wildlife Refuge operated during study period (water years 2000–2004); ERAT1, gaging station used for developing monthly estimation coefficients for watersheds with maximum elevations less than about 5,000 feet (above the North American Vertical Datum of 1988); ERAT2, gaging station used for developing monthly estimation coefficients for watersheds south of the Missouri River with maximum elevations greater than about 5,000 feet; ERAT3, gaging station used for developing monthly estimation coefficients for watersheds north of the Missouri River with maximum elevations greater than about 5,000 feet; RAR1, long-term index gaging station used in Regional Adjustment Relationship for estimating long-term monthly and annual streamflow characteristics for short-term gaging stations; RAR2, long-term index gaging station used in Regional Adjustment Relationship for estimating peak-flow characteristics for short-term gaging stations; REGR1, gaging station used for developing regression equations for estimating long-term monthly and annual streamflow characteristics for ungaged sites on the basis of basin characteristics; REGR2N, gaging station used for developing regression equations for estimating peak-flow characteristics for ungaged sites on the basis of basin characteristics in North Region; REGR2S, gaging station used for developing regression equations for estimating peak-flow characteristics for ungaged sites on the basis of basin characteristics in South Region. Symbol: --, no data]

Site number (fig. 1)	Station number	Station name	Type of gaging station or use of gaging-station records	Drainage area, in square miles	Period of daily mean streamflow records through 2005, water years	Period of annual peak-flow records through 2005, water years
36	06177150	Redwater River at Brockway	REGR2S	216	--	1957–73, 1986
37	06177200	Tusler Creek near Brockway	REGR2S	90	--	1957–72
38	06177500	Redwater River at Circle	RAR1, RAR2, ERAT1, REGR1, REGR2S	547	1937–72, 1974–2004	1929–30, 1932–72, 1975–2004
39	06177700	Cow Creek tributary near Vida	REGR2S	1.7	1982–85	1963–2005
40	06181000	Poplar River near Poplar	RAR1, RAR2	3,174	1908–24, 1947–69, 1975–79, 1982–2005	1909, 1915, 1921, 1923, 1946, 1948–63, 1965–69, 1975–79, 1982–2005
41	06183450	Big Muddy Creek near Antelope	RAR1, RAR2	967	1979–2005	1979–2005
42	06294900	Middle Fork Froze to Death Creek tributary near Ingomar	REGR2S	1.4	--	1962–76
43	06309020	Rock Springs Creek tributary at Rock Springs	REGR2S	1.0	--	1963–78, 1987
44	06309040	Dry House Creek near Angela	REGR2S	39	--	1963–77, 1987
45	06329200	Burns Creek near Savage	ERAT1, REGR1, REGR2S	233	1958–67, 1975–84, 1986	1958–67, 1975–84, 1986

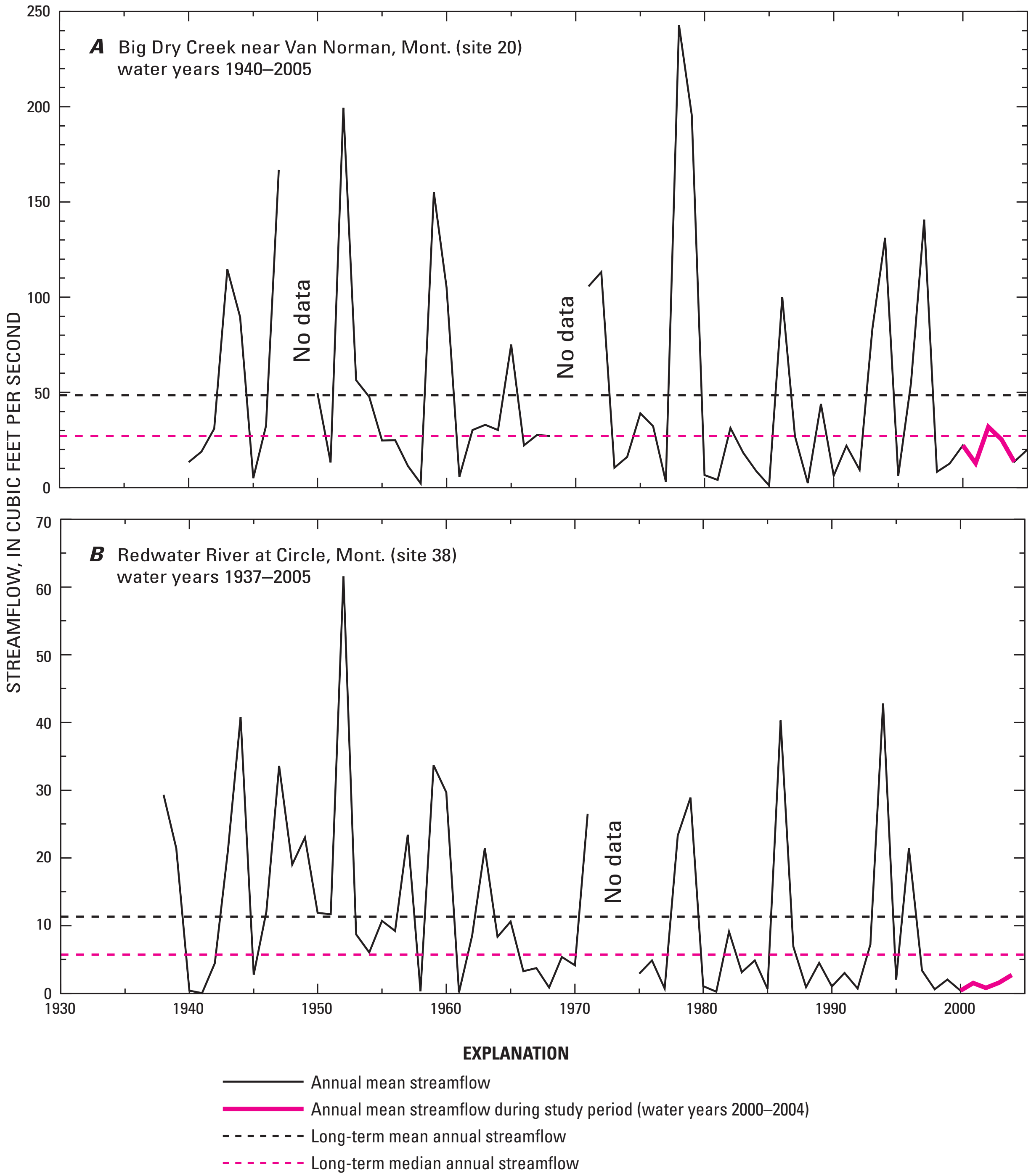


Figure 3. Annual mean streamflow for selected gaging stations. *A*, Big Dry Creek near Van Norman, Mont.; *B*, Redwater River at Circle, Mont.

index gaging stations (hereinafter referred to as index stations) within the defined region.

Selection of appropriate index stations for estimating regional streamflow relations is critical to application of the RAR. Bakke and others (1999) specify that index stations need to (1) be active during an appropriate long-term period and also active during the short-term period of interest, (2) not be substantially affected by regulation or diversions, (3) not have a substantial number of missing-value or zero-streamflow days, and (4) have a range in drainage areas that span the range of drainage areas for which estimation is needed.

Seven index stations (sites 20, 22, 23, 25, 38, 40, and 41; table 1 and fig. 1) were selected for use in estimating streamflow characteristics for the short-term CMR gaging stations (hereinafter referred to as CMR stations). The selected index stations generally are close to CMR and have more than 20 years of continuous streamflow records. The criteria specified by Bakke and others (1999) for selection of index stations generally were followed with the exception of the requirements that the index stations should not have a substantial number of zero-streamflow days and that the drainage areas span the range of drainage areas for which estimation are needed.

Zero streamflow is not unusual during the low-streamflow months of September through January for all but the largest Missouri River tributaries draining the northeastern plains of Montana. Thus, application of the RAR for low-streamflow months is not possible if index stations that have a substantial number of zero-streamflow days are excluded. The RAR originally was developed for application in southern Oregon where zero streamflows are uncommon and excluding candidate index stations on the basis of occurrence of zero streamflows would not substantially affect the accuracy of the results. However, excluding index stations on the basis of occurrence of zero streamflows would be inappropriate when applying the RAR to CMR. Inclusion of zero streamflows in the RAR poses problems because streamflow data are transformed to base-10 logarithms prior to performing regression analyses. For this study, any streamflow characteristic that was less than 0.01 ft^3/s was assigned a value of 0.01 ft^3/s.

The requirement that the drainage areas of the index stations span the range of drainage areas for which estimation are needed also was not strictly adhered to. Drainage areas for four of the five CMR stations are within the range of drainage areas for the index stations. However, one of the CMR stations (site 3; Duval Creek near Landusky; drainage area of 3.3 mi^2) has a drainage area that is smaller than the range for the index stations (25 to 3,174 mi^2). Thus, it was necessary to extrapolate below the range of drainage areas of the index stations to provide estimates of streamflow characteristics for site 3 (table 1 and fig. 1). Therefore, estimates of streamflow characteristics for this gaging station need to be used with caution.

For the CMR stations, the RAR was investigated for estimating the long-term Q.90, Q.80, Q.50, Q.20, and QM on a monthly basis and also on an annual basis. On a monthly basis, the RAR was applied by performing OLS regressions relating the long-term monthly characteristics of the index stations (dependent variables) to the study period mean monthly streamflows of the index stations (explanatory variables) for each streamflow characteristic and each month. All data were transformed to base-10 logarithms prior to analysis. For some months, improved regression results for a given month were obtained by averaging the study period mean monthly streamflows for the given month with those for the previous and/or following month(s). On an annual basis, the RAR was applied by performing OLS regressions relating each of the long-term annual characteristics of the index stations (dependent variables) to the study period mean annual streamflows of the index stations (explanatory variables). Study-period and long-term monthly and annual streamflow characteristics for the index stations used in the RAR are presented in Supplement 1 (at the back of this report).

The RAR regression results were reviewed for outliers, leverage, influence, distribution of residuals (that is, the differences between streamflow characteristics estimated by using regression-equations and streamflow characteristics estimated by using recorded streamflow data), and overall statistical significance (by using methods described by Helsel and Hirsch, 2002, pp. 228–251), and also evaluated for suitability for producing reliable estimates on the basis of the SEE. For some datasets, a regression equation can have a relatively high level of overall significance (that is, a low probability that the linear relation occurred by chance) but may not yield reliable results because of a large SEE. Strict guidelines for determining suitability of regression equations for producing reliable streamflow estimates are not well documented. Previous studies using regression methods for estimating various streamflow characteristics in northeastern Montana have reported values of SEE or SEP ranging from about 31 to 130 percent (Omang and Parrett, 1984; Parrett and others, 1989; Parrett and Johnson, 2003). For this study, the regression equations developed by using the RAR were determined to provide acceptable results when (1) the regression relations were not substantially affected by outliers, high-leverage values, high-influence values or non-normally distributed residuals; (2) the overall statistical significance exceeded about 95 percent (that is, the p-value was less than about 0.05); and (3) the SEE was less than about 125 percent. The median SEE for the RAR regression equations was 51.6 percent. Values of SEE ranged from 29.6 to 122.6 percent (table 2).

For the CMR stations, the RAR regression equations were determined to provide acceptable results for estimating the long-term Q.90, Q.80, Q.50, Q.20, and QM on a monthly basis for the months of March through June, and also on an annual basis. For the months of September through January, the RAR regression equations did not provide acceptable results for any long-term streamflow characteristic. For the month of February, the RAR regression equations provided acceptable results for the long-term Q.50 and QM but poor results for the long-term Q.90, Q.80, and Q.20. For the months of July and August, the RAR provided acceptable results for the long-term Q.50, Q.20, and QM but poor results for the

Table 2. Regression equations used to estimate long-term monthly and annual streamflow characteristics for the short-term gaging stations.

[Equations were developed by using the Regional Adjustment Relationship. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow; RBCF, retransformation bias-correction factor; p-value, significance level; R^2, coefficient of determination; SEE, average standard error of estimate (in percent). Symbol: <, less than]

Long-term streamflow characteristic	Equation	RBCF	R^2	SEE	p-value
February Q.50	= 3.0 $QM(study\ period,\ February)^{0.40}$	1.04	0.48	81.5	0.083
February QM	= 4.2 $QM(study\ period,\ February/March)^{0.51}$	1.03	.58	72.9	.047
March Q.90	= 0.27 $QM(study\ period,\ March)^{0.73}$	1.04	.71	85.9	.018
March Q.80	= 0.75 $QM(study\ period,\ March)^{0.63}$	1.02	.75	62.8	.012
March Q.50	= 2.4 $QM(study\ period,\ March)^{0.69}$	1.01	.92	33.4	<.001
March Q.20	= 3.8 $QM(study\ period,\ March)^{0.93}$	1.03	.85	68.3	.003
March QM	= 3.6 $QM(study\ period,\ March)^{0.86}$	1.03	.83	66.5	.004
April Q.90	= 0.47 $QM(study\ period,\ April/May)^{1.0}$	1.01	.95	41.0	<.001
April Q.80	= 0.80 $QM(study\ period,\ April/May)^{0.95}$	1.01	.97	29.6	<.001
April Q.50	= 2.9 $QM(study\ period,\ April/May)^{0.85}$	1.01	.94	40.8	<.001
April Q.20	= 2.8 $QM(study\ period,\ March/April/May)^{0.97}$	1.03	.83	74.7	.004
April QM	= 2.8 $QM(study\ period,\ March/April/May)^{1.0}$	1.01	.94	39.0	<.001
May Q.90	= 0.28 $QM(study\ period,\ May)^{1.0}$	1.03	.85	88.9	.003
May Q.80	= 0.78 $QM(study\ period,\ May)^{0.86}$	1.01	.95	37.3	<.001
May Q.50	= 2.5 $QM(study\ period,\ May)^{0.73}$	1.01	.95	31.7	<.001
May Q.20	= 8.0 $QM(study\ period,\ May)^{0.64}$	1.01	.89	41.1	.001
May QM	= 7.8 $QM(study\ period,\ May)^{0.58}$	1.02	.77	63.7	.010
June Q.90	= 0.24 $QM(study\ period,\ May/June)^{0.77}$	1.03	.83	74.3	.004
June Q.80	= 0.52 $QM(study\ period,\ May/June)^{0.69}$	1.03	.79	78.1	.008
June Q.50	= 3.1 $QM(study\ period,\ May/June)^{0.56}$	1.02	.80	57.3	.007
June Q.20	= 21 $QM(study\ period,\ May/June)^{0.33}$	1.01	.69	44.6	.021
June QM	= 14 $QM(study\ period,\ May/June)^{0.31}$	1.02	.60	51.6	.040
July Q.50	= 0.75 $QM(study\ period,\ June/July)^{0.86}$	1.04	.81	95.3	.006
July Q.20	= 9.5 $QM(study\ period,\ June/July)^{0.47}$	1.01	.83	41.4	.004
July QM	= 7.7 $QM(study\ period,\ June/July)^{0.43}$	1.01	.88	31.0	.002
August Q.50	= 0.93 $QM(study\ period,\ August/September)^{1.0}$	1.06	.84	122.6	.004
August Q.20	= 5.5 $QM(study\ period,\ August/September)^{0.51}$	1.02	.82	54.6	.005
August QM	= 5.4 $QM(study\ period,\ August/September)^{0.46}$	1.01	.83	48.0	.005
Annual Q.90	= 0.55 $QM(study\ period,\ annual)^{0.90}$	1.01	.90	49.0	.001
Annual Q.80	= 1.0 $QM(study\ period,\ annual)^{0.82}$	1.01	.93	34.5	<.001
Annual Q.50	= 3.2 $QM(study\ period,\ annual)^{0.71}$	1.01	.93	31.0	<.001
Annual Q.20	= 11 $QM(study\ period,\ annual)^{0.61}$	1.02	.74	60.3	.013
Annual QM	= 6.1 $QM(study\ period,\ annual)^{0.64}$	1.01	.85	43.3	.003

long-term Q.90 and Q.80. RAR regression equations for long-term streamflow characteristics that had acceptable results are presented in table 2. Use of regression analysis on log-transformed data has been shown to result in systematic bias when the results are retransformed from log units to the original arithmetic units (Koch and Smillie, 1986). To compensate for this bias, retransformed results were multiplied by a nonparametric retransformation bias-correction factor (Duan, 1983) that is shown in table 2. Example plots that illustrate the regression relations used for estimating long-term annual 50-percent exceedance (median) and mean annual streamflows are presented in figure 4.

Estimation coefficients were developed for estimating the long-term streamflow characteristics for the CMR stations for the months that the RAR did not provide acceptable results. These coefficients were developed by using continuous streamflow records from streams in the study area or in nearby watersheds that generally are hydrologically similar to the streams that cross CMR. The estimation coefficients were determined by calculating the ratio of a given streamflow characteristic to the mean annual streamflow. Estimation coefficients were developed for three types of watersheds: (1) watersheds with maximum elevations less than about 5,000 ft (above NAVD 88); (2) watersheds on the south side of the Missouri River with maximum elevations greater than about 5,000 ft; and (3) watersheds on the north side of the Missouri River with maximum elevations greater than about 5,000 ft. Streamflow data for selected gaging stations (indicated in table 1 and fig. 1) in watersheds that met the criteria for each watershed type were analyzed to determine the ratio of each streamflow characteristic to the mean annual streamflow for each selected gaging station. Estimation coefficients for each watershed type and each streamflow characteristic (table 3) were calculated by determining the weighted average (weighting based on number of years of record) of the ratios of all the selected gaging stations for a given watershed type. Although the estimation coefficients were used only to estimate long-term streamflow characteristics for months that the RAR did not provide acceptable results, estimation coefficients for all streamflow characteristics and all months are presented in table 3 for informational purposes.

Actual study-period monthly and annual streamflow characteristics (calculated by using recorded data) and estimated long-term monthly and annual streamflow characteristics (determined by using the RAR and estimation coefficients) for the CMR stations are presented in table 4. Example plots showing the actual study period and the estimated long-term median and mean monthly streamflows for the CMR stations are presented in figure 5. Example plots showing the actual study period and the actual long-term median and mean monthly streamflows for selected index stations are presented in figure 6. The relations between the actual study period and estimated long-term streamflow characteristics for the CMR stations (fig. 5) generally are similar to the relations between the actual study period and actual long-term streamflow characteristics for the index stations (fig. 6). Streams in the northeastern plains of Montana generally are characterized by higher streamflows during February through August and lower streamflows during September through January. For most of the index stations, March and April, when most snowmelt runoff typically occurs in northeastern Montana, have the highest mean monthly streamflow. Spring rainstorms also contribute to higher streamflows in March and April. Mean monthly streamflow for February typically is larger than late fall and early winter streamflows, indicating that during some years snowmelt begins in February. Some of the index stations show a mid-spring (about April or May) decrease in streamflow following completion of snowmelt at lower elevations. Late spring and summer rainstorms can increase streamflow during the months of June and July. Streamflows then generally decrease from August through the fall. The estimated long-term streamflow characteristics for the CMR stations generally indicate similar annual streamflow patterns to those of the index stations.

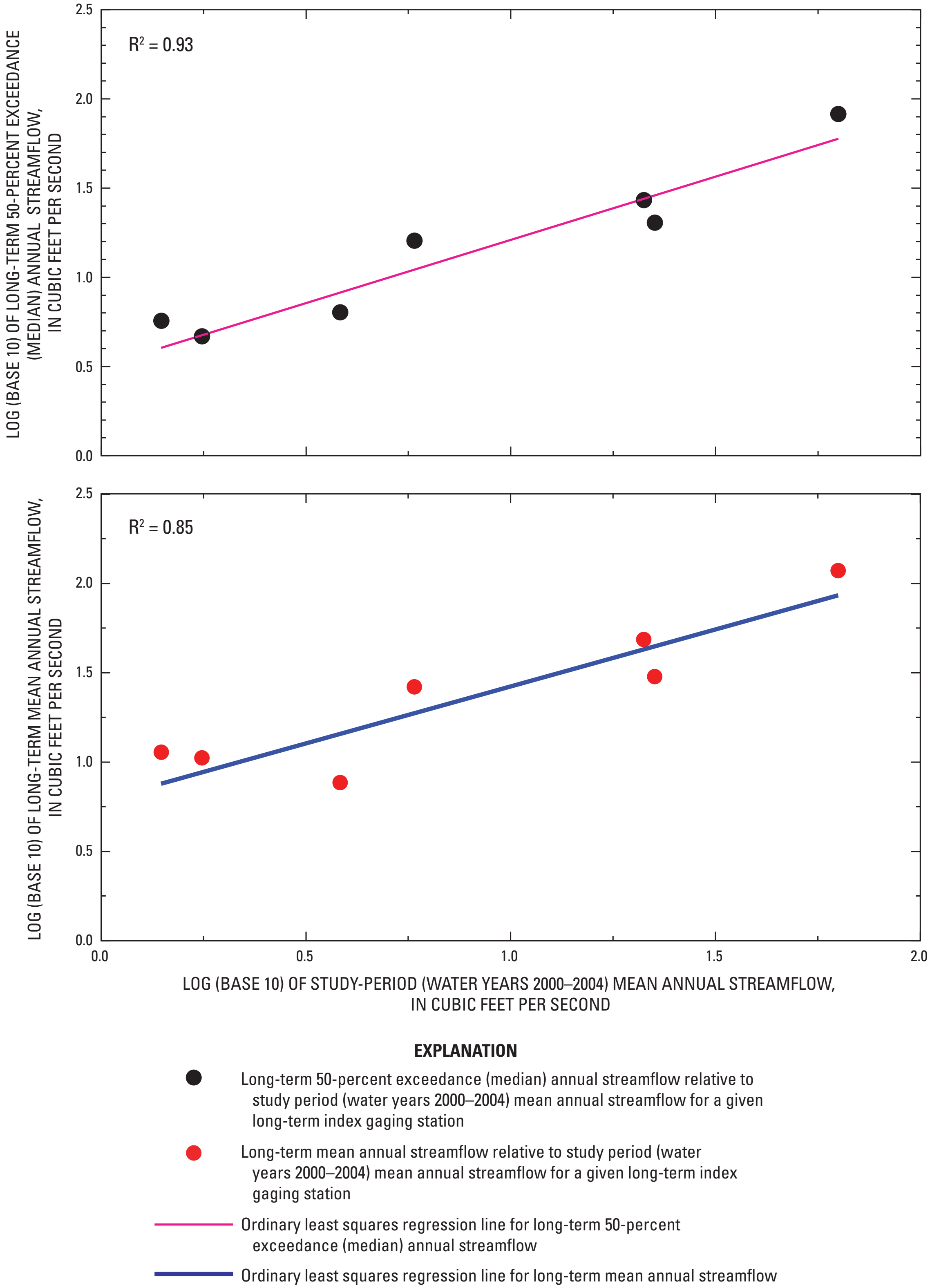


Figure 4. Regional Adjustment Relationship regression relations used to estimate the long-term 50-percent exceedance (median) and mean annual streamflows for the short-term gaging stations.

Table 3. Estimation coefficients used to estimate long-term streamflow characteristics.

[Coefficients were developed to estimate streamflow characteristics when regression-based methods were determined to be inappropriate. Elevation information is referenced to the North American Vertical Datum of 1988. Multiply estimation coefficient by long-term mean annual streamflow to obtain indicated streamflow characteristic. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Long-term streamflow characteristic	Estimation coefficient for indicated characteristic												
	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Watersheds with maximum elevations less than about 5,000 feet													
Q.90	0.004	0.010	0.004	0.001	0.002	0.097	0.074	0.035	0.059	0.018	0.003	0.000	0.135
Q.80	.008	.015	.009	.003	.010	.186	.110	.063	.082	.038	.005	.002	.191
Q.50	.035	.031	.024	.013	.083	1.361	.278	.210	.309	.167	.043	.017	.589
Q.20	.094	.068	.048	.070	1.801	8.216	1.079	.677	1.335	1.145	.320	.083	1.705
QM	.089	.052	.047	.089	1.378	5.470	1.632	.562	1.171	.937	.295	.289	1.000
Watersheds south of the Missouri River with maximum elevations greater than about 5,000 feet													
Q.90	0.000	0.000	0.000	0.000	0.000	0.054	0.006	0.002	0.065	0.001	0.000	0.000	0.206
Q.80	.000	.000	.000	.000	.000	.099	.048	.029	.107	.004	.000	.000	.386
Q.50	.000	.002	.002	.000	.009	1.171	.256	.554	.923	.102	.019	.000	.712
Q.20	.002	.008	.010	.013	.875	5.982	.565	5.168	5.331	1.033	.288	.012	1.628
QM	.016	.006	.009	.013	1.129	2.770	.570	2.654	4.019	.707	.135	.005	1.000
Watersheds north of the Missouri River with maximum elevations greater than about 5,000 feet													
Q.90	0.000	0.001	0.001	0.003	0.018	0.193	0.113	0.065	0.052	0.000	0.000	0.000	0.127
Q.80	.000	.002	.003	.007	.026	.370	.181	.193	.098	.047	.000	.000	.223
Q.50	.031	.060	.050	.036	.199	1.415	.801	.665	.681	.209	.026	.006	.529
Q.20	.349	.414	.329	.291	1.140	4.522	2.290	1.992	2.206	1.322	.176	.162	1.734
QM	.277	.232	.193	.232	.918	3.285	1.821	2.135	1.574	.738	.152	.430	1.000

Table 4. Actual study period (water years 2000–2004) mean monthly and annual streamflows and estimated long-term monthly and annual streamflow characteristics for the short-term gaging stations.

[Long-term streamflow characteristics estimated by using the Regional Adjustment Relationship (shaded values) and estimation coefficients (unshaded values). All streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 2 (Armells Creek near Landusky)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
Years of record	4	4	4	4	5	5	5	5	5	5	5	5	4
QM	0.00	0.00	0.00	0.00	14	36	2.0	9.1	14	7.2	0.62	0.00	8.5
Estimated long-term streamflow characteristics													
Q.90	<0.01	<0.01	<0.01	<0.01	<0.01	3.9	2.7	2.8	1.6	0.02	<0.01	<0.01	3.8
Q.80	<.01	<.01	<.01	<.01	<.01	7.4	4.1	5.3	2.9	.10	<.01	<.01	6.1
Q.50	<.01	.04	.04	<.01	8.9	29	13	13	12	6.0	0.31	<.01	14
Q.20	.04	.20	.24	.31	21	110	43	33	47	29	3.1	.28	40
QM	.38	.13	.22	.31	22	81	45	29	31	21	3.2	.12	24
Site 3 (Duval Creek near Landusky)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
Years of record	4	4	4	4	5	5	5	5	5	5	5	5	4
QM	0.00	0.00	0.00	0.00	0.16	0.43	0.00	0.01	0.06	0.13	0.11	0.00	0.09
Estimated long-term streamflow characteristics													
Q.90	<0.01	0.01	<0.01	<0.01	<0.01	0.15	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.07
Q.80	.01	.02	.01	<.01	.01	.46	.01	.02	.06	.05	<.01	<.01	.15
Q.50	.05	.04	.03	.02	1.5	1.3	.07	.12	.52	.11	.06	.02	.60
Q.20	.13	.09	.06	.10	2.5	1.8	.47	.54	7.1	3.2	1.4	.11	2.6
QM	.12	.07	.06	.12	2.3	1.8	.42	.66	5.2	2.8	1.6	.39	1.4
Site 4 (Rock Creek near Landusky)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
Years of record	4	5	5	5	5	5	5	5	5	5	5	5	4
QM	0.39	1.2	1.1	1.0	2.0	13	2.7	1.6	1.3	4.2	.20	.00	2.4

Table 4. Actual study period (water years 2000–2004) mean monthly and annual streamflows and estimated long-term monthly and annual streamflow characteristics for the short-term gaging stations.—Continued

[Long-term streamflow characteristics estimated by using the Regional Adjustment Relationship (shaded values) and estimation coefficients (unshaded values). All streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 4 (Rock Creek near Landusky)—Continued													
Estimated long-term streamflow characteristics													
Q.90	<0.01	<0.01	0.01	0.03	0.19	1.9	1.0	0.47	0.32	<0.01	<0.01	<0.01	1.2
Q.80	<.01	.02	.03	.08	.27	4.0	1.6	1.2	.68	.50	<.01	<.01	2.1
Q.50	.33	.64	.54	.39	4.1	14	5.5	3.5	3.9	1.9	.10	.06	5.9
Q.20	3.7	4.4	3.5	3.1	12	44	16	11	23	15	1.8	1.7	18
QM	3.0	2.5	2.1	2.5	12	34	17	10	16	12	2.0	4.6	11
Site 14 (Hell Creek near Jordan)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
Years of record	4	4	4	4	5	5	5	5	5	5	5	5	4
QM	.33	.09	.03	.19	1.4	5.8	.47	2.4	7.8	6.9	1.6	.49	2.2
Estimated long-term streamflow characteristics													
Q.90	0.05	0.11	0.04	0.01	0.02	1.0	0.68	0.73	0.87	0.18	0.03	<0.01	1.1
Q.80	.08	.16	.09	.03	.10	2.3	1.1	1.7	1.7	.39	.05	.02	2.0
Q.50	.36	.32	.24	.14	3.6	8.1	4.0	4.8	7.9	4.3	1.0	.17	5.6
Q.20	.96	.70	.49	.72	19	20	8.2	14	36	24	5.7	.86	18
QM	.91	.53	.48	.91	8.3	17	8.2	13	24	18	5.6	3.0	10
Site 21 (Nelson Creek near Van Norman)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
Years of record	4	4	4	4	5	5	5	5	5	5	5	5	4
QM	.00	.00	.00	.04	.45	5.2	.28	.18	.56	3.2	1.1	.00	.97
Estimated long-term streamflow characteristics													
Q.90	0.03	0.06	0.03	<0.01	0.01	0.93	0.11	0.05	0.12	0.11	0.02	<0.01	0.54
Q.80	.05	.09	.05	.02	.06	2.2	.20	.19	.27	.23	.03	.01	1.0
Q.50	.21	.19	.14	.08	2.2	7.5	.86	.75	1.8	1.3	.54	.10	3.1
Q.20	.57	.41	.29	.43	11	18	5.4	2.8	15	13	4.1	.50	11
QM	.54	.31	.29	.54	7.3	15	5.3	3.0	11	10	4.2	1.8	6.1

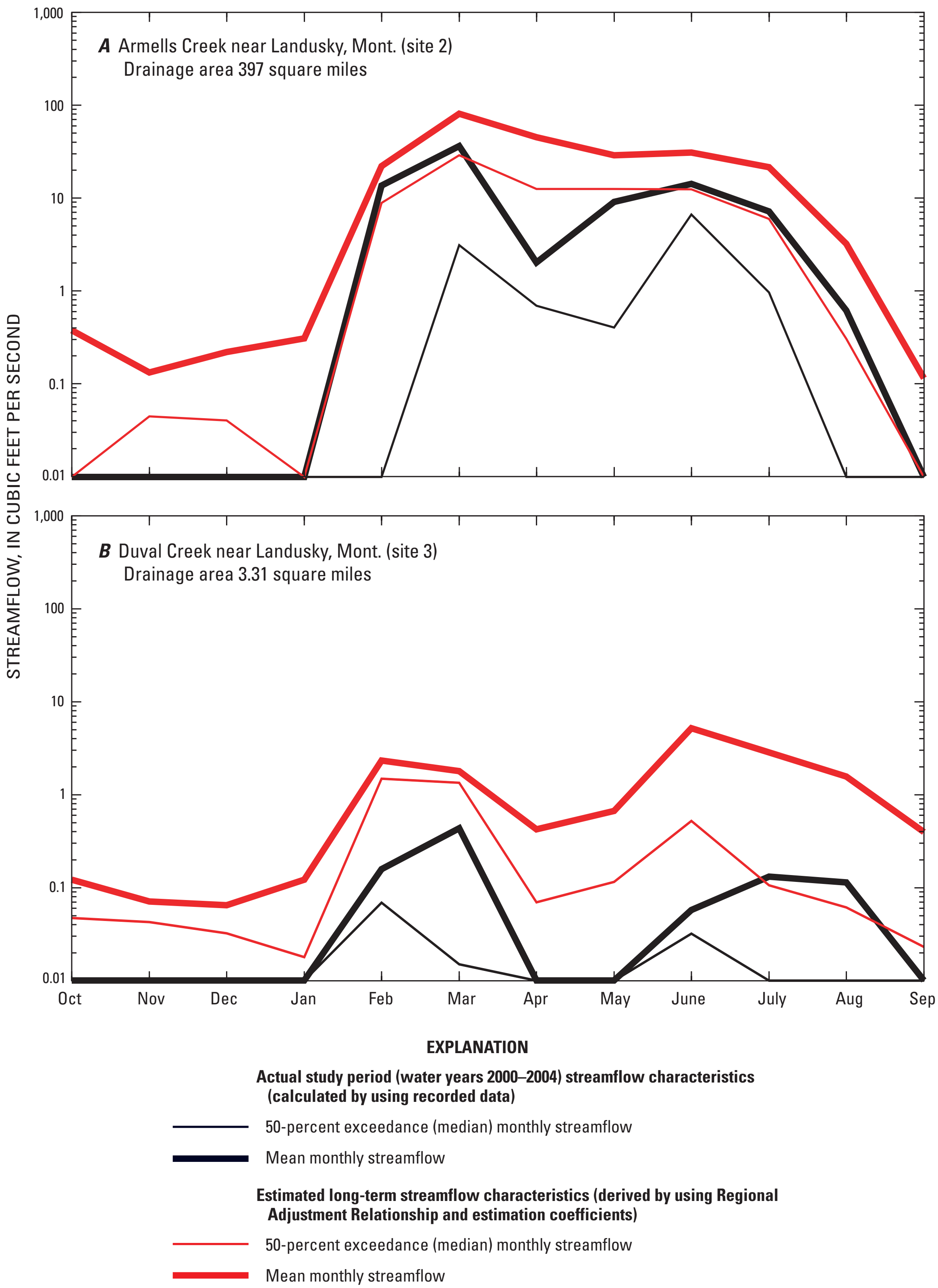


Figure 5. Comparison of actual study period (water years 2000–2004) and estimated long-term selected monthly streamflow characteristics for the short-term gaging stations. *A*, Armells Creek near Landusky, Mont.; *B*, Duval Creek near Landusky, Mont.; *C*, Rock Creek near Landusky, Mont.; *D*, Hell Creek near Jordan, Mont.; *E*, Nelson Creek near Van Norman, Mont.

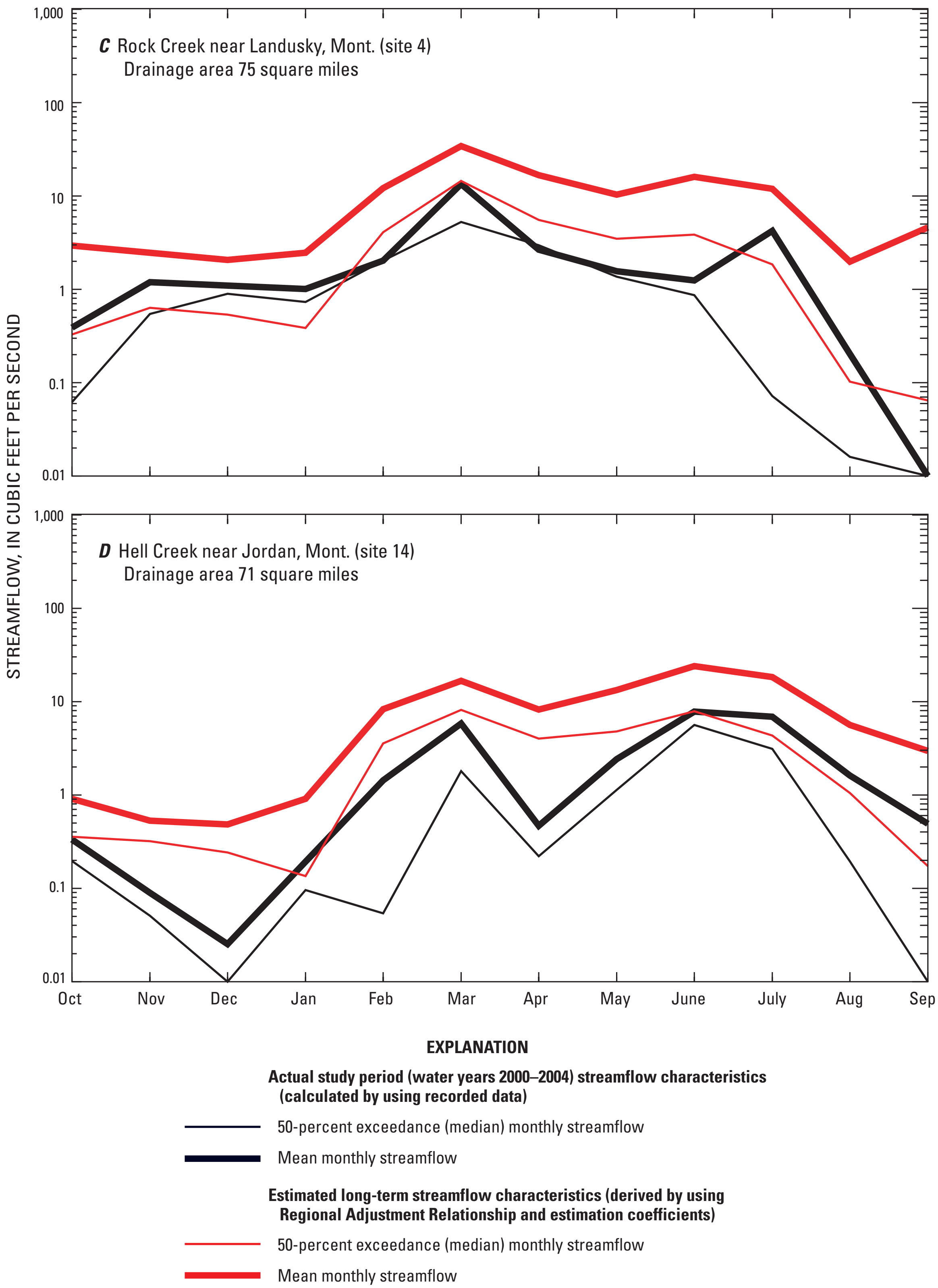


Figure 5. Comparison of actual study period (water years 2000–2004) and estimated long-term selected monthly streamflow characteristics for the short-term gaging stations. *A*, Armells Creek near Landusky, Mont.; *B*, Duval Creek near Landusky, Mont.; *C*, Rock Creek near Landusky, Mont.; *D*, Hell Creek near Jordan, Mont.; *E*, Nelson Creek near Van Norman, Mont.—Continued

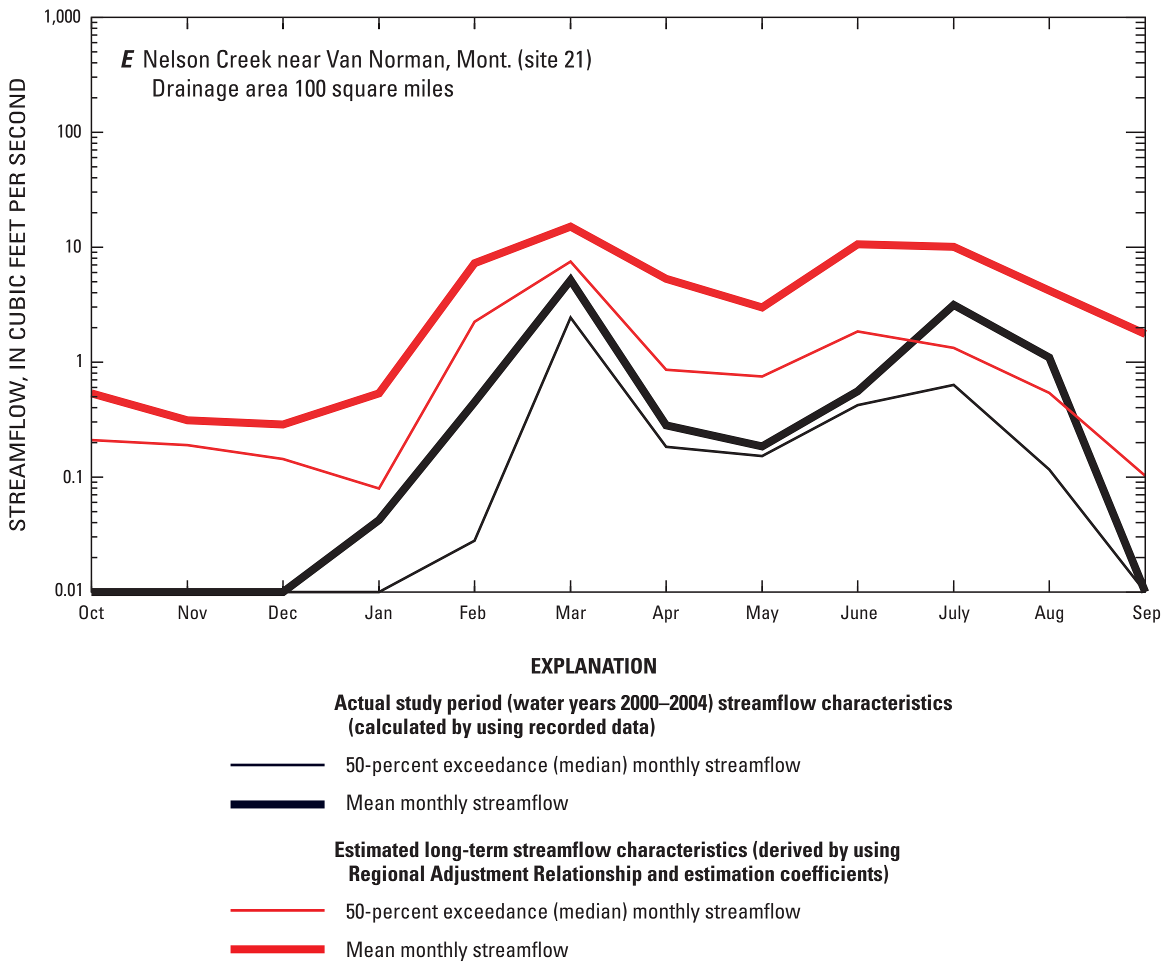


Figure 5. Comparison of actual study period (water years 2000–2004) and estimated long-term selected monthly streamflow characteristics for the short-term gaging stations. *A*, Armells Creek near Landusky, Mont.; *B*, Duval Creek near Landusky, Mont.; *C*, Rock Creek near Landusky, Mont.; *D*, Hell Creek near Jordan, Mont.; *E*, Nelson Creek near Van Norman, Mont.—Continued

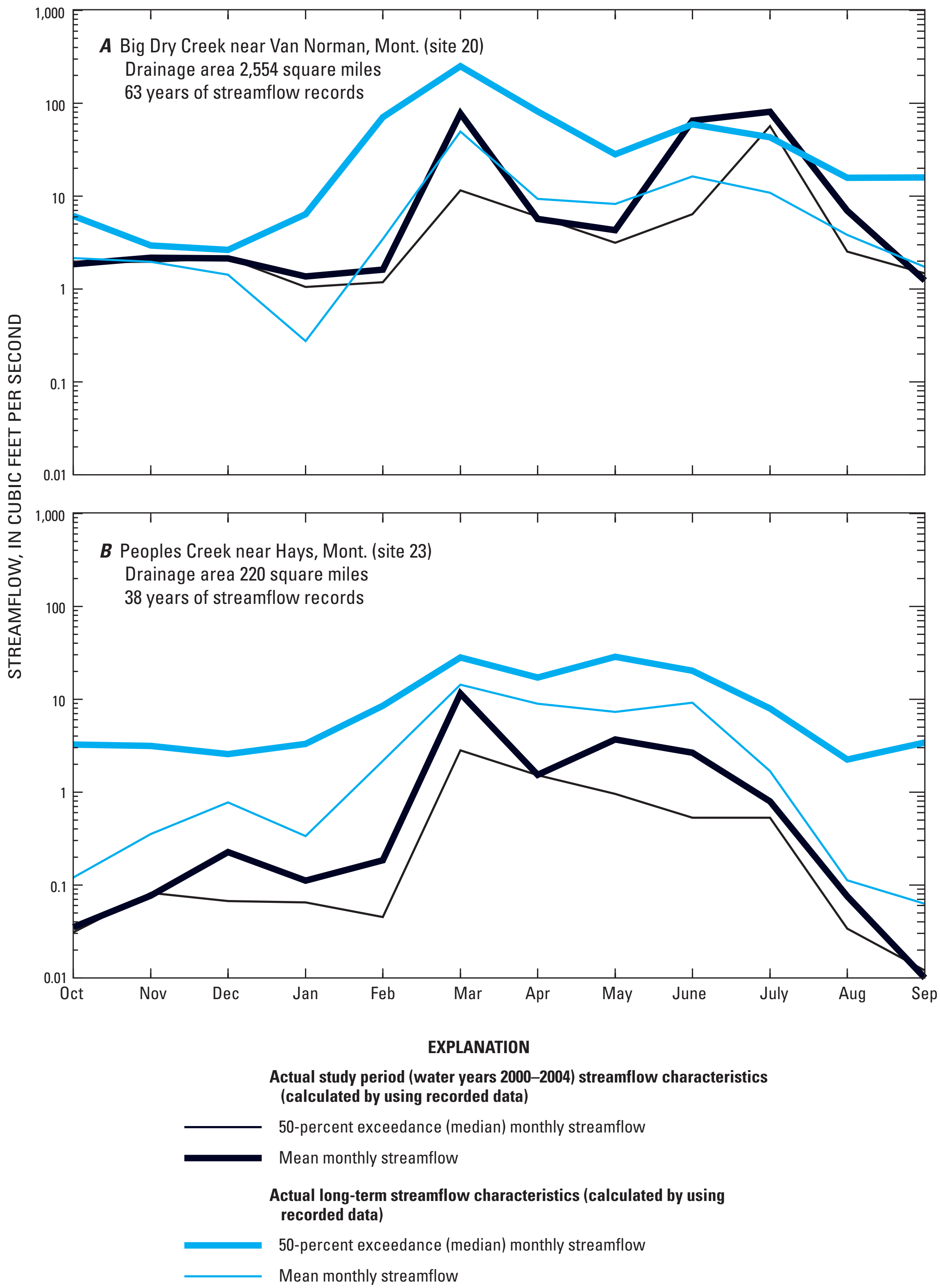


Figure 6. Comparison of actual study period (water years 2000–2004) and actual long-term selected monthly streamflow characteristics for selected long-term index gaging stations used in the Regional Adjustment Relationship. *A*, Big Dry Creek near Van Norman, Mont.; *B*, Peoples Creek near Hays, Mont.; *C*, Peoples Creek below Kuhr Coulee, near Dodson, Mont.; *D*, Redwater River at Circle, Mont.

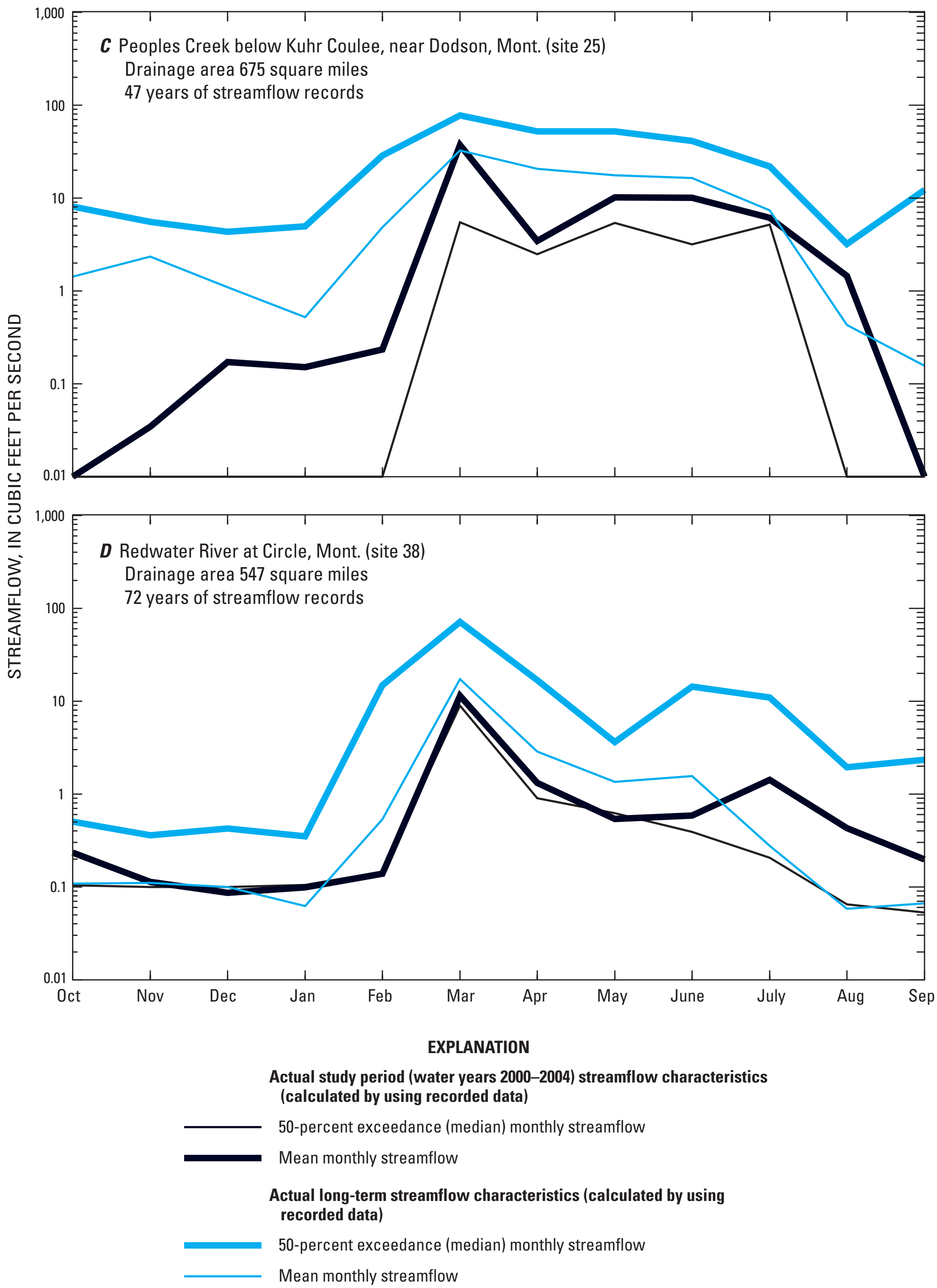


Figure 6. Comparison of actual study period (water years 2000–2004) and actual long-term selected monthly streamflow characteristics for selected long-term index gaging stations used in the Regional Adjustment Relationship. *A*, Big Dry Creek near Van Norman, Mont.; *B*, Peoples Creek near Hays, Mont.; *C*, Peoples Creek below Kuhr Coulee, near Dodson, Mont.; *D*, Redwater River at Circle, Mont.—Continued

Estimates of *T*-Year Peak Flows for Short-Term Gaging Stations

The RAR also was investigated for estimating the long-term 1.5-, 2-, and 2.33-year peak flows (PK1.5, PK2, and PK2.33, respectively) for three of the CMR stations (sites 2, 4, and 14; table 1 and fig. 1). Two of the CMR stations (sites 3 and 21; table 1 and fig. 1) had suitable peak-flow records (43 and 17 years, respectively) for determining *T*-year peak-flow characteristics directly and could serve as index stations. Thus, nine index stations (table 1) were used to represent regional study period and long-term peak-flow relations. Study-period mean peak flow (PKM) and long-term PK1.5, PK2, and PK2.33 for the index stations used in the RAR are presented in Supplement 2 (at the back of this report). The PK1.5, PK2, and PK2.33 were determined by using procedures described in Bulletin 17B, "Guidelines for Determining Flood Flow Frequency" (Interagency Advisory Committee on Water Data, 1982; hereinafter referred to as Bulletin 17B). PeakFQ, a computer program developed by the USGS (Flynn and others, 2006) was used to perform the Bulletin 17B flood-frequency analyses.

The nine index stations used in the RAR to estimate long-term PK1.5, PK2, and PK2.33 satisfied the criteria for selection of long-term index stations specified by Bakke and others (1999). For estimating long-term *T*-year peak flows at the three CMR stations, OLS regression equations relating the PK1.5, PK2, and PK2.33 (dependent variables) to the study period PKM (explanatory variable) were developed. Procedures to determine suitability of the regression to provide acceptable results were identical to those used for estimating monthly and annual streamflow characteristics.

The RAR regression equations (table 5) were determined to provide acceptable results for estimating the PK1.5, PK2, and PK2.33 for the three CMR stations (sites 2, 4, and 14; table 1 and fig. 1). As with the estimates for monthly and annual streamflow characteristics, retransformation bias for the PK1.5, PK2, and PK2.33 was compensated for by multiplying by a nonparametric bias-correction factor (Duan, 1983), which is presented in table 5. The relations used for estimating the PK2 are illustrated in figure 7. Estimates of the PK1.5, PK2, and PK2.33 for the short-term CMR gaging stations are presented in table 6.

Estimation of Streamflow Characteristics at Ungaged Sites

Methods for estimating streamflow characteristics at ungaged sites also were needed by the U.S. Fish and Wildlife Service. Regression analyses that relate individual streamflow characteristics to various basin and climatic characteristics for gaging stations were performed to develop regional regression equations to estimate streamflow characteristics at ungaged sites. Of particular interest to the FWS in the process of negotiating water rights is the bankfull discharge, which is an index of streamflow that is considered to be closely related to channel shape, size, and slope (Lawlor, 2004). The PK2 commonly is used to approximate the bankfull discharge (Lawlor, 2004; Wilkerson, 2008). However, various studies have found that the peak-flow recurrence interval associated with the bankfull discharge is variable (Williams, 1978), generally is less than 5 years, and might be more closely approximated by the PK1.5 or the PK2.33 at many stream locations (U.S. Environmental Protection Agency, 2006). Accordingly, separate regression equations for the PK1.5, PK2, and PK2.33 were developed for this study. Determination of the *T*-year peak flow most closely associated with the bankfull discharge for tributaries that cross CMR was beyond the scope of the current (2008) study. However, the bankfull discharge for most streams probably will be within the range of the PK1.5 and PK2.33.

Selected basin and climatic characteristics that were considered as potential explanatory variables in regression analyses for estimating streamflow characteristics at ungaged sites are presented in table 7. All basin characteristics considered were determined by using a geographic information system (GIS) and NHDPlus (Horizon Systems Corporation, 2006), which is an integrated suite of geospatial datasets that determine stream networks, drainage boundaries, selected topographic characteristics, selected climatic characteristics, and selected basin land-cover characteristics. Primary datasets incorporated into NHDPlus include the 1:100,000 scale National Hydrography Dataset (U.S. Geological Survey, 2007), the 30-meter resolution National Elevation Dataset (U.S. Geological Survey, 2006), the 1:24,000 scale Watershed Boundary Dataset (Natural Resources Conservation Service, 2008b), the 30-meter resolution 2006 National Land Cover Dataset (U.S. Environmental Protection Agency, 2007), and the 2-kilometer resolution Parameter-elevation Regressions on Independent Slopes Model (PRISM) for estimating climatic variables using 1971–2000 data (Daly, 1996; Natural Resources Conservation Service, 2008a).

Estimation of Monthly and Annual Streamflow Characteristics at Ungaged Sites

Thirteen gaging stations (table 1 and fig. 1) were used in developing regression equations for monthly and annual streamflow characteristics. These gaging stations were selected because they generally are close to the study area. The watersheds of the gaging stations located outside of the study area generally are topographically and hydrologically similar to watersheds within the study area. Ten of the 13 stations (sites 8, 15, 20, 21, 23, 25, 30, 32, 38, and 45) had 10 or more years of continuous streamflow records (through water year 2005); monthly and annual streamflow characteristics for these gaging stations were determined from recorded data (Supplement 3 at the back of this report). Three of the 13 gaging stations (sites 2, 4, and 14) were CMR stations with record only during the study period. Estimated monthly

Table 5. Regression equations for estimating peak-flow characteristics for the short-term gaging stations.

[Equations were developed by using the Regional Adjustment Relationship. Abbreviations: PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow; PKM, mean peak flow; RBCF, retransformation bias-correction factor; p-value, significance level; R^2, coefficient of determination; SEE, average standard error of estimate (in percent)]

Long-term streamflow characteristic	Equation	RBCF	R^2	SEE	p-value
PK1.5	$= 2.1\ PKM(study\ period)^{0.81}$	1.03	0.81	76.6	0.002
PK2	$= 3.8\ PKM(study\ period)^{0.80}$	1.03	.80	78.5	.003
PK2.33	$= 5.0\ PKM(study\ period)^{0.80}$	1.04	.80	79.9	.003

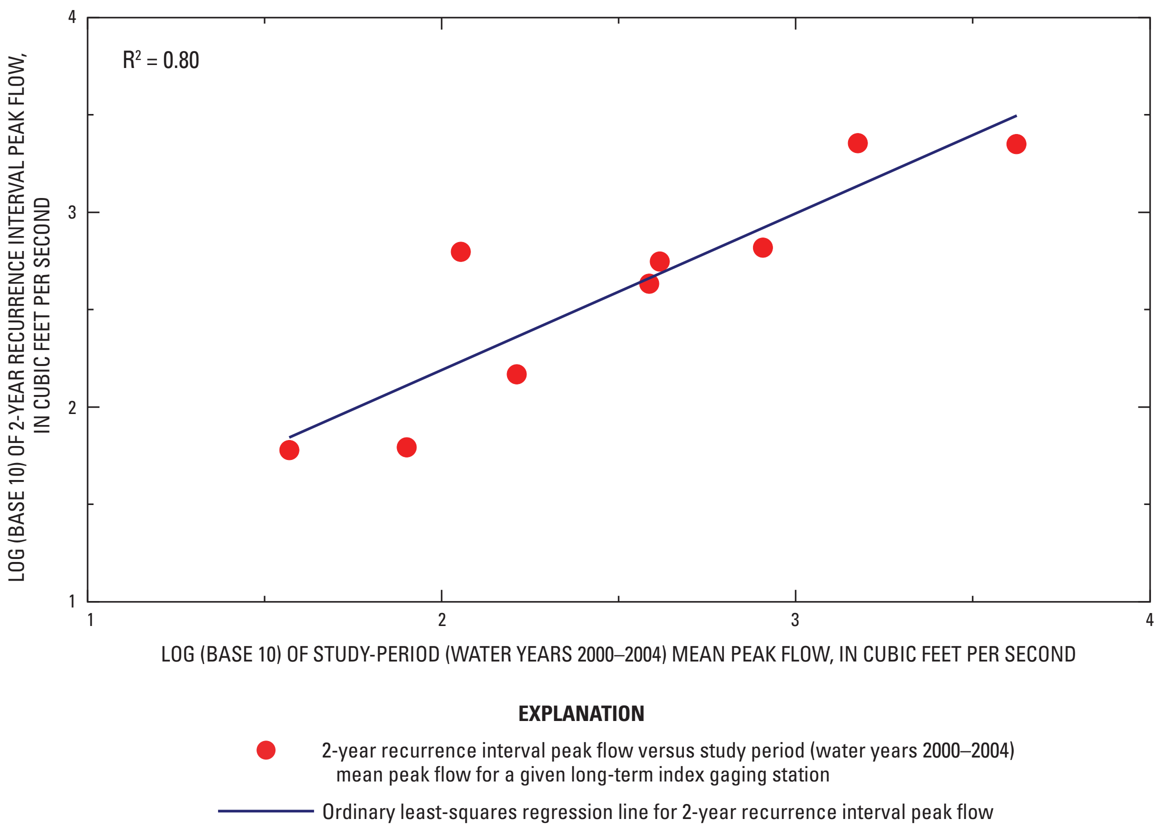


Figure 7. Regional Adjustment Relationship regression relations used to estimate the 2-year recurrence interval peak flow for the short-term gaging stations.

and annual streamflow characteristics (table 4) determined by using the RAR and estimation coefficients were used in the regression analyses for these stations. One of the CMR stations (site 3) had a much smaller drainage area than the other gaging stations and consistently had significantly high-leverage and high-influence values (as discussed in Helsel and Hirsch, 2002, p. 245–248) that substantially affected regression results; this gaging station was excluded from the regression analyses for monthly and annual streamflow characteristics. All data were transformed to base-10 logarithms prior to analysis. Any streamflow characteristic that was less than 0.01 ft^3/s was assigned a value of 0.01 ft^3/s.

For each monthly and annual streamflow characteristic (Q.90, Q.80, Q.50, Q.20, and QM), preliminary OLS regressions were performed to identify the most influential explanatory variables and select a regression model for subsequent weighted least squares (WLS) regression. Regression models were selected on the basis of (1) determining that explanatory

Table 6. Estimates of peak-flow characteristics for the short-term gaging stations.

[Peak-flow characteristics (in cubic feet per second) estimated by using the Regional Adjustment Relationship. Abbreviations: PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow; PKM, mean peak flow]

Site number (fig. 1)	Station number	Station name	PKM for study period (water years 2000–2004)	PK1.5	PK2	PK2.33
2	06115270	Armells Creek near Landusky	1,260	668	1,230	1,570
4	06115350	Rock Creek near Landusky	587	362	665	852
14	06130650	Hell Creek near Jordan	927	523	960	1,230

Table 7. Selected basin and climatic characteristics considered as potential explanatory variables in regression analyses for estimating streamflow characteristics at ungaged sites.

Basin or climatic characteristic	Description	References
Drainage area	Area that drains to a stream point, in square miles, determined from 30-meter resolution National Elevation Dataset, 1:24,000 scale Watershed Boundary Dataset, and 1:100,000 scale National Hydrography Dataset	Horizon Systems Corporation (2006), Natural Resources Conservation Service (2008b), U.S. Geological Survey (2006).
Mean elevation	Basinwide mean elevation, in feet, determined from 30-meter resolution National Elevation Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2006).
Maximum elevation	Maximum elevation of basin, in feet, determined from 30-meter resolution National Elevation Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2006).
Minimum elevation	Minimum elevation of basin, in feet, determined from 30-meter resolution National Elevation Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2006).
Relief	Difference between maximum and minimum elevation of basin, in feet, determined from 30-meter resolution National Elevation Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2006).
Mean slope	Basinwide mean slope, in percent, determined from 30-meter resolution National Elevation Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2006).
Mean annual precipitation	Basinwide mean annual precipitation, in inches, determined from 2-kilometer resolution Parameter-elevation Regressions on Independent Slopes Model (PRISM)	Daly (1996), Horizon Systems Corporation (2006), Natural Resources Conservation Service (2008a).
Percent forest	Basinwide forest cover, in percent, determined from the 30-meter resolution National Land Cover Dataset	Horizon Systems Corporation (2006), U.S. Environmental Protection Agency (2007).
Percent lakes	Basinwide lake cover, in percent, determined from the 1:100,000 scale National Hydrography Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2007).
Compactness ratio	A measure of basin shape related to basin perimeter and drainage area, determined from 30-meter resolution National Elevation Dataset, 1:24,000 scale Watershed Boundary Dataset, and 1:100,000 scale National Hydrography Dataset	Horizon Systems Corporation (2006), Natural Resources Conservation Service (2008b), U.S. Geological Survey (2006).
Total stream length	Basinwide length of mapped streams, in miles, determined from the 1:100,000 scale National Hydrography Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2007).
Stream density ratio	Basinwide length of mapped streams, in miles, divided by the drainage area, in square miles, determined from 30-meter resolution National Elevation Dataset and 1:100,000 scale National Hydrography Dataset	Horizon Systems Corporation (2006), U.S. Geological Survey (2006), U.S. Geological Survey (2007).

variables were statistically significant (p-value less than 0.05); (2) minimizing Mallow's Cp and the Press statistic (Helsel and Hirsch, 2002, p. 313) among different candidate models; (3) reviewing regression diagnostics to ensure that final regression models were not substantially affected by outliers, high-leverage values, high-influence values, or non-normally distributed residuals (by using methods described by Helsel and Hirsch, 2002, p. 228–251); (4) determining that the overall statistical significance exceeded 95 percent (p-value was less than 0.05); and (5) determining that the SEE was less than about 100 percent. As a result of the preliminary OLS regression analyses, the explanatory variables used in the final WLS regression models for any of the monthly and annual streamflow characteristics were drainage area (*A*) and relief (*REL*). Data for these variables for all gaging stations are presented in Supplement 4 (at the back of this report). Supplement 4 also includes data for other basin and climatic characteristics (that were not used in final regression models), as well as manually determined basin and climatic characteristics for informational purposes.

Final regressions were performed by using WLS regression. Because individual gaging stations have varying periods of record that might be associated with climatically different conditions, the reliability of calculations of streamflow characteristics determined by using recorded data might vary among gaging stations. Generally, calculations of streamflow characteristics for gaging stations with shorter periods of record are expected to be less reliable than calculations for gaging stations with longer periods of record. Weighting the streamflow characteristics for a gaging station proportionally to record length of the station helps to compensate for differences in the reliability of the characteristics. However, appropriate weighting factors also incorporate information on the variance of the streamflow records for a given gaging station, which helps to reduce effects of nonconstant variance on regression results. For this study, a weighting factor developed by Ries and Friesz (2000) that considers both record length and variance of the streamflow characteristic was used. The weighting factor for each gaging station was calculated by using the following equation:

$$WT_{\mathrm{i}} = (Y_{\mathrm{i}}/\overline{Y}_{1,\mathrm{N}})/(V_{\mathrm{i}}/\overline{V}_{1,\mathrm{N}}), \tag{1}$$

where

WT_{i} is the weighting factor for gaging station *i*, dimensionless;

Y_{i} is the number of years of record for gaging station *i*;

$\overline{Y}_{1,\mathrm{N}}$ is the mean number of years of record for all gaging stations;

N is the number of gaging stations used in the regression analysis;

V_{i} is the variance of the streamflow characteristic for gaging station *i*; and

$\overline{V}_{1,\mathrm{N}}$ is the mean variance of the streamflow characteristic for all gaging stations.

Regression equations for the annual Q.50, Q.20, and QM and retransformation bias-correction factors (Duan, 1983) are presented in table 8. Individual regression analyses were performed to investigate if acceptable equations for estimating Q.90, Q.80, Q.50, Q.20, and QM on a monthly basis and also on an annual basis could be developed. Acceptable equations were developed for estimating QM for the months of February, March, April, June, and July, and Q.50, Q.20, and QM on an annual basis. However, equations for QM for the months of February, March, April, June, and July were determined to be less consistent and reliable than the use of estimation coefficients (table 3) applied to the regression equation results for the annual QM (table 8). Thus, the regression equations for the long-term mean streamflows for the months of February, March, April, June, and July are not reported. The monthly and annual streamflow characteristics for which acceptable regression equations were not developed or reported can be estimated by using the estimation coefficients (table 3).

Estimation of Peak-Flow Characteristics at Ungaged Sites

Forty-two gaging stations (indicated in table 1) were used in developing regression equations for peak-flow characteristics. These gaging stations were selected because they are in or generally close to the study area. The watersheds of the gaging stations located outside of the study area generally are topographically and hydrologically similar to watersheds within the study area. Thirty-nine of the gaging stations had 10 or more years of annual peak-flow records (on the basis of data through water year 2005). The PK1.5, PK2, and PK2.33 for these 39 gaging stations (Supplement 5 at the back of this report) were determined from recorded data by using procedures described in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) and incorporated in the PEAKFQ computer program (Flynn and others, 2006). Three of the 42 gaging stations were CMR stations (sites 2, 4, and 14) with annual peak-flow records only during the study period. Estimated PK1.5, PK2, and PK2.33 for these three gaging stations (table 6) were determined by using the RAR.

In developing regression equations for peak-flow characteristics, the study area was divided into two regions: (1) the North Region, which includes that part of the study area north of the Missouri River, and (2) the South Region, which includes that part of the study area south of the Missouri River (fig. 1). Eleven gaging stations north of the Missouri River (table 1 and fig. 1) were used to develop regression equations for the North Region. Thirty-one gaging stations south of the Missouri River (table 1 and fig. 1) were used to develop regression equations for the South Region.

For each region and each peak-flow characteristic, preliminary OLS regressions were performed to identify the most influential explanatory variables and select a regression model for subsequent GLS regression (Tasker and Stedinger, 1989). Regression models were selected on the

Table 8. Regression equations for estimating annual streamflow characteristics at ungaged sites.

[Abbreviations: *A*, drainage area (in square miles); p-value, significance level; Q.50, 50-percent exceedance (median) streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow; RBCF, retransformation bias-correction factor; *REL*, relief (in feet); SEE, average standard error of estimate (in percent). Symbol: <, less than]

Long-term streamflow characteristic	Equation	RBCF	SEE	p-value
Annual Q.50	$= 0.30\,A^{0.49}\,(REL/1{,}000)^{0.55}$	1.05	49.0	<0.001
Annual Q.20	$= 0.69\,A^{0.52}\,(REL/1{,}000)^{0.70}$	1.03	65.1	.001
Annual QM	$= 0.56\,A^{0.48}\,(REL/1{,}000)^{0.59}$	1.04	52.0	<.001

basis of (1) determination of significant (p-value less than 0.05) explanatory variables; (2) minimizing Mallow's Cp and the Press statistic (Helsel and Hirsch, 2002, p. 313) among different candidate models; (3) reviewing regression diagnostics to ensure the final regression models were not substantially affected by outliers, high-leverage values, high-influence, values or non-normally distributed residuals (by using methods described by Helsel and Hirsch, 2002, p. 228–251); (4) determining that the overall statistical significance exceeded 95 percent (that is, the p-value was less than 0.05); and (5) determining that the SEP was less than about 100 percent. Explanatory variables used in final regression models for any of the peak-flow characteristics were area (*A*) and basinwide mean elevation (*E*). Data for these variables for all gaging stations are presented in Supplement 4. Supplement 4 also includes data for other basin and climatic characteristics (that were not used in final regression models), as well as manually determined basin and climatic characteristics for informational purposes.

For each region, final regressions were performed by using GLS regression (Tasker and Stedinger, 1989). GLS regression accounts for time-sampling error that is inherent when individual gaging stations have been operated for different lengths of time and under different climatic conditions. GLS regression also accounts for cross correlation of annual peak flows among different gaging stations. For this study, GLS regression was applied by using a program based on methods described by Stedinger and Tasker (1985) and Tasker and Stedinger (1989) and discussed in Kenney and others (2007). Numerical methods used in the program to estimate time-sampling error are based on statistics for the log-Pearson Type III probability distribution, which routinely is used for determining peak-flow magnitude and frequency relations (Interagency Advisory Committee on Water Data, 1982). Thus, GLS regression is appropriate for developing regression equations for peak-flow characteristics but was not used for developing regression equations for monthly and annual streamflow characteristics, which are not necessarily well represented by the log-Pearson Type III probability distribution. Acceptable equations were developed for the PK1.5, PK2, and PK2.33. Regression equations for estimating peak-flow characteristics and retransformation bias-correction factors (Duan, 1983) are presented in table 9. SEPs for regression equations for the PK1.5, PK2, and PK2.33 for the North Region were 56.6, 62.1, and 63.8 percent, respectively. SEPs for regression equations for the PK1.5, PK2, and PK2.33 for the South Region were 62.1, 57.3, and 55.6 percent, respectively.

Limitations on Use of the Regression Equations

The following limitations need to be considered when using the regression equations presented in this report to estimate monthly and annual streamflow characteristics and peak-flow characteristics for ungaged sites in the study area: (1) the regression equations should not be used for sites near dams, flood-detention structures, and other manmade structures that might substantially affect the specific streamflow characteristics being estimated; (2) the regression equations generally should be used only for sites within the study area; (3) basin characteristics used in the regression equations should be determined by using methods identical to those used in this study; and (4) the regression equations generally should be used only for sites that have basin characteristics that are within the range of characteristics used to develop the regression equations (table 10).

Estimated Streamflow Characteristics for Selected Ungaged Sites in Charles M. Russell National Wildlife Refuge

Of particular interest to the FWS are estimates of monthly and annual streamflow characteristics and peak-flow characteristics at ungaged sites (fig. 8) on tributary streams where they enter CMR, and also where they enter Fort Peck Reservoir. Basin characteristics for these ungaged sites are presented in Supplement 6 (at the back of this report). Esti-

Table 9. Regression equations for estimating peak-flow characteristics at ungaged sites.

[Abbreviations: A, drainage area (in square miles); E, basinwide mean elevation (in feet above North American Vertical Datum of 1988); EYR, equivalent years of record; ME, average model error (in percent); PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow; RBCF, retransformation bias-correction factor; SEP, average standard error of prediction (in percent); TE, time-sampling error (in percent)]

Peak-flow characteristic	Equation	RBCF	SEP	TE	ME	EYR
		North Region				
PK1.5	$= 16\,A^{0.39}$	1.08	56.6	8.5	48.1	8.8
PK2	$= 28\,A^{0.42}$	1.06	62.1	8.8	53.3	7.1
PK2.33	$= 35\,A^{0.43}$	1.05	63.8	8.9	54.9	6.9
		South Region				
PK1.5	$= 71\,A^{0.62}\,(E/1{,}000)^{-1.80}$	1.06	62.1	5.1	57.0	7.0
PK2	$= 155\,A^{0.60}\,(E/1{,}000)^{-1.92}$	1.05	57.3	4.3	53.0	5.6
PK2.33	$= 214\,A^{0.59}\,(E/1{,}000)^{-1.97}$	1.04	55.6	4.1	51.5	5.3

Table 10. Ranges for basin characteristics used to develop regression equations for estimating streamflow characteristics at ungaged sites.

[Elevation information is referenced to the North American Vertical Datum of 1988. Symbol: --, not applicable]

Type of regression equation	Drainage area (*A*), in square miles	Relief (*REL*), in feet	Basinwide mean elevation (*E*), in feet
Annual streamflow characteristics (table 8)	70–2,551	606–4,149	--
Peak-flow characteristics (table 9) for North Region	0.9–920	--	--
Peak-flow characteristics (table 9) for South Region	1.1–2,551	--	2,398–4,003

mated monthly and annual streamflow characteristics for these ungaged sites (derived by using regression equations, table 8, and estimation coefficients, table 3) are presented in Supplement 7 (at the back of this report) and example plots of monthly streamflow characteristics for selected ungaged sites are shown in figure 9. Example plots of selected annual streamflow characteristics for various exceedance probabilities for the selected ungaged sites are shown in figure 10.

The estimated mean and median monthly streamflows for the selected ungaged sites (fig. 9) are similar to those of long-term gaging stations close to the study area (fig. 6). Streams in the northeastern plains of Montana generally are characterized by higher streamflows during February through August and lower streamflows during September through January. For most streams, March and April, when most snowmelt runoff typically occurs in northeastern Montana, have the highest mean monthly streamflow. Spring rainstorms also contribute to higher streamflows in March and April. Mean monthly streamflow for February typically is larger than late fall and early winter streamflows, indicating that during some years snowmelt begins in February. Some streams show a mid-spring (about April or May) decrease in streamflow following completion of snowmelt at lower elevations. Late spring and summer rainstorms can increase streamflow during the months of June and July. Streamflows then generally decrease from August through the fall.

The estimated median monthly and annual streamflows generally are substantially less than the estimated mean monthly and annual streamflows for the ungaged sites. This pattern also was noted by Parrett (2006) for several tributaries to the Milk River that are near the study area. Large differences between median and mean monthly and annual streamflows are typical of streams with highly variable streamflow from year to year. Differences between median and mean monthly streamflows are especially large for some months (including January, February, August, September, and October) when streamflows typically transition between base-flow and runoff dominance.

The estimated long-term streamflow characteristics for the selected ungaged sites generally indicate similar annual streamflow patterns to those of the long-term gaging stations. However, the methods used to estimate the monthly and annual streamflow characteristics (that is, the regression equations, table 8, and estimation coefficients, table 3) for

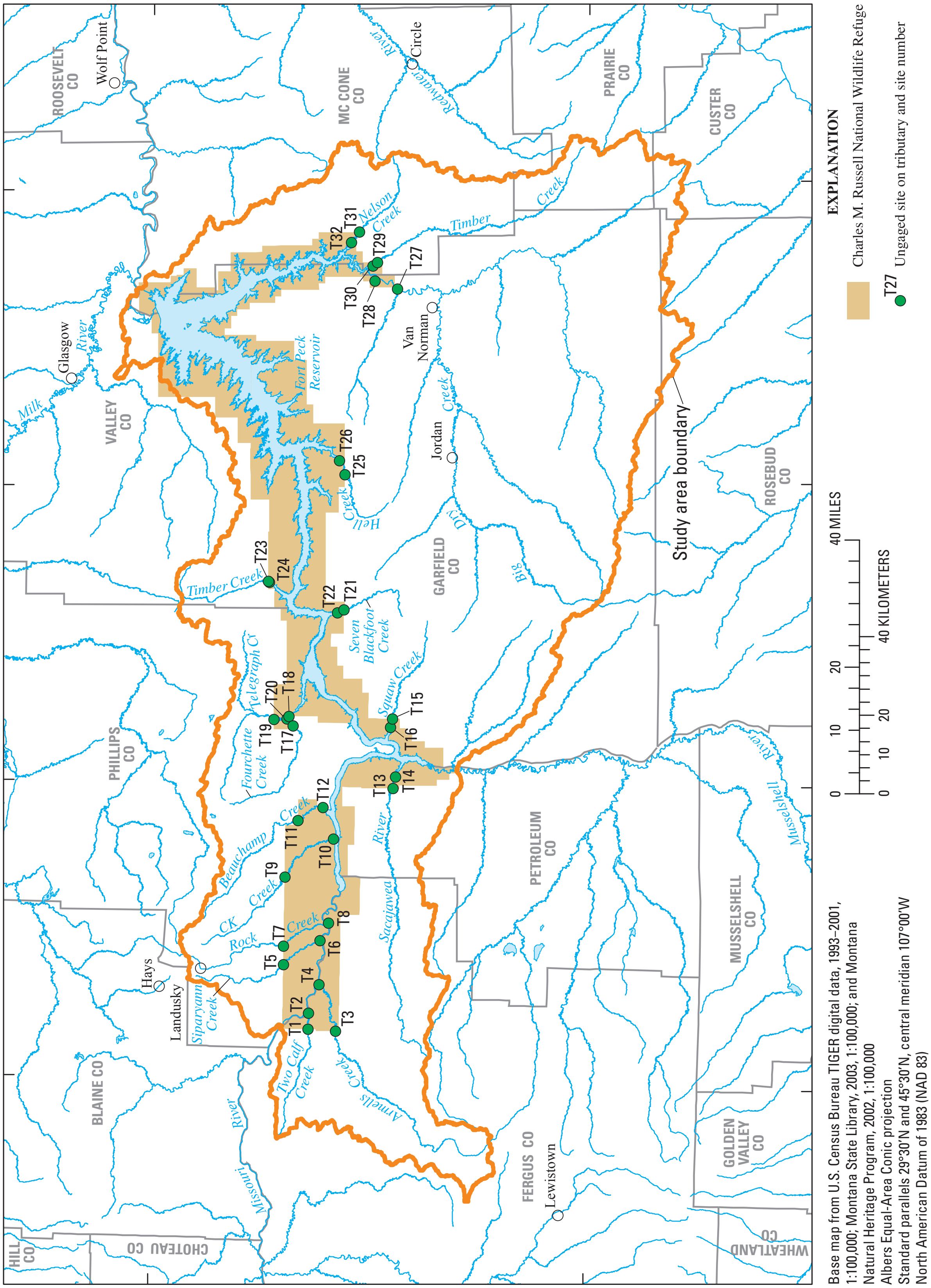


Figure 8. Locations of selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge, northeastern Montana.

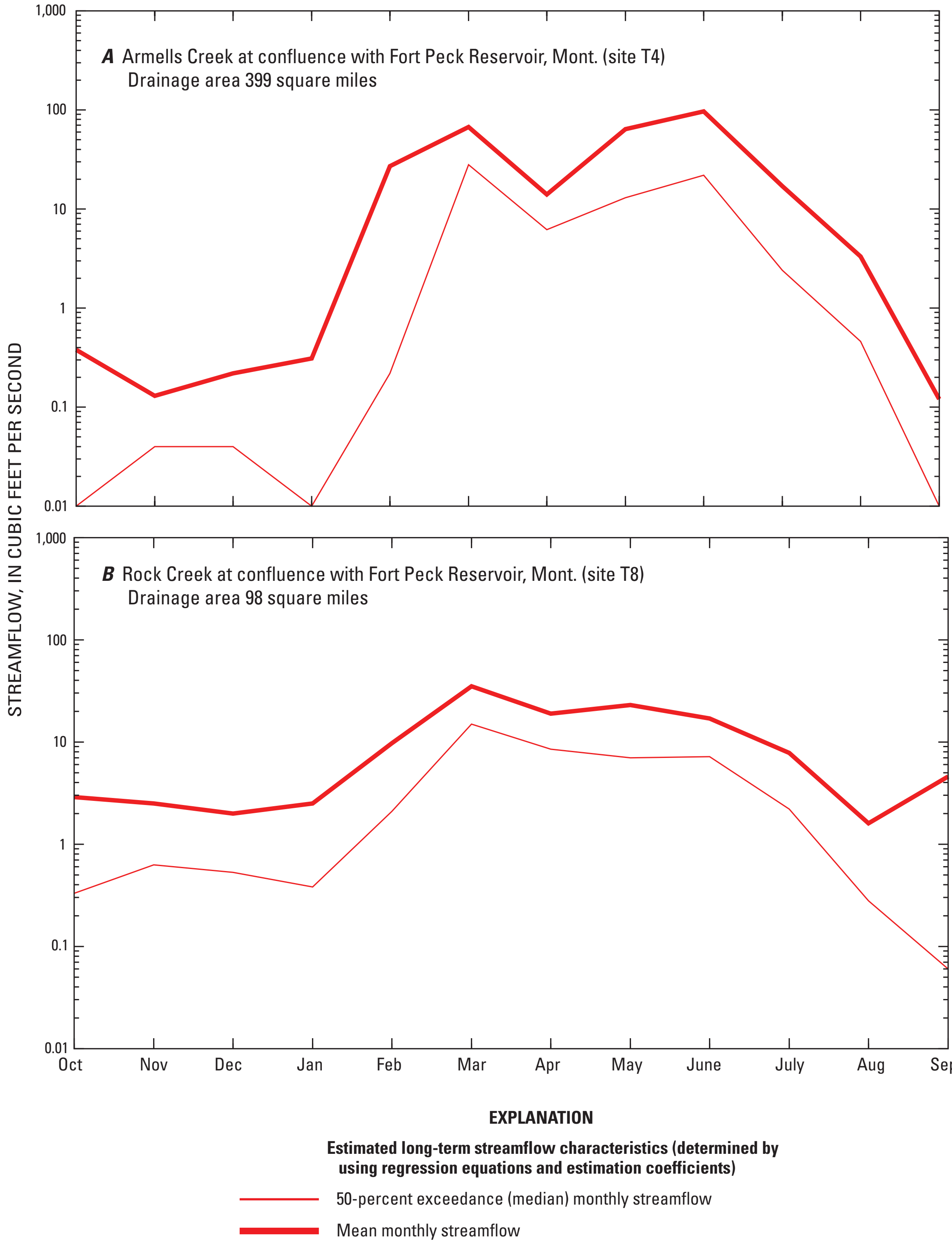


Figure 9. Estimated long-term monthly streamflow characteristics (derived by using regression equations, table 8, and estimation coefficients, table 3) for selected ungaged sites. *A*, Armells Creek at confluence with Fort Peck Reservoir, Mont.; *B*, Rock Creek at confluence with Fort Peck Reservoir, Mont.; *C*, Big Dry Creek at confluence with Fort Peck Reservoir, Mont.; *D*, Nelson Creek at confluence with Fort Peck Reservoir, Mont.

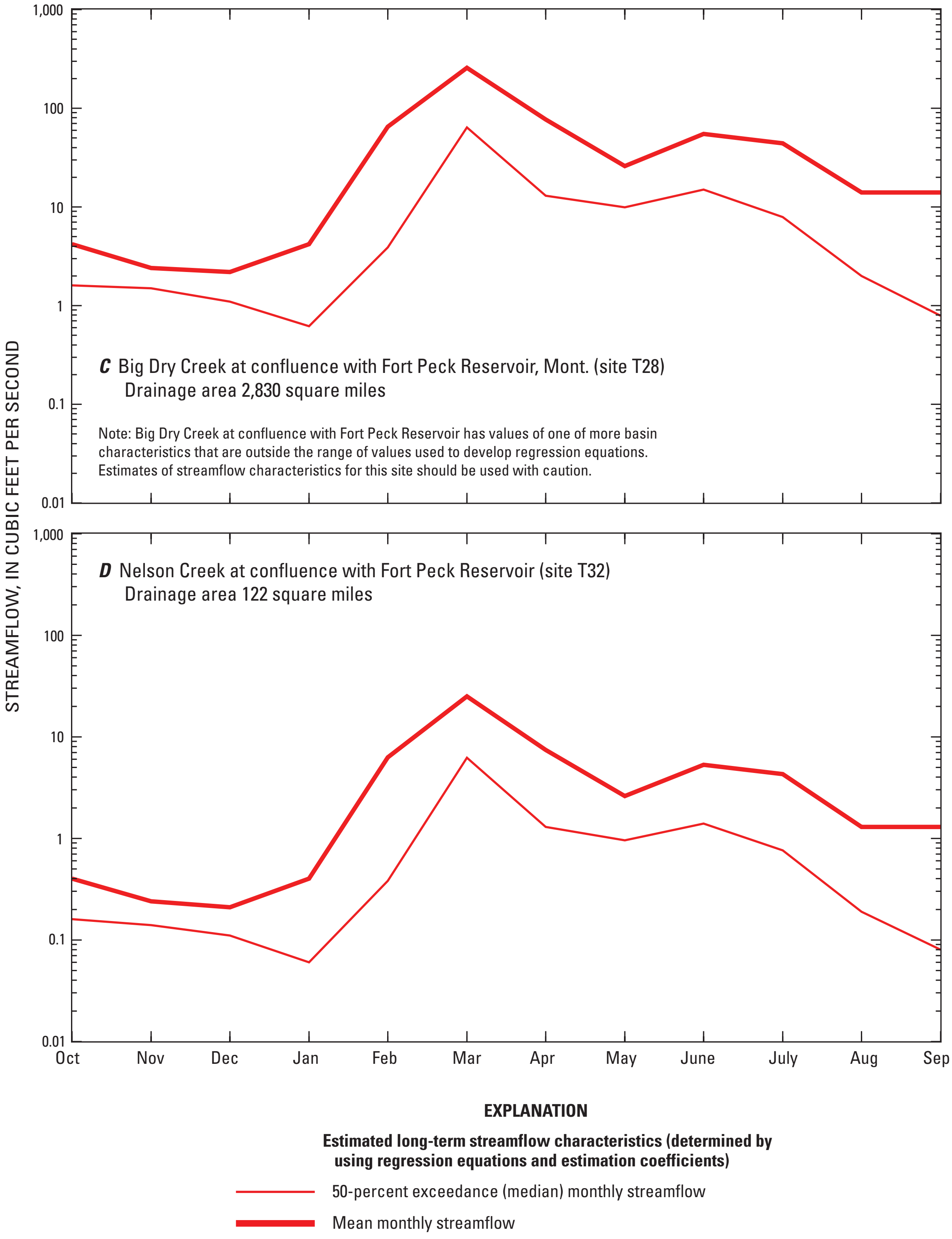


Figure 9. Estimated long-term monthly streamflow characteristics (derived by using regression equations, table 8, and estimation coefficients, table 3) for selected ungaged sites. *A*, Armells Creek at confluence with Fort Peck Reservoir, Mont.; *B*, Rock Creek at confluence with Fort Peck Reservoir, Mont.; *C*, Big Dry Creek at confluence with Fort Peck Reservoir, Mont.; *D*, Nelson Creek at confluence with Fort Peck Reservoir, Mont.—Continued

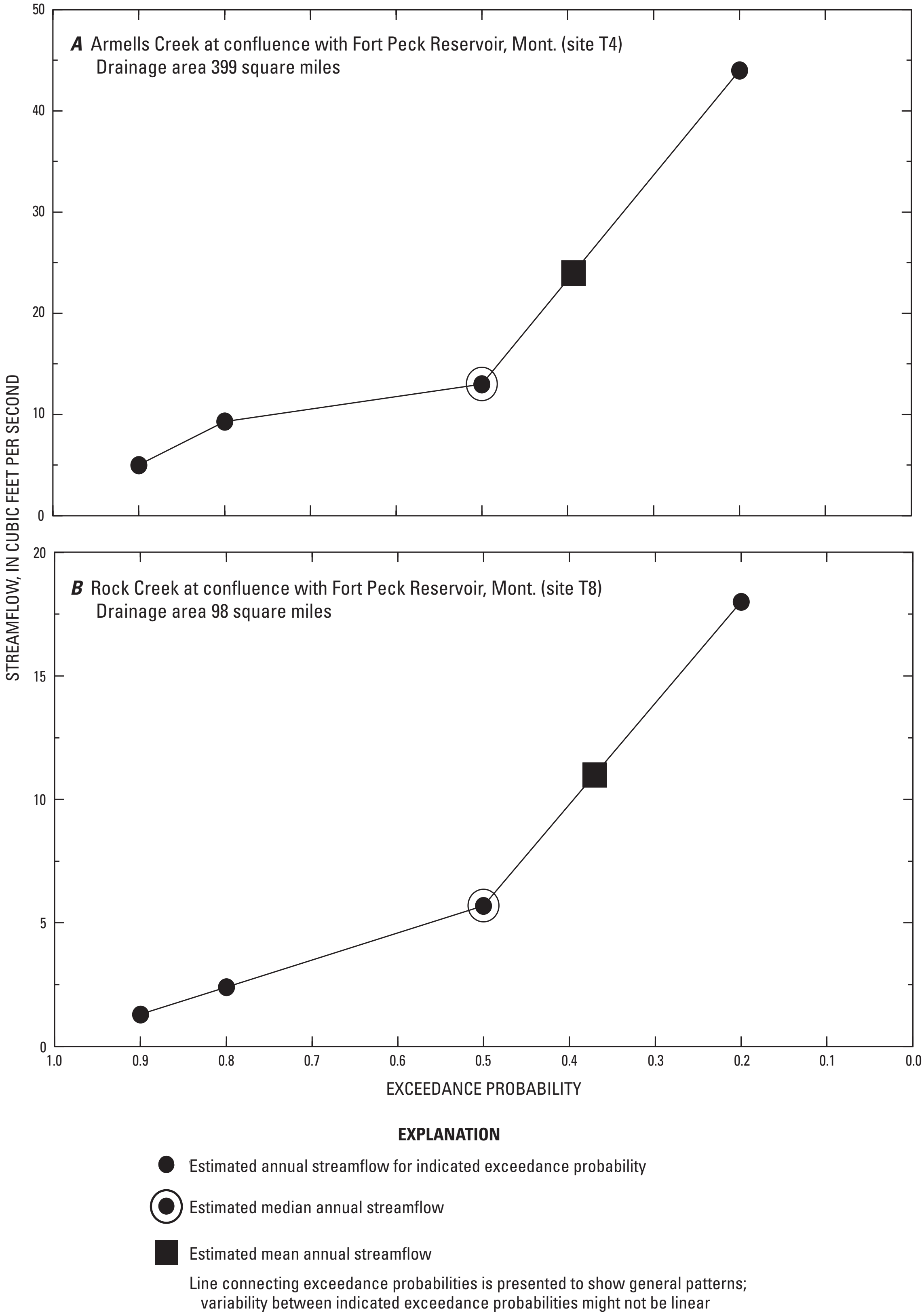


Figure 10. Estimated annual streamflow (derived by using regression equations, table 8, and estimation coefficients, table 3) for various exceedance probabilities for selected ungaged sites. *A*, Armells Creek at confluence with Fort Peck Reservoir, Mont.; *B*, Rock Creek at confluence with Fort Peck Reservoir, Mont.; *C*, Big Dry Creek at confluence with Fort Peck Reservoir, Mont.; *D*, Nelson Creek at confluence with Fort Peck Reservoir, Mont.

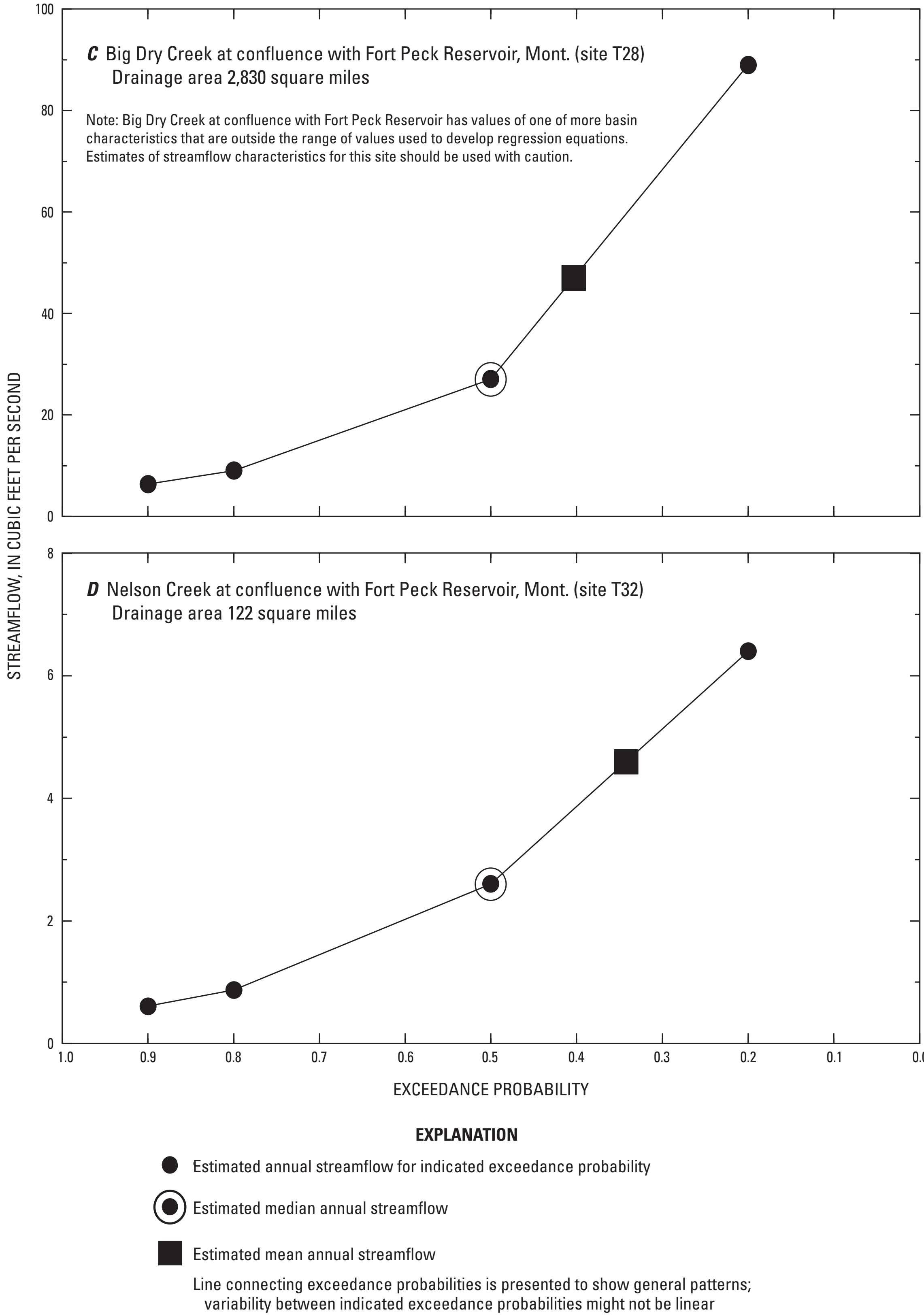


Figure 10. Estimated annual streamflow (derived by using regression equations, table 8, and estimation coefficients, table 3) for various exceedance probabilities for selected ungaged sites. *A*, Armells Creek at confluence with Fort Peck Reservoir, Mont.; *B*, Rock Creek at confluence with Fort Peck Reservoir, Mont.; *C*, Big Dry Creek at confluence with Fort Peck Reservoir, Mont.; *D*, Nelson Creek at confluence with Fort Peck Reservoir, Mont.—Continued

the ungaged sites homogenize general regional streamflow patterns. Thus, actual site-to-site variability is very likely to be larger than that indicated by the estimates presented in Supplement 7 and figure 9.

Estimated peak-flow characteristics for the selected ungaged sites (estimated by using regression equations, table 9) are presented in Supplement 8 (at the back of this report), and example plots of peak-flow characteristics for ungaged sites are shown in figure 11. Parrett and Johnson (2003) noted that peak-flow characteristics for streams in eastern Montana tend to be more variable, both spatially and temporally, than those for streams in other parts of Montana and that most annual peak flows in the study area occur during the months of March through July.

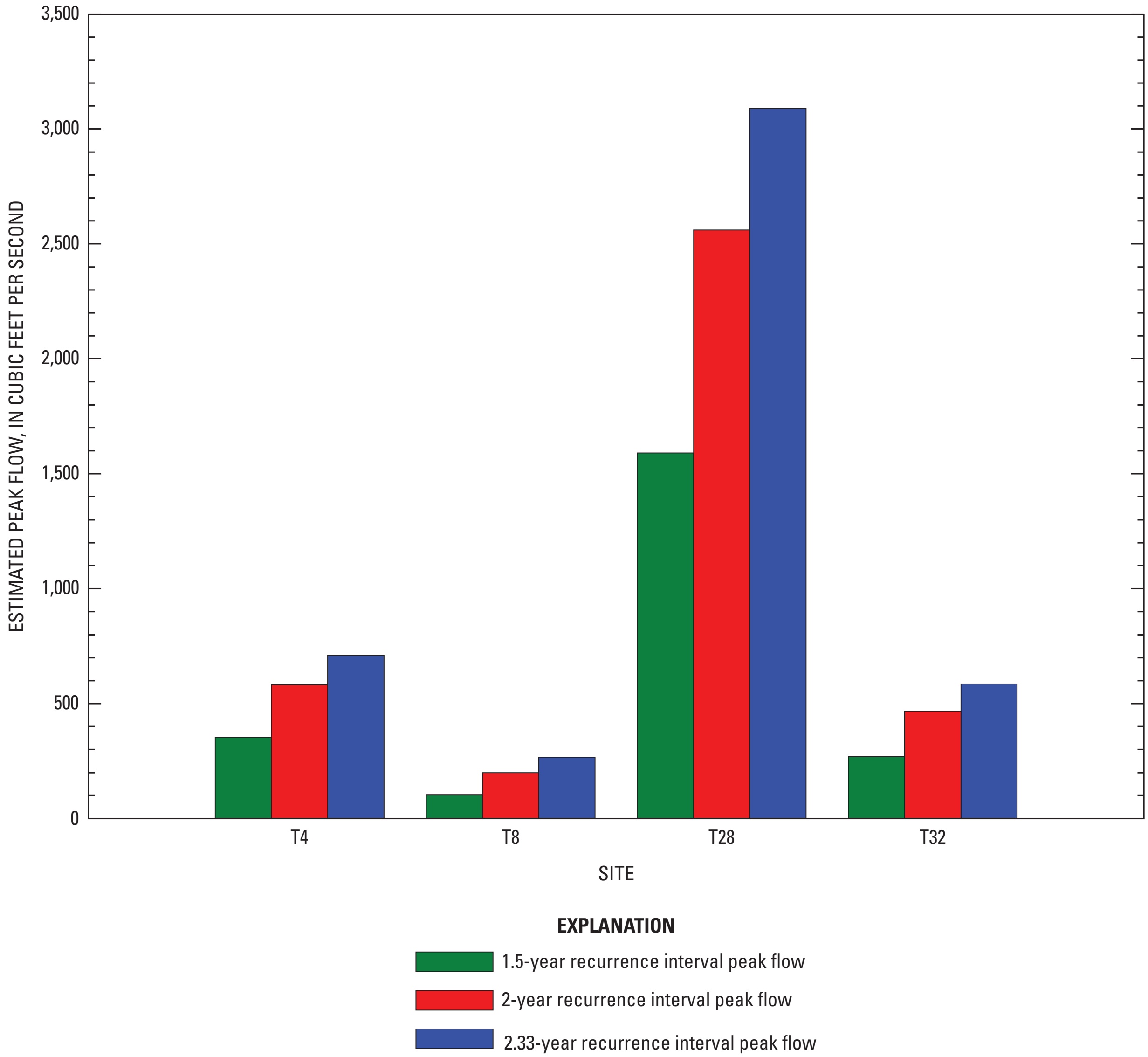


Figure 11. Estimated 1.5-, 2-, and 2.33-year recurrence interval peak flows (determined by using regression equations, table 9) for selected ungaged sites: T4 (Armells Creek at confluence with Fort Peck Reservoir, Mont.), T8 (Rock Creek at confluence with Fort Peck Reservoir, Mont.), T28 (Big Dry Creek at confluence with Fort Peck Reservoir, Mont.), and T32 (Nelson Creek at confluence with Fort Peck Reservoir, Mont.).

Summary

Charles M. Russell National Wildlife Refuge (CMR) encompasses about 1.1 million acres (including Fort Peck Reservoir on the Missouri River) in northeastern Montana. To ensure that sufficient streamflow remains in the tributary streams to maintain the riparian corridors, the U.S. Fish and Wildlife Service (FWS) is negotiating water-rights issues with the Reserved Water Rights Compact Commission of Montana. These negotiations require accurate information about current and long-term streamflow characteristics for Missouri River tributary streams that cross CMR. However, there are very few long-term streamflow data for these streams. Thus, the U.S. Geological Survey (USGS), in cooperation with the FWS, conducted a study to gage, for a short period, selected streams that cross CMR, and analyze data to estimate long-term streamflow characteristics for CMR.

To address the need for streamflow information in CMR, a three-phased approach was used that involved (1) collecting continuous records of daily mean streamflow for a 5-year period (water years 2000–2004, hereinafter referred to as the study period) for five streams that cross CMR, (2) estimating long-term streamflow characteristics for the five gaging stations by using relations between study-period streamflow characteristics and long-term streamflow characteristics for nearby long-term gaging stations to adjust recorded study-period streamflow characteristics, and (3) developing regional regression equations to relate streamflow characteristics to basin characteristics. The long-term streamflow characteristics of primary interest include the monthly and annual 90-, 80-, 50-, and 20-percent exceedance streamflows and mean streamflows (Q.90, Q.80, Q.50, Q.20, and QM, respectively), and the 1.5-, 2-, and 2.33-year peak flows (PK1.5, PK2, and PK2.33, respectively).

The Regional Adjustment Relationship (RAR) was investigated for estimating the monthly and annual Q.90, Q.80, Q.50, Q.20, and QM, and the PK1.5, PK2, and PK2.33 for the short-term CMR gaging stations (hereinafter referred to as CMR stations). The conceptual basis of the RAR is that at any given stream site the correlation between a streamflow characteristic for a short period of record and long-term streamflow characteristics is consistent over a somewhat broad and climatically homogeneous region.

For the CMR stations, the RAR regression equations were determined to provide acceptable results for estimating the long-term Q.90, Q.80, Q.50, Q.20, and QM on a monthly basis for the months of March through June, and also on an annual basis. For the months of September through January, the RAR regression equations did not provide acceptable results for any long-term streamflow characteristic. For the month of February, the RAR regression equations provided acceptable results for the long-term Q.50 and QM but poor results for the long-term Q.90, Q.80, and Q.20. For the months of July and August, the RAR provided acceptable results for the long-term Q.50, Q.20, and QM but poor results for the long-term Q.90 and Q.80.

Estimation coefficients were developed for estimating the long-term streamflow characteristics for which the RAR did not provide acceptable results. These coefficients were developed by using continuous streamflow records from streams in the study area or in nearby watersheds that generally are hydrologically similar to the streams that cross CMR. The estimation coefficients were determined by calculating the ratio of a given streamflow characteristic to the mean annual streamflow. Estimation coefficients were developed for three types of watersheds: (1) watersheds with maximum elevations less than about 5,000 ft (above NAVD 88), (2) watersheds on the south side of the Missouri River with maximum elevations greater than about 5,000 ft, and (3) watersheds on the north side of the Missouri River with maximum elevations greater than about 5,000 ft. Estimation coefficients for each watershed type and each streamflow characteristic were calculated by determining the weighted average (weighting based on number of years of record) of the ratios of all the selected gaging stations for a given watershed type.

The RAR also was investigated for estimating the long-term PK1.5, PK2, and PK2.33 for three of the CMR stations. The RAR regression equations were determined to provide acceptable results for estimating PK1.5, PK2, and PK2.33 for the three CMR stations.

Methods for estimating streamflow characteristics at ungaged sites also were needed by the FWS. Regression analyses that relate individual streamflow characteristics to various basin and climatic characteristics for gaging stations were performed to develop regression equations to estimate streamflow characteristics at ungaged sites. Selected basin and climatic characteristics that were considered as potential explanatory variables in regression analyses were determined by using a geographic information system.

Individual regression analyses were performed to determine if acceptable equations for estimating Q.90, Q.80, Q.50, Q.20, and QM on a monthly basis and an annual basis could be developed. Final equations for the annual Q.50, Q.20, and QM were developed by using weighted least squares regression. Acceptable equations also were developed for estimating QM for the months of February, March, April, June, and July, and Q.50, Q.20, and QM on an annual basis. However, equations for QM for the months of February, March, April, June, and July were determined to be less consistent and reliable than the use of estimation coefficients applied to the regression equation results for the annual QM. The monthly and annual streamflow characteristics for which acceptable regression equations were not developed or reported can be estimated by using the estimation coefficients.

Individual regression analyses also were performed to investigate if acceptable equations for the PK1.5, PK2, and PK2.33 could be developed. Final equations were developed using generalized least squares regression. In developing regression equations for peak-flow characteristics, the study area was divided into two regions: (1) the North Region, which includes that part of the study area north of the Missouri River, and (2) the South Region, which includes that part of the study area south of the Missouri River. Acceptable regression equations were developed for the PK1.5, PK2, and PK2.33.

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Supplemental Data

Supplement 1. Monthly and annual streamflow characteristics for long-term index gaging stations used in the Regional Adjustment Relationship (RAR).

[The gaging stations presented in this table are long-term index gaging stations used in the RAR to estimate long-term monthly and annual streamflow characteristics for short-term gaging stations in or near Charles M. Russell National Wildlife Refuge. All stations have 5 years of monthly mean streamflow (for all months) and annual mean streamflow record for the study period (water years 2000–2004). Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 20 (Big Dry Creek near Van Norman)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	1.9	2.2	2.1	1.4	1.6	78	5.7	4.3	65	81	7.0	1.2	21
Long-term monthly and annual streamflow characteristics (water years 1939–2005)													
Years of record	63	63	63	63	63	63	64	64	64	65	64	64	62
Q.90	.25	.36	.05	.00	.00	4.0	2.7	1.6	1.9	.78	.17	.05	5.7
Q.80	.53	.72	.30	.00	.23	5.8	4.4	3.3	2.7	1.6	.46	.24	9.6
Q.50	2.2	2.0	1.4	.27	3.5	50	9.4	8.2	16	11	3.8	1.7	27
Q.20	5.7	4.0	2.6	2.9	83	281	44	19	76	58	13	6.8	88
QM	6.1	3.0	2.6	6.4	71	250	81	28	59	43	16	16	49
Site 22 (Big Sandy Creek at reservation boundary, near Rocky Boy)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	2.7	2.6	2.1	2.0	1.8	4.3	5.1	5.6	9.6	5.0	2.9	2.4	3.8
Long-term monthly and annual streamflow characteristics (water years 1982–2005)													
Years of record	23	23	23	23	23	23	23	24	24	24	24	24	23
Q.90	2.1	1.7	1.7	1.5	1.2	2.1	4.5	3.3	2.3	2.3	1.1	1.5	3.4
Q.80	2.4	2.4	1.8	1.7	1.7	3.6	4.8	5.3	5.6	3.2	1.7	2.3	3.9
Q.50	4.3	3.8	3.4	2.9	3.3	4.9	8.0	9.5	14	9.8	5.8	4.4	6.4
Q.20	6.7	5.5	4.5	4.0	4.9	7.8	12	18	30	17	8.3	6.7	11
QM	5.2	4.5	4.0	3.4	4.1	6.3	10	13	18	13	6.5	5.3	7.7
Site 23 (Peoples Creek near Hays)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	0.04	0.08	0.23	0.11	0.18	12	1.5	3.7	2.6	0.79	0.08	0.01	1.8
Long-term monthly and annual streamflow characteristics (water years 1966–2005)													
Years of record	38	38	39	39	39	39	39	39	39	39	39	39	38
Q.90	.00	.01	.01	.00	.01	.92	.80	.25	.38	.00	.00	.00	.93
Q.80	.01	.02	.02	.02	.05	2.5	1.5	2.4	.95	.12	.01	.01	2.6

Supplement 1. Monthly and annual streamflow characteristics for long-term index gaging stations used in the Regional Adjustment Relationship (RAR).—Continued

[The gaging stations presented in this table are long-term index gaging stations used in the RAR to estimate long-term monthly and annual streamflow characteristics for short-term gaging stations in or near Charles M. Russell National Wildlife Refuge. All stations have 5 years of monthly mean streamflow (for all months) and annual mean streamflow record for the study period (water years 2000–2004). Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 23 (Peoples Creek near Hays)—Continued													
Long-term monthly and annual streamflow characteristics (water years 1966–2005)—Continued													
Q.50	0.12	0.35	0.78	0.34	2.2	14	9.0	7.3	9.2	1.7	0.11	0.06	4.7
Q.20	5.1	6.8	5.3	5.1	7.8	27	27	26	31	18	2.0	1.7	18
QM	3.2	3.2	2.6	3.3	8.5	28	17	29	20	7.9	2.2	3.4	11
Site 25 (Peoples Creek below Kuhr Coulee, near Dodson)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	0.00	0.03	0.17	0.15	0.23	37	3.5	10	10	6.2	1.5	0.00	5.8
Long-term monthly and annual streamflow characteristics (water years 1951–73, 1982–2005)													
Years of record	47	47	46	46	46	46	49	50	51	51	50	51	46
Q.90	.00	.00	.00	.00	.00	6.3	2.4	4.2	1.6	.00	.00	.00	3.9
Q.80	.00	.02	.00	.00	.23	11	4.2	6.1	2.5	2.4	.00	.00	5.7
Q.50	1.4	2.3	1.1	.52	4.9	32	21	18	16	7.40	.43	.16	16
Q.20	8.0	7.7	5.5	4.2	40	120	61	46	65	34	5.3	3.7	47
QM	8.1	5.5	4.3	5.0	29	78	52	52	41	22	3.2	12	26
Site 38 (Redwater River at Circle)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	0.23	0.11	0.09	0.1	0.14	11	1.3	0.54	0.58	1.4	0.43	0.2	1.4
Long-term monthly and annual streamflow characteristics (water years 1937–72, 1974–2004)													
Years of record	72	72	69	67	68	70	72	73	73	72	72	72	66
Q.90	.00	.00	.00	.00	.00	.63	.50	.21	.18	.02	.00	.00	.63
Q.80	.02	.03	.01	.00	.02	2.0	.9	.37	.34	.05	.00	.00	1.0
Q.50	.11	.11	.10	.06	.53	17	2.9	1.4	1.6	.28	.06	.07	5.7
Q.20	.35	.34	.26	.37	17	109	10	5.5	19	8.2	1.5	.31	21
QM	.51	.36	.43	.35	15	71	17	3.6	14	11	2.0	2.3	11

Supplement 1. Monthly and annual streamflow characteristics for long-term index gaging stations used in the Regional Adjustment Relationship (RAR).—Continued

[The gaging stations presented in this table are long-term index gaging stations used in the RAR to estimate long-term monthly and annual streamflow characteristics for short-term gaging stations in or near Charles M. Russell National Wildlife Refuge. All stations have 5 years of monthly mean streamflow (for all months) and annual mean streamflow record for the study period (water years 2000–2004). Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 40 (Poplar River near Poplar)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	22	29	20	9.1	10	209	132	100	125	65	19	15	63
Long-term monthly and annual streamflow characteristics (water years 1908–24, 1947–69, 1975–79, 1982–2005)													
Years of record	67	66	66	66	66	66	66	66	67	67	69	69	66
Q.90	8.3	9.8	5.1	.67	.47	18	71	37	19	11	2.0	4.4	35
Q.80	11	15	9.4	1.9	1.1	32	96	47	26	13	5.5	7.4	43
Q.50	24	25	15	7.1	10	128	236	83	59	52	19	14	82
Q.20	44	34	24	14	19	484	823	208	137	125	36	28	199
QM	28	27	17	8.5	26	326	649	123	89	77	27	24	118
Site 41 (Big Muddy Creek near Antelope)													
Study period (water years 2000–2004) mean monthly or annual streamflow													
QM	5.0	6.3	3.4	1.9	1.6	126	47	27	32	10	4.2	2.4	23
Long-term streamflow characteristics (water years 1979–2005)													
Years of record	27	27	27	27	27	27	27	27	27	27	27	27	27
Q.90	.42	2.3	1.6	.31	.3	12	13	6.7	1.7	1.3	.44	.07	6.2
Q.80	1.1	4.1	1.9	.65	.94	19	18	7.4	3.1	2.7	.72	.22	11
Q.50	4.4	5.4	3.3	1.6	2.0	40	40	16	9.4	10	3.4	2.8	20
Q.20	7.9	7.8	5.7	3.3	13	238	70	35	30	26	6.2	5.2	38
QM	5.3	5.8	3.6	1.9	22	133	109	26	19	24	8.5	4.2	30

Supplement 2. Selected peak-flow information for long-term index gaging stations used in the Regional Adjustment Relationship (RAR).

[The gaging stations presented in this table are long-term index gaging stations used in the RAR to estimate peak-flow characteristics for short-term gaging stations. All stations have 5 years of annual peak-flow records for the study period. Streamflow values are in cubic feet per second. Abbreviations: PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow; PKM, mean peak flow]

Site number (fig. 1)	Station number	Station name	PKM for study period (water years 2000–2004)	PKM for period of record (through water year 2005)	Years of annual peak flow records (through water year 2005)	PK1.5	PK2	PK2.33
3	06115300	Duval Creek near Landusky	80	126	43	31	62	82
20	06131000	Big Dry Creek near Van Norman	4,210	4,160	66	1,180	2,240	2,900
21	06131200	Nelson Creek near Van Norman	386	579	17	259	432	529
22	06137400	Big Sandy Creek at reservation boundary, near Rocky Boy	37	108	24	37	60	74
23	06154400	Peoples Creek near Hays	163	547	39	72	148	199
25	06154550	Peoples Creek below Kuhr Coulee, near Dodson	414	1,080	45	320	558	700
38	06177500	Redwater River at Circle	113	1,390	73	304	628	842
40	06181000	Poplar River near Poplar	1,490	5,790	55	1,170	2,260	2,970
41	06183450	Big Muddy Creek near Antelope	807	1,030	27	405	657	800

Supplement 3. Long-term monthly and annual streamflow characteristics (calculated by using period-of-record data through water year 2005) for selected gaging stations used to develop regression equations.

[The gaging stations presented in this table are stations that have 10 or more years of streamflow records and were used to develop regression equations that estimate monthly and annual streamflow characteristics for ungaged sites in or near Charles M. Russell National Wildlife Refuge. Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 8 (Box Elder Creek near Winnett)													
Long-term monthly and annual streamflow characteristics (water years 1930–33, 1934–36, 1958–72)													
Years of record	19	19	19	18	18	19	20	21	22	21	20	20	17
Q.90	.00	.00	.00	.00	.00	.72	.09	.00	.00	.00	.00	.00	4.7
Q.80	.00	.00	.00	.00	.00	1.7	1.2	.11	.16	.05	.00	.00	9.3
Q.50	.00	.05	.05	.00	.25	8.0	6.9	9.3	20	4.0	.21	.00	16
Q.20	.12	.26	.27	.35	7.9	112	17	49	175	21	6.6	.45	38
QM	.42	.16	.24	.34	20	51	14	57	100	23	3.1	.83	23
Site 15 (Sand Creek near Jordan)													
Long-term monthly and annual streamflow characteristics (water years 1957–67)													
Years of record	10	10	10	10	10	10	10	10	10	10	11	11	10
Q.90	.00	.00	.00	.00	.00	.28	.48	.14	.01	.00	.00	.00	1.3
Q.80	.00	.00	.00	.00	.06	.34	.54	.31	.06	.03	.00	.00	1.8
Q.50	.05	.06	.02	.04	.53	6.0	.75	.99	1.1	1.7	.00	.00	4.1
Q.20	.26	.41	.30	.19	11	29	7.0	3.5	5.7	20	.08	.10	6.6
QM	.11	.18	.11	.14	6.1	36	6.8	2.6	5.7	8.0	.15	.06	5.5
Site 20 (Big Dry Creek near Van Norman)													
Long-term monthly and annual streamflow characteristics (water years 1939–2005)													
Years of record	63	63	63	63	63	63	64	64	64	65	64	64	62
Q.90	.25	.36	.05	.00	.00	4.0	2.7	1.6	1.9	.78	.17	.05	5.7
Q.80	.53	.72	.30	.00	.23	5.8	4.4	3.3	2.7	1.6	.46	.24	9.6
Q.50	2.2	2.0	1.4	.27	3.5	50	9.4	8.2	16	11	3.8	1.7	27
Q.20	5.7	4.0	2.6	2.9	83	281	44	19	76	58	13	6.8	88
QM	6.1	3.0	2.6	6.4	71	250	81	28	59	43	16	16	49

Supplement 3. Long-term monthly and annual streamflow characteristics (calculated by using period-of-record data through water year 2005) for selected gaging stations used to develop regression equations.—Continued

[The gaging stations presented in this table are stations that have 10 or more years of streamflow records and were used to develop regression equations that estimate monthly and annual streamflow characteristics for ungaged sites in or near Charles M. Russell National Wildlife Refuge. Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 21 (Nelson Creek near Van Norman)													
Long-term monthly and annual streamflow characteristics (water years 1976–85, 2000–2004)													
Years of record	14	14	14	14	15	15	15	15	15	15	15	15	14
Q.90	.00	.00	.00	.00	.00	.18	.10	.00	.01	.00	.00	.00	.58
Q.80	.00	.00	.00	.00	.00	.51	.11	.00	.02	.00	.00	.00	.60
Q.50	.00	.00	.00	.00	.07	1.3	.30	.14	.42	.20	.01	.00	.97
Q.20	.11	.02	.00	.34	3.1	9.8	.75	.69	3.6	4.0	1.4	.00	1.6
QM	.16	.02	.02	.35	2.2	5.5	3.1	1.4	1.6	2.4	1.2	1.1	1.6
Site 23 (Peoples Creek near Hays)													
Long-term monthly and annual streamflow characteristics (water years 1966–2005)													
Years of record	38	38	39	39	39	39	39	39	39	39	39	39	38
Q.90	.00	.01	.01	.00	.01	.92	.80	.25	.38	.00	.00	.00	.93
Q.80	.01	.02	.02	.02	.05	2.5	1.5	2.4	.95	.12	.01	.01	2.6
Q.50	.12	.35	.78	.34	2.2	14	9.0	7.3	9.2	1.7	.11	.06	4.7
Q.20	5.1	6.8	5.3	5.1	7.8	27	27	26	31	18	2.0	1.7	18
QM	3.2	3.2	2.6	3.3	8.5	28	17	29	20	7.9	2.2	3.4	11
Site 25 (Peoples Creek below Kuhr Coulee, near Dodson)													
Long-term monthly and annual streamflow characteristics (water years 1951–73, 1982–2005)													
Years of record	47	47	46	46	46	46	49	50	51	51	50	51	46
Q.90	.00	.00	.00	.00	.00	6.3	2.4	4.2	1.6	.00	.00	.00	3.9
Q.80	.00	.02	.00	.00	.23	11	4.2	6.1	2.5	2.4	.00	.00	5.7
Q.50	1.4	2.3	1.1	.52	4.9	32	21	18	16	7.4	.43	.16	16
Q.20	8.0	7.7	5.5	4.2	40	120	61	46	65	34	5.3	3.7	47
QM	8.1	5.5	4.3	5.0	29	78	52	52	41	22	3.2	12	26

Supplement 3. Long-term monthly and annual streamflow characteristics (calculated by using period-of-record data through water year 2005) for selected gaging stations used to develop regression equations.—Continued

[The gaging stations presented in this table are stations that have 10 or more years of streamflow records and were used to develop regression equations that estimate monthly and annual streamflow characteristics for ungaged sites in or near Charles M. Russell National Wildlife Refuge. Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 30 (Beaver Creek above Dix Creek near Malta)													
Long-term monthly and annual streamflow characteristics (water years 1967–69, 1976–82)													
Years of record	10	10	10	10	10	10	10	10	10	10	10	10	10
Q.90	.00	.00	.00	.00	2.1	5.7	2.3	.53	.04	.00	.00	.00	2.2
Q.80	.00	.00	.00	.60	2.4	11	6.9	1.5	1.4	.00	.00	.00	4.5
Q.50	0.16	0.51	1.1	1.9	4.4	126	31	38	7.7	2.6	0.00	0.00	26
Q.20	3.6	2.7	4.4	3.4	38	524	194	156	38	46	.63	8.8	94
QM	2.6	1.7	2.8	3.9	28	318	117	68	34	26	1.5	33	53
Site 32 (Prairie Elk Creek near Oswego)													
Long-term monthly and annual streamflow characteristics (water years 1975–85)													
Years of record	10	10	10	10	10	10	10	10	10	10	10	10	10
Q.90	1.6	1.3	.47	.05	.04	3.4	1.7	1.6	2.6	.87	.68	.96	3.3
Q.80	1.8	1.3	.61	.10	.10	4.3	1.9	2.0	3.0	1.1	.80	1.0	4.0
Q.50	3.6	1.6	.78	.43	5.9	12	5.2	4.9	6.9	4.3	1.7	1.7	8.9
Q.20	9.3	2.1	1.0	11	33	77	14	15	73	21	4.5	5.3	24
QM	5.6	1.8	.9	3.8	30	70	24	10	27	12	3.3	8.5	16
Site 38 (Redwater River at Circle)													
Long-term monthly and annual streamflow characteristics (water years 1937–72, 1974–2004)													
Years of record	72	72	69	67	68	70	72	73	73	72	72	72	66
Q.90	.00	.00	.00	.00	.00	.63	.50	.21	.18	.02	.00	.00	.63
Q.80	.02	.03	.01	.00	.02	2.0	.9	.37	.34	.05	.00	.00	1.0
Q.50	.11	.11	.10	.06	.53	17	2.9	1.4	1.6	.28	.06	.07	5.7
Q.20	.35	.34	.26	.37	17	109	10	5.5	19	8.2	1.5	.31	21
QM	.51	.36	.43	.35	15	71	17	3.6	14	11	2.0	2.3	11

Supplement 3. Long-term monthly and annual streamflow characteristics (calculated by using period-of-record data through water year 2005) for selected gaging stations used to develop regression equations.—Continued

[The gaging stations presented in this table are stations that have 10 or more years of streamflow records and were used to develop regression equations that estimate monthly and annual streamflow characteristics for ungaged sites in or near Charles M. Russell National Wildlife Refuge. Streamflow values are in cubic feet per second. Abbreviations: Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow]

Indicated characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Site 45 (Burns Creek near Savage)													
Long-term monthly and annual streamflow characteristics (water years 1958–67, 1975–84, 1986)													
Years of record	21	21	21	20	20	20	20	20	20	20	20	20	20
Q.90	.19	.53	.26	.06	.00	1.1	1.9	.82	1.7	.14	.00	.00	1.2
Q.80	.22	.63	.45	.14	.24	1.7	2.3	1.1	2.0	.55	.01	.00	1.4
Q.50	1.0	.91	.66	.40	.79	15	4.8	3.0	4.4	1.8	.25	.21	5.3
Q.20	2.3	1.5	1.1	1.0	27	93	9.2	7.2	11	5.3	1.1	1.3	11
QM	1.5	1.1	.81	.76	13	38	12	4.4	6.1	4.3	.56	1.1	7.0

Supplement 4. Selected basin and climatic characteristics for gaging stations used in various analyses to estimate streamflow characteristics.

[Elevation information is referenced to the North American Vertical Datum of 1988. Abbreviation: GIS, geographic information system. Symbol: --, no data]

Site number (fig. 1)	Station number	Station name	Drainage area, in square miles		Basinwide mean elevation, in feet		Maximum elevation, in feet	
			Manually determined[1]	GIS determined[2, 3]	Manually determined[1]	GIS determined[2]	Manually determined[1]	GIS determined[1]
1	06114900	Taffy Creek tributary near Winifred	3.0	2.9	3,290	3,295	--	3,450
2	06115270	Armells Creek near Landusky	--	397	--	3,339	--	6,427
3	06115300	Duval Creek near Landusky	3.3	3.9	3,110	3,101	--	3,264
4	06115350	Rock Creek near Landusky	--	75	--	3,398	--	5,528
5	06127520	Home Creek near Sumatra	2.0	2.3	3,190	3,183	--	3,328
6	06127570	Butts Coulee near Melstone	6.7	6.8	3,000	3,008	--	3,222
7	06128900	Box Elder Creek tributary near Winnett	16	16	2,900	2,913	--	3,181
8	06129000	Box Elder Creek near Winnett	684	690	3,470	3,440	--	6,382
9	06129500	McDonald Creek at Winnett	421	428	4,140	4,003	--	6,078
10	06129700	Gorman Coulee near Cat Creek	2.3	2.4	2,910	2,931	--	3,005
11	06130600	Cat Creek near Cat Creek	37	35	2,870	2,900	--	3,176
12	06130610	Bair Coulee near Mosby	1.8	1.8	3,130	3,152	--	3,361
13	06130620	Blood Creek tributary near Valentine	2.0	2.0	3,100	3,093	--	3,293
14	06130650	Hell Creek near Jordan	71	70	--	2,779	--	3,115
15	06130700	Sand Creek near Jordan	317	315	3,050	3,036	--	3,650
16	06130850	Second Creek tributary No. 2 near Jordan	2.1	2.1	2,830	2,794	--	2,928
17	06130915	Russian Coulee near Jordan	3.5	3.4	2,660	2,658	--	2,777
18	06130940	Spring Creek tributary near Van Norman	1.4	1.3	2,570	2,596	--	2,748
19	06130950	Little Dry Creek near Van Norman	1,224	1,222	2,860	2,853	--	3,621
20	06131000	Big Dry Creek near Van Norman	2,554	2,551	2,870	2,874	--	3,650
21	06131200	Nelson Creek near Van Norman	100	110	2,620	2,593	--	2,904
22	06137400	Big Sandy Creek at reservation boundary, near Rocky Boy	25	25	4,860	4,776	--	6,359
23	06154400	Peoples Creek near Hays	220	226	3,570	3,588	--	5,978
24	06154410	Little Peoples Creek near Hays	13	13	4,640	4,547	--	5,692
25	06154550	Peoples Creek below Kuhr Coulee, near Dodson	675	697	3,500	3,218	--	5,978
26	06155100	Black Coulee near Malta	6.6	12	2,550	2,564	--	2,679
27	06155200	Alkali Creek near Malta	162	184	2,470	2,508	--	2,809
28	06155300	Disjardin Coulee near Malta	4.8	3.9	2,470	2,521	--	2,664

Supplement 4. Selected basin and climatic characteristics for gaging stations used in various analyses to estimate streamflow characteristics.—Continued

[Elevation information is referenced to the North American Vertical Datum of 1988. Abbreviation: GIS, geographic information system. Symbol: --, no data]

Site number (fig. 1)	Station number	Station name	Drainage area, in square miles		Basinwide mean elevation, in feet		Maximum elevation, in feet	
			Manually determined[1]	GIS determined[2, 3]	Manually determined[1]	GIS determined[2]	Manually determined[1]	GIS determined[1]
29	06164600	Beaver Creek tributary near Zortman	3.9	3.8	3,260	3,255	--	3,734
30	06164800	Beaver Creek above Dix Creek, near Malta	929	920	2,730	2,710	--	5,607
31	06173300	Willow Creek tributary near Fort Peck	0.9	0.9	2,360	2,357	--	2,458
32	06175540	Prairie Elk Creek near Oswego	352	340	2,460	2,398	--	2,848
33	06175550	East Fork Sand Creek near Vida	8.5	8.7	2,440	2,432	--	2,666
34	06177050	East Fork Duck Creek near Brockway	12	15	2,910	2,932	--	3,387
35	06177100	Duck Creek near Brockway	54	55	2,910	2,951	--	3,599
36	06177150	Redwater River at Brockway	216	217	2,810	2,844	--	3,610
37	06177200	Tusler Creek near Brockway	90	89	2,980	2,953	--	3,526
38	06177500	Redwater River at Circle	547	550	2,810	2,813	--	3,610
39	06177700	Cow Creek tributary near Vida	1.7	1.9	2,490	2,494	--	2,615
40	06181000	Poplar River near Poplar	3,174	--	2,730	2,625	--	3,306
41	06183450	Big Muddy Creek near Antelope	967	--	2,380	2,384	--	2,842
42	06294900	Middle Fork Froze to Death Creek tributary near Ingomar	1.4	1.4	3,220	3,201	--	3,428
43	06309020	Rock Springs Creek tributary at Rock Springs	1.0	1.1	3,000	3,011	--	3,078
44	06309040	Dry House Creek near Angela	39	37	2,940	2,932	--	3,128
45	06329200	Burns Creek near Savage	233	234	2,600	2,586	--	3,098

[1]Basin or climatic characteristic not used in final regression models for any annual streamflow or peak-flow characteristics; provided for informational purposes only.

[2]Basin characteristic used in final regression models for estimating peak-flow characteristics.

[3]Basin characteristic used in final regression models for estimating annual streamflow characteristics.

Supplement 5. Selected peak-flow characteristics (calculated by using period-of-record data through water year 2005) for selected gaging stations used to develop regression equations.

[The gaging stations presented in this table are stations that have 10 or more years of annual peak-flow records and were used to develop regression equations that estimate peak-flow characteristics for ungaged sites. Streamflow values are in cubic feet per second. Abbreviations: PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow]

Site number (fig. 1)	Station number	Station name	Years of annual peak records	PK1.5	PK2	PK2.33
1	06114900	Taffy Creek tributary near Winifred	29	29	48	58
3	06115300	Duval Creek near Landusky	43	31	62	82
5	06127520	Home Creek near Sumatra	33	13	26	34
6	06127570	Butts Coulee near Melstone	43	54	84	100
7	06128900	Box Elder Creek tributary near Winnett	19	81	124	147
8	06129000	Box Elder Creek near Winnett	20	867	1,270	1,490
9	06129500	McDonald Creek at Winnett	36	223	338	401
10	06129700	Gorman Coulee near Cat Creek	33	32	71	98
11	06130600	Cat Creek near Cat Creek	18	60	93	111
12	06130610	Bair Coulee near Mosby	32	7.4	16	22
13	06130620	Blood Creek tributary near Valentine	32	4.1	8.2	11
15	06130700	Sand Creek near Jordan	11	414	647	780
16	06130850	Second Creek tributary No. 2 near Jordan	33	12	24	31
17	06130915	Russian Coulee near Jordan	32	21	36	46
18	06130940	Spring Creek tributary near Van Norman	32	22	39	49
19	06130950	Little Dry Creek near Van Norman	20	1,510	2,130	2,450
20	06131000	Big Dry Creek near Van Norman	66	1,180	2,240	2,900
21	06131200	Nelson Creek near Van Norman	17	259	432	529
23	06154400	Peoples Creek near Hays	39	72	148	199
24	06154410	Little Peoples Creek near Hays	33	25	42	53
25	06154550	Peoples Creek below Kuhr Coulee, near Dodson	45	320	558	700
26	06155100	Black Coulee near Malta	13	49	73	88
27	06155200	Alkali Creek near Malta	18	66	149	209
28	06155300	Disjardin Coulee near Malta	47	17	27	33
29	06164600	Beaver Creek tributary near Zortman	32	31	55	70
30	06164800	Beaver Creek above Dix Creek, near Malta	12	355	831	1,170
31	06173300	Willow Creek tributary near Fort Peck	19	24	47	62
32	06175540	Prairie Elk Creek near Oswego	10	690	1,050	1,250
33	06175550	East Fork Sand Creek near Vida	15	112	178	216
34	06177050	East Fork Duck Creek near Brockway	48	44	75	94
35	06177100	Duck Creek near Brockway	17	77	164	222
36	06177150	Redwater River at Brockway	18	315	558	701
37	06177200	Tusler Creek near Brockway	16	82	140	173
38	06177500	Redwater River at Circle	73	304	628	842
39	06177700	Cow Creek tributary near Vida	43	32	65	87
42	06294900	Middle Fork Froze to Death Creek tributary near Ingomar	15	50	69	79
43	06309020	Rock Springs Creek tributary at Rock Springs	17	6.1	10	12
44	06309040	Dry House Creek near Angela	16	73	144	190
45	06329200	Burns Creek near Savage	21	158	311	409

Supplement 6. Selected basin and climatic characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.

[All basin and climatic characteristics determined by using geographic information system (GIS). Elevation information is referenced to the North American Vertical Datum of 1988. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir]

Stream name	Site map number	Location on stream	Drainage area, in square miles[1, 2]	Mean elevation, in feet[1]	Maximum elevation, in feet[3]	Minimum elevation, in feet[4]	Relief, in feet[2]	Basinwide mean slope, in feet per mile[4]	Mean annual precipitation, in inches[4]
Two Calf Creek	T1	at CMR boundary	93	3,003	3,556	2,350	1,206	11.2	14.3
	T2	at confluence with FPR	122	2,973	3,556	2,253	1,302	11.8	14.3
Armells Creek	T3	at CMR boundary	335	3,430	6,427	2,436	3,991	10.1	15.2
	T4	at confluence with FPR	399	3,336	6,427	2,244	4,183	10.8	15.1
Siparyann Creek	T5	at CMR boundary	41	3,256	5,164	2,641	2,523	8.4	13.9
	T6	at confluence with FPR	58	3,086	5,164	2,268	2,896	11.1	13.8
Rock Creek	T7	at CMR boundary	75	3,398	5,528	2,670	2,858	10.8	14.6
	T8	at confluence with FPR	98	3,236	5,528	2,249	3,279	12.0	14.3
C K Creek	T9	at CMR boundary	82	3,398	5,725	2,656	3,070	9.4	15.0
	T10	at confluence with FPR	122	3,180	5,725	2,250	3,475	10.2	14.4
Beauchamp Creek	T11	at CMR boundary	141	2,865	4,044	2,381	1,662	6.7	13.2
	T12	at confluence with FPR	162	2,829	4,044	2,252	1,792	7.6	13.2
Sacajawea River	T13	at CMR boundary	372	2,866	3,505	2,281	1,223	6.6	13.7
	T14	at confluence with FPR	387	2,855	3,505	2,263	1,241	6.9	13.6
Squaw Creek	T15	at CMR boundary	191	2,851	3,397	2,283	1,114	12.1	13.1
	T16	at confluence with FPR	194	2,845	3,397	2,260	1,137	12.2	13.1
Fourchette Creek	T17	at CMR boundary	69	2,636	2,845	2,342	503	3.9	12.6
	T18	at confluence with FPR	350	2,583	3,232	2,252	980	4.4	12.7

Supplement 6. Selected basin and climatic characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[All basin and climatic characteristics determined by using geographic information system (GIS). Elevation information is referenced to the North American Vertical Datum of 1988. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir]

Stream name	Site map number	Location on stream	Drainage area, in square miles[1, 2]	Mean elevation, in feet[1]	Maximum elevation, in feet[3]	Minimum elevation, in feet[4]	Relief, in feet[2]	Basinwide mean slope, in feet per mile[4]	Mean annual precipitation, in inches[4]
Telegraph Creek	T19	at CMR boundary	169	2,631	3,232	2,282	950	4.7	12.8
	T20	at confluence with Fourchette Creek	207	2,611	3,232	2,261	971	4.6	12.8
Seven Blackfoot Creek	T21	at CMR boundary	86	3,066	3,406	2,298	1,108	14.5	13.3
	T22	at confluence with FPR	90	3,048	3,406	2,253	1,153	15.0	13.3
Timber Creek (north of the Missouri River)	T23	at CMR boundary	147	2,714	3,346	2,264	1,082	10.4	12.9
	T24	at confluence with FPR	147	2,713	3,346	2,264	1,082	10.4	12.9
Hell Creek	T25	at CMR boundary	64	2,799	3,115	2,325	791	9.0	13.1
	T26	at confluence with FPR	73	2,771	3,115	2,242	873	10.0	13.1
Big Dry Creek	T27	at CMR boundary	2,761	2,852	3,650	997	2,653	5.5	12.8
	T28	at confluence with FPR	2,830	2,843	3,650	997	2,653	5.5	12.8
Timber Creek (south of the Missouri River)	T29	at CMR boundary	329	2,663	3,406	2,276	1,131	5.3	12.5
	T30	at confluence with FPR	331	2,661	3,406	2,257	1,149	5.4	12.5
Nelson Creek	T31	at CMR boundary	118	2,584	2,904	2,285	619	7.5	12.6
	T32	at confluence with FPR	122	2,578	2,904	2,247	656	7.6	12.6

[1]Basin characteristic used in final regression models for estimating peak-flow characteristics.

[2]Basin characteristic used in final regression models for estimating annual streamflow characteristics.

[3]Basin characteristic not used in final regression models for any annual streamflow or peak-flow characteristic; however, basin characteristic was used to determine applicable estimation coefficients for monthly streamflow characteristics.

[4]Basin or climatic characteristic not used in final regression models for any annual streamflow or peak-flow characteristic; provided for informational purposes only.

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Two Calf Creek	T1	at CMR boundary	Q.90	0.03	0.06	0.02	<0.01	0.01	0.55	0.43	0.2	0.34	0.1	0.01	<0.01	0.77
			Q.80	.04	.09	.05	.02	.06	1.1	.63	.36	.47	.22	.03	.01	1.1
			Q.50	.20	.18	.14	.08	.48	7.8	1.6	1.2	1.8	.96	.24	.10	3.2
			Q.20	.54	.39	.27	.40	10	47	6.2	3.9	7.7	6.6	1.8	.48	8.6
			QM	.51	.30	.27	.51	7.9	31	9.4	3.2	6.7	5.4	1.7	1.7	5.7
	T2	at confluence with FPR	Q.90	.03	.07	.03	<.01	.02	.66	.51	.24	.41	.12	.02	<.01	0.92
			Q.80	.05	.10	.06	.02	.07	1.3	.75	.43	.56	.26	.04	.01	1.3
			Q.50	.24	.21	.16	.09	.57	9.3	1.9	1.4	2.1	1.1	.29	.12	3.8
			Q.20	.64	.47	.33	.48	12	56	7.4	4.6	9.1	7.8	2.2	.57	10
			QM	.61	.35	.32	.61	9.4	37	11	3.8	8.0	6.4	2.0	2.0	6.8
Armells Creek	T3	at CMR boundary	Q.90	<.01	<.01	<.01	<.01	<.01	1.2	.12	.05	1.4	.02	<.01	<.01	4.4
			Q.80	<.01	<.01	<.01	<.01	<.01	2.1	1.0	.63	2.3	.09	<.01	<.01	8.3
			Q.50	<.01	.04	.04	<.01	.20	25	5.5	12	20	2.2	.41	<.01	12
			Q.20	.03	.18	.22	.28	19	129	12	111	115	22	6.2	.25	39
			QM	.34	.12	.20	.28	24	60	12	57	86	15	2.9	.10	22
	T4	at confluence with FPR	Q.90	<.01	<.01	<.01	<.01	<.01	1.3	.14	.06	1.6	.02	<.01	<.01	5.0
			Q.80	<.01	<.01	<.01	<.01	<.01	2.4	1.1	.70	2.6	.11	<.01	<.01	9.3
			Q.50	<.01	.04	.04	<.01	.22	28	6.2	13	22	2.4	.46	<.01	13
			Q.20	.04	.20	.24	.31	21	144	14	124	128	25	6.9	.28	44
			QM	.38	.13	.22	.31	27	67	14	64	97	17	3.3	.12	24

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Siparyann Creek	T51	at CMR boundary	Q.90	<0.01	<0.01	<0.01	0.02	0.10	1.2	0.67	0.39	0.31	<0.01	<0.01	<0.01	0.75
			Q.80	<.01	.01	.02	.04	.15	2.2	1.1	1.2	.59	.28	<.01	<.01	1.3
			Q.50	.18	.35	.30	.22	1.2	8.4	4.8	4.0	4.1	1.2	.16	.04	3.2
			Q.20	2.1	2.5	2.0	1.7	6.8	27	14	12	13	7.9	1.0	.96	9.5
			QM	1.6	1.4	1.2	1.4	5.5	20	11	13	9.4	4.4	.91	2.6	6.0
	T61	at confluence with FPR	Q.90	<.01	<.01	.01	.02	.13	1.5	.87	.50	.40	<.01	<.01	<.01	.97
			Q.80	<.01	.01	.02	.06	.20	2.8	1.4	1.5	.76	.36	<.01	<.01	1.7
			Q.50	.24	.46	.39	.28	1.5	11	6.2	5.1	5.2	1.6	.20	.05	4.1
			Q.20	2.7	3.2	2.5	2.2	8.8	35	18	15	17	10	1.4	1.2	13
			QM	2.1	1.8	1.5	1.8	7.0	25	14	16	12	5.7	1.2	3.3	7.7
Rock Creek	T7	at CMR boundary	Q.90	<.01	<.01	.01	.02	.15	1.7	.97	.56	.45	<.01	<.01	<.01	1.1
			Q.80	<.01	.02	.02	.06	.22	3.2	1.6	1.6	.85	.40	<.01	<.01	1.9
			Q.50	.26	.51	.43	.31	1.7	12	6.9	5.7	5.8	1.8	.23	.05	4.6
			Q.20	3.0	3.6	2.8	2.5	9.8	39	20	17	19	11	1.5	1.4	14
			QM	2.4	2.0	1.7	2.0	7.9	28	16	18	14	6.3	1.3	3.7	8.6
	T8	at confluence with FPR	Q.90	<.01	<.01	.01	.03	.19	2.0	1.2	.69	.55	<.01	<.01	<.01	1.3
			Q.80	<.01	.02	.03	.08	.27	3.9	1.9	2.0	1.0	.49	<.01	<.01	2.4
			Q.50	.33	.63	.53	.38	2.1	15	8.5	7.0	7.2	2.2	.28	.06	5.7
			Q.20	3.7	4.4	3.5	3.1	12	48	24	21	23	14	1.9	1.7	18
			QM	2.9	2.5	2.0	2.5	9.7	35	19	23	17	7.8	1.6	4.6	11

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
C K Creek	T9	at CMR boundary	Q.90	<0.01	<0.01	0.01	0.03	0.16	1.8	1.1	0.61	0.49	<0.01	<0.01	<0.01	1.2
			Q.80	<.01	.02	.02	.07	.24	3.5	1.7	1.8	.92	.44	<.01	<.01	2.1
			Q.50	.29	.56	.47	.34	1.9	13	7.5	6.2	6.4	2.0	.25	.06	5.1
			Q.20	3.3	3.9	3.1	2.7	11	42	21	19	21	12	1.6	1.5	16
			QM	2.6	2.2	1.8	2.2	8.6	31	17	20	15	6.9	1.4	4.0	9.4
	T10	at confluence with FPR	Q.90	<.01	<.01	.02	.03	.21	2.4	1.4	.80	.64	<.01	<.01	<.01	1.6
			Q.80	<.01	.02	.03	.09	.31	4.5	2.2	2.4	1.2	.57	<.01	<.01	2.7
			Q.50	.37	.73	.61	.44	2.4	17	9.8	8.1	8.3	2.6	.32	.07	6.6
			Q.20	4.3	5.0	4.0	3.6	14	55	28	24	27	16	2.2	2.0	21
			QM	3.4	2.8	2.4	2.8	11	40	22	26	19	9.0	1.9	5.2	12
Beauchamp Creek	T11	at CMR boundary	Q.90	.04	.09	.04	<.01	.02	.82	.63	.29	.50	.15	.02	<.01	1.1
			Q.80	.06	.13	.08	.02	.09	1.6	.93	.53	.70	.32	.04	.02	1.6
			Q.50	.29	.26	.20	.11	.70	12	2.4	1.8	2.6	1.4	.36	.14	4.7
			Q.20	.79	.58	.40	.59	15	69	9.1	5.7	11	9.7	2.7	.70	13
			QM	.75	.44	.40	.75	12	46	14	4.8	9.9	7.9	2.5	2.4	8.5
	T12	at confluence with FPR	Q.90	.04	.10	.04	<.01	.02	.92	.70	.33	.56	.17	.02	<.01	1.3
			Q.80	.07	.14	.09	.03	.10	1.8	1.0	.59	.78	.36	.05	.02	1.8
			Q.50	.33	.29	.22	.12	.79	13	2.6	2.0	2.9	1.6	.40	.16	5.3
			Q.20	.89	.64	.45	.66	17	78	10	6.4	13	11	3.0	.79	15
			QM	.84	.49	.45	.84	13	52	15	5.3	11	8.9	2.8	2.7	9.5

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Sacajawea River	T13	at CMR boundary	Q.90	0.05	0.12	0.05	0.01	0.02	1.1	0.84	0.39	0.67	0.20	0.03	<0.01	1.5
			Q.80	.09	.17	.10	.03	.11	2.1	1.2	.70	.93	.43	.06	.02	2.2
			Q.50	.39	.35	.27	.15	.94	15	3.1	2.4	3.5	1.9	.48	.19	6.4
			Q.20	1.1	.77	.54	.79	20	93	12	7.6	15	13	3.6	.94	18
			QM	1.0	.58	.53	1.0	16	62	18	6.3	13	11	3.3	3.3	11
	T14	at confluence with FPR	Q.90	.05	.12	.05	.01	.03	1.1	.86	.40	.69	.20	.03	<.01	1.6
			Q.80	.09	.18	.10	.03	.12	2.2	1.3	.72	.95	.44	.06	.02	2.2
			Q.50	.40	.36	.27	.15	.96	16	3.2	2.4	3.6	1.9	.49	.19	6.6
			Q.20	1.1	.79	.55	.81	21	95	12	7.8	15	13	3.7	.96	18
			QM	1.0	.60	.55	1.0	16	63	19	6.5	14	11	3.4	3.4	12
Squaw Creek	T15	at CMR boundary	Q.90	.03	.08	.03	<.01	.02	.75	.58	.27	.46	.14	.02	<.01	1.0
			Q.80	.06	.12	.07	.02	.08	1.4	.85	.48	.64	.3	.04	.01	1.5
			Q.50	.27	.24	.18	.10	.64	11	2.2	1.6	2.4	1.3	.33	.13	4.4
			Q.20	.72	.53	.37	.54	14	64	8.3	5.2	10	8.9	2.5	.64	12
			QM	.69	.40	.36	.68	11	42	13	4.4	9.0	7.2	2.3	2.2	7.7
	T16	at confluence with FPR	Q.90	.03	.08	.03	<.01	.02	.76	.59	.27	.47	.14	.02	<.01	1.1
			Q.80	.06	.12	.07	.02	.08	1.5	.87	.49	.65	.30	.04	.02	1.5
			Q.50	.27	.25	.19	.10	.65	11	2.2	1.7	2.4	1.3	.34	.13	4.5
			Q.20	.74	.54	.37	.55	14	65	8.5	5.3	11	9.0	2.5	.66	12
			QM	.70	.41	.37	.70	11	43	13	4.4	9.2	7.4	2.3	2.3	7.9

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Fourchette Creek	T17[1]	at CMR boundary	Q.90	0.01	0.03	0.01	<0.01	<0.01	0.29	0.22	0.10	0.18	0.05	<0.01	<0.01	0.40
			Q.80	.02	.05	.03	<.01	.03	.55	.33	.19	.24	.11	.02	<.01	.57
			Q.50	.10	.09	.07	.04	.25	4.0	.82	.62	.91	.49	.13	.05	1.7
			Q.20	.28	.20	.14	.21	5.3	24	3.2	2.0	4.0	3.4	.95	.25	4.0
			QM	.26	.15	.14	.26	4.1	16	4.8	1.7	3.5	2.8	.87	.86	3.0
	T18	at confluence with FPR	Q.90	.04	.10	.04	<.01	.02	.93	.71	.33	.57	.17	.03	<.01	1.3
			Q.80	.07	.15	.09	.03	.10	1.8	1.1	.60	.79	.37	.05	.02	1.8
			Q.50	.33	.30	.23	.13	.80	13	2.7	2.0	3.0	1.6	.41	.16	5.5
			Q.20	.90	.65	.46	.67	17	79	10	6.5	13	11	3.1	.80	15
			QM	.85	.49	.45	.85	13	52	16	5.4	11	9.0	2.8	2.8	9.6
Telegraph Creek	T19	at CMR boundary	Q.90	.03	.07	.03	<.01	.01	.64	.49	.23	.40	.12	.02	<.01	.90
			Q.80	.05	.10	.06	.02	.07	1.2	.73	.42	.55	.26	.04	.01	1.3
			Q.50	.23	.21	.16	.09	.55	9.0	1.8	1.4	2.1	1.1	.28	.11	3.8
			Q.20	.62	.45	.32	.47	12	55	7.2	4.5	8.9	7.6	2.1	.55	10
			QM	.59	.34	.31	.59	9.2	36	11	3.7	7.8	6.2	2.0	1.9	6.6
	T20	at confluence with Fourchette Creek	Q.90	.03	.08	.03	<.01	.02	.72	.55	.26	.44	.13	.02	<.01	1.0
			Q.80	.06	.11	.07	.02	.08	1.4	.82	.46	.61	.28	.04	.01	1.4
			Q.50	.26	.23	.18	.10	.62	10	2.1	1.6	2.3	1.2	.32	.12	4.2
			Q.20	.70	.51	.35	.52	13	61	8.0	5.0	9.9	8.5	2.4	.62	11
			QM	.66	.38	.35	.66	10	41	12	4.2	8.7	7.0	2.2	2.2	7.4

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Seven Blackfoot Creek	T21	at CMR boundary	Q.90	0.02	0.05	0.02	<0.01	0.01	0.51	0.39	0.18	0.31	0.09	0.01	<0.01	0.71
			Q.80	.04	.08	.05	.01	.05	.98	.58	.33	.43	.20	.03	.01	1.0
			Q.50	.18	.16	.12	.07	.44	7.2	1.5	1.1	1.6	.88	.22	.09	3.0
			Q.20	.49	.36	.25	.37	9.5	43	5.7	3.6	7.0	6.0	1.7	.44	7.8
			QM	.47	.27	.25	.47	7.2	29	8.6	3.0	6.2	4.9	1.6	1.5	5.3
	T22	at confluence with FPR	Q.90	.02	.06	.02	<.01	.01	.53	.41	.19	.33	.10	.01	<.01	.74
			Q.80	.04	.08	.05	.02	.06	1.0	.61	.34	.45	.21	.03	.01	1.0
			Q.50	.19	.17	.13	.07	.46	7.5	1.5	1.2	1.7	.92	.24	.09	3.1
			Q.20	.52	.38	.26	.39	9.9	45	5.9	3.7	7.4	6.3	1.8	.46	8.2
			QM	.49	.28	.26	.49	7.6	30	9.0	3.1	6.4	5.2	1.6	1.6	5.5
Timber Creek (north of the Missouri River)	T23	at CMR boundary	Q.90	.03	.07	.03	<.01	.01	.65	.50	.23	.40	.12	.02	<.01	.90
			Q.80	.05	.10	.06	.02	.07	1.2	.74	.42	.55	.26	.04	.01	1.3
			Q.50	.23	.21	.16	.09	.56	9.1	1.9	1.4	2.1	1.1	.29	.11	3.8
			Q.20	.63	.46	.32	.47	12	55	7.2	4.5	9.0	7.7	2.1	.56	10
			QM	.59	.35	.32	.59	9.2	37	11	3.8	7.8	6.3	2.0	1.9	6.7
	T24	at confluence with FPR	Q.90	.03	.07	.03	<.01	.01	.65	.50	.23	.40	.12	.02	<.01	.90
			Q.80	.05	.10	.06	.02	.07	1.2	.74	.42	.55	.26	.04	.01	1.3
			Q.50	.23	.21	.16	.09	.56	9.1	1.9	1.4	2.1	1.1	.29	.11	3.8
			Q.20	.63	.46	.32	.47	12	55	7.2	4.5	9.0	7.7	2.2	.56	10
			QM	.60	.35	.32	.59	9.2	37	11	3.8	7.9	6.3	2.0	1.9	6.7

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Hell Creek	T251	at CMR boundary	Q.90	0.02	0.04	0.02	<0.01	<0.01	0.36	0.28	0.13	0.22	0.07	<0.01	<0.01	0.50
			Q.80	.03	.06	.03	.01	.04	.70	.41	.23	.31	.14	.02	<.01	.71
			Q.50	.13	.12	.09	.05	.31	5.1	1.0	.79	1.2	.62	.16	.06	2.1
			Q.20	.35	.25	.18	.26	6.7	31	4.0	2.5	5.0	4.3	1.2	.31	5.3
			QM	.33	.19	.18	.33	5.2	20	6.1	2.1	4.4	3.5	1.1	1.1	3.7
	T26	at confluence with FPR	Q.90	.02	.04	.02	<.01	<.01	.41	.31	.15	.25	.07	.01	<.01	.57
			Q.80	.03	.06	.04	.01	.04	.79	.46	.26	.35	.16	.02	<.01	.81
			Q.50	.15	.13	.10	.06	.35	5.7	1.2	.89	1.3	.70	.18	.07	2.4
			Q.20	.40	.29	.20	.30	7.6	35	4.6	2.9	5.6	4.8	1.4	.35	6.0
			QM	.37	.22	.20	.37	5.8	23	6.9	2.4	4.9	4.0	1.2	1.2	4.2
Big Dry Creek	T271	at CMR boundary	Q.90	.20	.48	.20	.05	.10	4.5	3.5	1.6	2.8	.82	.12	.02	6.3
			Q.80	.36	.71	.42	.13	.47	8.7	5.1	2.9	3.8	1.8	.25	.09	8.9
			Q.50	1.6	1.4	1.1	.61	3.9	63	13	9.8	14	7.8	2.0	.78	26
			Q.20	4.4	3.2	2.2	3.3	84	382	50	32	62	53	15	3.9	88
			QM	4.1	2.4	2.2	4.1	64	255	76	26	54	44	14	13	47
	T281	at confluence with FPR	Q.90	.21	.49	.20	.05	.10	4.6	3.5	1.6	2.8	.83	.12	.02	6.4
			Q.80	.36	.72	.43	.13	.48	8.8	5.2	3.0	3.9	1.8	.25	.09	9.0
			Q.50	1.6	1.5	1.1	.62	3.9	64	13	9.9	15	7.9	2.0	.79	27
			Q.20	4.4	3.2	2.2	3.3	85	387	51	32	63	54	15	3.9	89
			QM	4.2	2.4	2.2	4.2	65	258	77	26	55	44	14	14	47

Supplement 7. Estimates of long-term monthly and annual streamflow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 8, shaded values) and estimation coefficients (table 3, unshaded values). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; Q.90, 90-percent exceedance streamflow; Q.80, 80-percent exceedance streamflow; Q.50, 50-percent exceedance streamflow; Q.20, 20-percent exceedance streamflow; QM, mean streamflow. Symbol: <, less than]

Stream name	Site number	Location on stream	Streamflow characteristic	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Timber Creek (south of the Missouri River)	T29	at CMR boundary	Q.90	0.04	0.11	0.04	<0.01	0.02	0.98	0.75	0.35	0.6	0.18	0.03	<0.01	1.4
			Q.80	.08	.16	.09	.03	.10	1.9	1.1	.63	.83	.39	.05	.02	1.9
			Q.50	.35	.32	.24	.13	.84	14	2.8	2.1	3.1	1.7	.43	.17	5.8
			Q.20	.95	.69	.48	.71	18	83	11	6.9	14	12	3.2	.84	16
			QM	.90	.52	.48	.90	14	55	17	5.7	12	9.5	3.0	2.9	10
	T30	at confluence with FPR	Q.90	.05	.11	.04	.01	.02	.99	.76	.36	.61	.18	.03	<.01	1.4
			Q.80	.08	.16	.09	.03	.10	1.9	1.1	.64	.84	.39	.05	.02	2.0
			Q.50	.36	.32	.24	.13	.85	14	2.8	2.2	3.2	1.7	.44	.17	5.8
			Q.20	.96	.70	.49	.72	18	84	11	7.0	14	12	3.3	.85	16
			QM	.91	.53	.48	.91	14	56	17	5.8	12	9.6	3.0	3.0	10
Nelson Creek	T31	at CMR boundary	Q.90	.02	.04	.02	<.01	<.01	.42	.32	.15	.26	.08	.01	<.01	.58
			Q.80	.03	.07	.04	.01	.04	.81	.48	.27	.36	.17	.02	<.01	.83
			Q.50	.15	.14	.10	.06	.36	5.9	1.2	.91	1.3	.72	.19	.07	2.5
			Q.20	.41	.30	.21	.30	7.8	36	4.7	2.9	5.8	5.0	1.4	.36	6.1
			QM	.38	.22	.20	.38	6.0	24	7.1	2.4	5.1	4.1	1.3	1.2	4.3
	T32	at confluence with FPR	Q.90	.02	.05	.02	<.01	.01	.44	.34	.16	.27	.08	.01	<.01	.61
			Q.80	.03	.07	.04	.01	.05	.85	.50	.29	.38	.18	.02	<.01	.87
			Q.50	.16	.14	.11	.06	.38	6.2	1.3	.96	1.4	.76	.19	.08	2.6
			Q.20	.43	.31	.22	.32	8.2	37	4.9	3.1	6.1	5.2	1.5	.38	6.4
			QM	.40	.24	.21	.40	6.3	25	7.4	2.6	5.3	4.3	1.3	1.3	4.6

[1]This site has values of one or more basin characteristics that are outside the range of values used in developing regression equations. Estimates of streamflow characteristics for this site should be used with caution.

Supplement 8. Estimates of selected peak-flow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.

[Estimates determined by using regression equations (table 9). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow. Streamflow values are in cubic feet per second]

Stream name	Site number	Region	Location on stream	PK1.5	PK2	PK2.33
Two Calf Creek	T1	South	at CMR boundary	173	297	369
	T2		at confluence with FPR	208	357	443
Armells Creek	T3	South	at CMR boundary	301	497	606
	T4		at confluence with FPR	353	582	709
Siparyann Creek	T5	North	at CMR boundary	72	138	183
	T6		at confluence with FPR	83	160	214
Rock Creek	T7	North	at CMR boundary	92	178	238
	T8		at confluence with FPR	102	200	267
C K Creek	T9	North	at CMR boundary	95	186	248
	T10		at confluence with FPR	111	219	294
Beauchamp Creek	T11	North	at CMR boundary	118	233	312
	T12		at confluence with FPR	124	247	332
Sacajawea River	T13	South	at CMR boundary	445	748	919
	T14		at confluence with FPR	459	772	947
Squaw Creek	T15	South	at CMR boundary	296	506	626
	T16		at confluence with FPR	301	513	635
Fourchette Creek	T17	North	at CMR boundary	89	172	229
	T18		at confluence with FPR	168	341	462
Telegraph Creek	T19	North	at CMR boundary	126	252	339
	T20		at confluence with Fourchette Creek	137	274	369
Seven Blackfoot Creek	T21	South	at CMR boundary	159	273	339
	T22		at confluence with FPR	165	284	352
Timber Creek (north of the Missouri River)	T23	North	at CMR boundary	120	237	319
	T24		at confluence with FPR	120	237	319

Supplement 8. Estimates of selected peak-flow characteristics for selected ungaged sites on tributaries that cross Charles M. Russell National Wildlife Refuge.—Continued

[Estimates determined by using regression equations (table 9). Streamflow values are in cubic feet per second. Abbreviations: CMR, Charles M. Russell National Wildlife Refuge; FPR, Fort Peck Reservoir; PK1.5, 1.5-year recurrence interval peak flow; PK2, 2-year recurrence interval peak flow; PK2.33, 2.33-year recurrence interval peak flow. Streamflow values are in cubic feet per second]

Stream name	Site number	Region	Location on stream	PK1.5	PK2	PK2.33
Hell Creek	T25	South	at CMR boundary	156	272	340
	T26		at confluence with FPR	172	300	375
Big Dry Creek	T27	South	at CMR boundary	1,550	2,510	3,020
	T28		at confluence with FPR	1,590	2,560	3,090
Timber Creek (south of the Missouri River)	T29	South	at CMR boundary	470	800	987
	T30		at confluence with FPR	472	804	992
Nelson Creek	T31	South	at CMR boundary	262	457	571
	T32		at confluence with FPR	269	468	585

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