ESTIMATES OF MONTHLY STREAMFLOW CHARACTERISTICS AND DOMINANT-DISCHARGE HYDROGRAPHS FOR SELECTED SITES IN THE LOWER MISSOURI AND LITTLE MISSOURI RIVER BASINS IN MONTANA

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Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer

Estimates of Monthly Streamflow Characteristics and Dominant-Discharge Hydrographs for Selected Sites in the Lower Missouri and Little Missouri River Basins in Montana

By Charles Parrett and Dave R. Johnson

Abstract

Various streamflow characteristics were estimated for water-reservation purposes for 17 sites in the lower Missouri River Basin and four sites in the Little Missouri River Basin in Montana. The characteristics were mean monthly and annual streamflow and monthly mean streamflow that is exceeded 90, 80, 50, and 20 percent of the time. In addition, dominant-discharge hydrographs were estimated for 10 of the 17 sites in the lower Missouri River Basin and for all four sites in the Little Missouri River Basin. Dominant discharge, generally defined as the bankfull discharge, was considered to be equal to the peak discharge having a recurrence interval of two years.

Monthly streamflow characteristics generally were based on a common 1937-86 base period. A mixed-station record-extension program was used to estimate missing flow data during the base period for streamflow-gaging stations.

Two methods were used to estimate characteristics at ungaged sites. One method was based on correlating miscellaneous discharge measurements at the estimating site with concurrent daily mean discharges at a nearby gaged site. The second method was based on using a drainage-area ratio to transfer streamflow characteristics at a gaged site to the estimating site.

Dominant discharges for gaged sites were obtained from a previous flood-frequency report or by fitting a log-Pearson Type 3 probability distribution to recorded peak-flow data. A drainage-area-ratio adjustment was used to transfer dominant discharges from gaged sites to ungaged sites. Dominant-discharge hydrographs were determined from visual examination of recorded hydrographs having maximum daily discharges that were relatively close to the estimated dominant discharges.

INTRODUCTION

The surface-water supply for most tributary streams in the lower Missouri and Little Missouri River Basins in Montana is seasonally variable and generally unable to satisfy demands of all users. To allocate the remaining finite supply among the competing users, the State of Montana developed an administrative process enabling governmental agencies to reserve surface water for existing and future beneficial uses. Among the uses for which water may be reserved are fish, wildlife, and recreation. To establish an instream-flow reservation for these uses, the Montana Department of Fish, Wildlife and Parks (DFWP) needs to determine various streamflow characteristics. The U.S. Geological Survey (USGS) previously determined monthly streamflow characteristics for several hundred sites in the upper Missouri River Basin (Parrett and others, 1989) for water-reservation purposes. The USGS, in cooperation with DFWP, conducted the study reported here to determine streamflow characteristics at 17 sites in the lower Missouri River Basin and 4 sites in the Little Missouri River Basin for which water reservations are requested.

PURPOSE AND SCOPE

The purpose of this report is to present the estimated streamflow characteristics and data for the dominant-discharge hydrographs and to describe the methods used to make the estimates for 21 selected sites in the lower Missouri and Little Missouri River Basins in Montana. The estimates include (1) mean monthly and annual streamflow; (2) various points on the monthly mean streamflow-duration curve (monthly mean streamflow that is exceeded 90, 80, 50, and 20 percent of the time) for all 21 selected sites; and (3) dominant-discharge hydrographs for 14 of the 21 sites where DFWP considered the maintenance of existing stream-channel morphology to be important for water-reservation purposes. To ensure that estimates of monthly and annual streamflow were consistent with estimates previously made for the upper Missouri

River Basin (Parrett and others, 1989), the common base period used in the previous study (water years 1937-86) was also used in this study. The dominant-discharge hydrograph at each of the 14 sites was based on a hydrograph duration of 14 or 21 days and a maximum daily discharge equal to the dominant (bankfull) discharge. The dominant discharge was assumed to be equal to the peak discharge having a recurrence interval of 2 years.

Monthly streamflow characteristics were estimated for 17 sites in the lower Missouri River Basin between Fort Peck Lake and the Montana-North Dakota border and 4 sites in the Little Missouri River Basin in Montana (fig. 1). Of the 21 selected sites, 7 are located at streamflow-gaging stations having continuous-record streamflow data, 2 have miscellaneous discharge-measurement data, and 12 have no flow data, although a streamflow-gaging station is located on the same stream upstream or downstream from each of the 12 sites. Three of the estimation sites (18, 20, and 21) are located at the Montana border. Streamflow-gaging stations are located just downstream from all three sites, and the gaged streamflows are considered to be equivalent to those at the border. Streamflow data from nearby streamflow-gaging stations were used to estimate monthly streamflow characteristics at the 2 sites having only miscellaneous measurements and the 12 sites having no streamflow data. Of the 14 sites selected for the determination of dominant-discharge hydrographs, 10 are in the lower Missouri River Basin and 4 are in the Little Missouri River Basin. None of the 10 sites in the lower Missouri River Basin have gaged data, but a streamflow-gaging station is located on the same stream upstream or downstream from each of the 10 ungaged sites. Although all four sites in the Little Missouri River Basin have gaged data, data from one gaged site (site 21) were not used to determine a dominant-discharge hydrograph because streamflow during the short period of record was considered to be unrepresentative of long-term hydrologic conditions. Recorded streamflow data from a streamflow-gaging station on the same stream were used to estimate dominant-discharge hydrographs at each of the 10 ungaged sites and the site having a short period of record. The locations of the estimation sites and the nearby streamflow-gaging stations used for estimation purposes are shown on figure 1. The sites, types of streamflow data available, and whether dominant-discharge hydrographs were estimated are shown in table 1. The estimated monthly streamflow characteristics at the sites are presented in table 7 at the back of the report, and daily mean discharges from the estimated dominant-discharge hydrographs are presented in table 8 at the back of the report.

ESTIMATES OF MONTHLY STREAMFLOW CHARACTERISTICS

The 7 streamflow-gaging stations for which monthly streamflow characteristics were estimated and the 11 nearby gaging stations used for estimation have variable record lengths as shown in table 2. To ensure that estimated monthly streamflow characteristics were representative of the same general hydrologic conditions, a common base period of record (1937-86) was developed for 16 of the 18 stations using a streamflow record-extension program (Alley and Burns, 1983) that was previously used for the study in the upper Missouri River Basin. Monthly streamflow characteristics at the 2 mainstem Missouri River sites (sites 1 and 17) were based on the period since Fort Peck Lake was substantially filled and became operational (1943). After streamflow records were extended to the common base period, two general methods, the concurrent-measurement method and the drainage-area-ratio-adjustment method, were used to estimate monthly streamflow characteristics at ungaged sites. Both methods are based on the use of monthly streamflow characteristics at gaged sites to estimate those characteristics at ungaged sites.

Development of the common base period, 1937-86 water years

As described by Alley and Burns (1983), the streamflow record-extension program is a mixed-station program that selects the best base station from all the available streamflow-gaging stations in a region to estimate each month of missing streamflow record at a site. The criterion for selection is to use the base station that results in the smallest standard error of prediction for that station for that month. Only stations with streamflow record for a particular month were used to estimate missing values at other sites for that month; previously estimated monthly flows were not used to estimate any missing flows. To make full use of recorded flow data before 1937 and after 1986, the record-extension program was used to estimate missing monthly flows at all 18 stations for the period 1906-90. All estimated and recorded flows for the periods 1906-36 and 1987-90 were eliminated and monthly streamflow characteristics at all gaged sites except the two mainstem Missouri River sites were determined based on only the 1937-86 period. For the 2 mainstem Missouri River sites, all estimated and recorded flows for

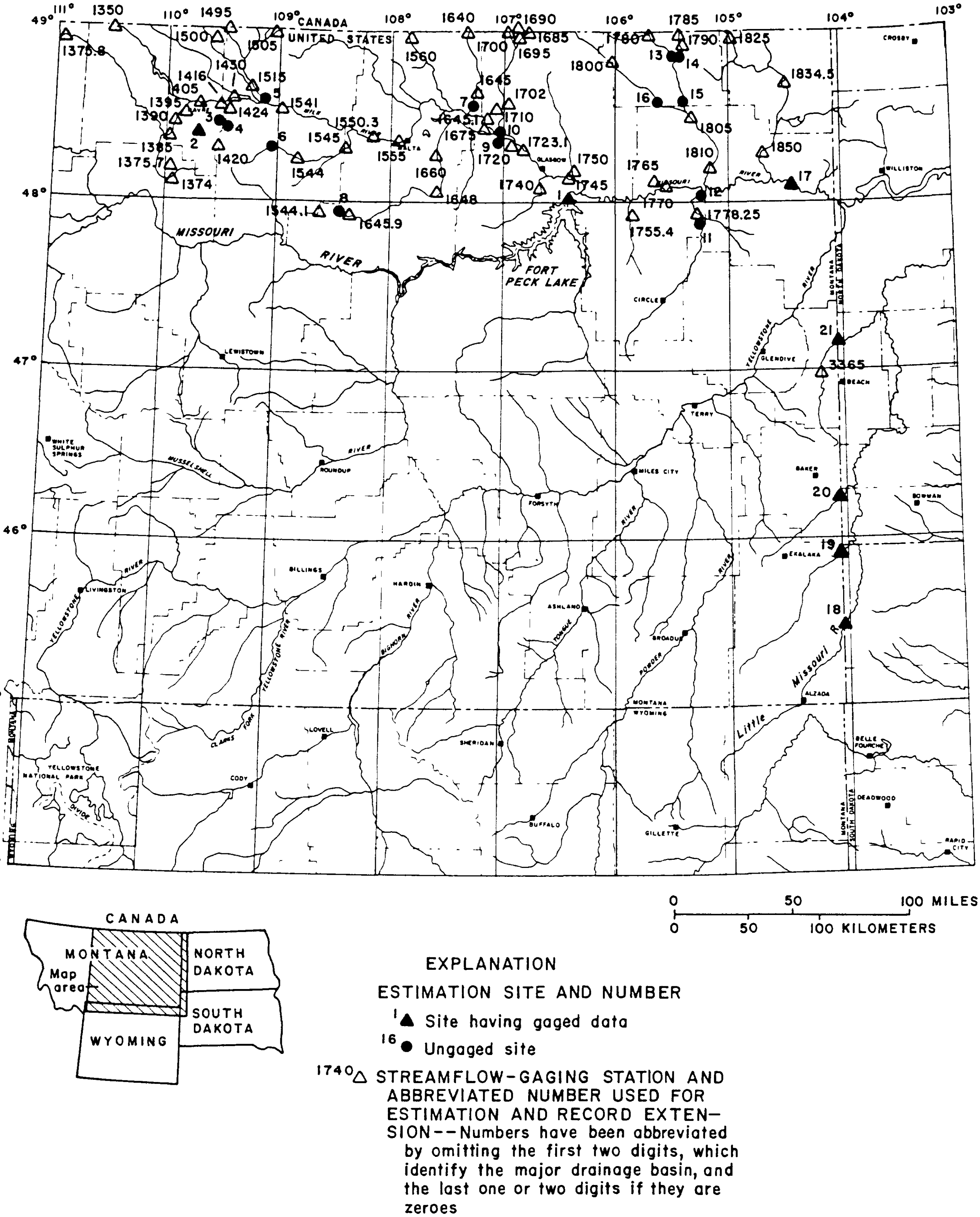


Figure 1. Location of streamflow estimation sites and streamflow-gaging stations.

Table 1. Streamflow estimation sites and available data

Site no.	Stream name	Drainage area, square miles	Type of streamflow data available: Gaged record	Miscellaneous measurement	None	Dominant-discharge hydrograph estimated
1	Missouri River below Fort Peck Dam, Mont.	57,556	X	--	--	--
2	Beaver Creek above Lower Lake, near Havre, Mont.	87.4	X	--	--	--
3	Little Boxelder Creek at Clear Creek Road, near Havre, Mont.	53.2	--	--	X	--
4	Clear Creek at Clear Creek Road crossing, near Lohman, Mont.	91.3	--	--	X	--
5	Battle Creek at mouth, near Chinook, Mont.	1,710	--	--	X	X
6	Peoples Creek at Barney Olsen Road, near Dodson, Mont.	90.6	--	--	X	--
7	Frenchman River at mouth, near Saco, Mont.	2,565	--	--	X	X
8	Beaver Creek at Fort Belknap Indian Reservation, near Zortman, Mont.	5.5	--	--	X	--
9	Beaver Creek at mouth, near Saco, Mont.	1,798	--	--	X	X
10	Rock Creek at mouth, near Hinsdale, Mont.	1,376	--	--	X	X
11	Redwater River above confluence of East Fork Redwater River, near Vida, Mont.	1,706	--	--	X	X
12	Redwater River near Vida, Mont.	2,113	--	--	X	X
13	Poplar River above confluence of East Poplar River, near Scobey, Mont.	572	--	--	X	X
14	East Poplar River at mouth, near Scobey, Mont.	755	--	--	X	X
15	Poplar River at Fort Peck Reservation boundary, near Scobey, Mont.	1,745	--	X	--	X
16	West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes, Mont.	732	--	X	--	X
17	Missouri River near Culbertson, Mont.	91,557	X	--	--	--
18	Little Missouri River at Montana-South Dakota border[1]	1,970	X	--	--	X
19	Boxelder Creek near Webster, Mont.	1,092	X	--	--	X
20	Little Beaver Creek at Montana-North Dakota border[2]	615	X	--	--	X
21	Beaver Creek at Montana-North Dakota border[3]	616	X	--	--	X

[1]Name of streamflow-gaging station is Little Missouri River at Camp Crook, S. Dak.
[2]Name of streamflow-gaging station is Little Beaver Creek near Marmarth, N. Dak.
[3]Name of streamflow-gaging station is Beaver Creek near Trotters, N. Dak.

the periods 1906-42 and 1987-90 were eliminated, and the monthly streamflow characteristics were determined based on the 1943-86 period. Base stations used for this study and their periods of record from 1906 to 1986 are shown in table 3. At one gaged site, East Poplar River at International Boundary (06178500), recorded flows prior to the completion of a reservoir in Canada in 1976 were not used in the analysis. All monthly flows for this site during the period 1937-76 were considered to be missing and were estimated using the streamflow record-extension program. Because the period 1977-86 generally was drier than normal in the lower Missouri River Basin in Montana, use of the streamflow record-extension program in this instance to estimate missing flows under regulated conditions was considered to provide a more reasonable and consistent flow record than the use of recorded, regulated flows for 1977-86 only. Table 4 shows the number of monthly flows estimated for each of the 18 stations (including the 2 mainstem Missouri River sites) using the streamflow record-extension program and the average standard error of prediction.

The average standard error of prediction shown in table 4 is the average across all months. The average standard error of prediction ranged from 18.6 percent to 176.5 percent. The number of monthly flows estimated by the streamflow-record extension program at each of the 18 sites ranged from 0 to 600. For the streamflow-gaging station, Little Box Elder Creek at mouth, near Havre (06141600), all 600 monthly flows in the base period were estimated. The only recorded flows at this station were 48 values outside the base period. At 5 other stations, more than 500 monthly flows out of the 600 in the 1937-86 base period were

Table 2. Monthly streamflow estimation sites and associated streamflow-gaging data

Site no.	Stream name	Streamflow-gaging station data			
		At estimation site		At nearby site used for estimation	
		Number	Period of record	Number	Period of record
1	Missouri River below Fort Peck Dam, Mont.	06132000	1943-90[1]	--	--
2	Beaver Creek above Lower Lake, near Havre, Mont.	06140299[2]	1966-90	--	--
3	Little Boxelder Creek at Clear Creek Road, near Havre, Mont.	--	--	06141600	1987-90[3]
4	Clear Creek at Clear Creek Road crossing, near Lohman, Mont.	--	--	06142400	1984-90[3]
5	Battle Creek at mouth, near Chinook, Mont.	--	--	06151500	1906-21; 1944; 1984-90[3]
6	Peoples Creek at Barney Olsen Road, near Dodson, Mont.	--	--	06154400	1967-90
7	Frenchman River at mouth, near Saco, Mont.	--	--	06164000	1917-90[3]
8	Beaver Creek at Fort Belknap Indian Reservation, near Zortman, Mont.	--	--	06164590	1983-90
9	Beaver Creek at mouth, near Saco, Mont.	--	--	06166000	1920-21; 1981-90[3]
10	Rock Creek at mouth, near Hinsdale, Mont.	--	--	06169500	1916-17; 1956-77; 1978-90[3]
11	Redwater River above confluence of East Fork Redwater River, near Vida, Mont.	--	--	06177825	1976-85
12	Redwater River near Vida, Mont.	--	--	06177825	1976-85
13	Poplar River above confluence of East Poplar River, near Scobey, Mont.	--	--	06178000	1931-90[3]
14	East Poplar River at mouth, near Scobey, Mont.	--	--	06178500	1931-90[3,4]
15	Poplar River at Fort Peck Reservation boundary, near Scobey, Mont.	--	([5])	06178000	1931-90[3]
16	West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes, Mont.	--	([6])	06178000	1931-90[3]
17	Missouri River near Culbertson, Mont.	06185500	1943-52; 1958-90[1]	--	--
18	Little Missouri River at Montana-South Dakota border[7]	06334500	1906-07; 1956-90	--	--
19	Boxelder Creek near Webster, Mont.	06334630	1961-73	--	--
20	Little Beaver Creek at Montana-North Dakota border[8]	06335000	1938-79	--	--
21	Beaver Creek at Montana-North Dakota border[9]	06336600	1977-90	--	--

[1] Period of record since completion of Fort Peck Dam. Earlier record not used to calculate monthly flow characteristics.

[2] Streamflow-gaging station operated by U.S. Soil Conservation Service. Number assigned for compatibility with USGS numbers.

[3] Seasonal data only available for some periods.

[4] Recorded data before 1977 not used because of completion of Canadian reservoir, 1976. Flows for 1937-76 were estimated using streamflow record-extension program.

[5] Sixty-seven measurements of discharge are available at a site several miles downstream.

[6] Nine measurements of discharge are available.

[7] Name of streamflow-gaging station is Little Missouri River at Camp Crook, S. Dak.

[8] Name of streamflow-gaging station is Little Beaver Creek near Marmarth, N. Dak.

[9] Name of streamflow-gaging station is Beaver Creek near Trotters, N. Dak.

Table 3. Streamflow-gaging stations used in the streamflow-record extension program

Streamflow-gaging station no.	Streamflow-gaging station name	Period of record from 1906-86
06135000	Milk River at eastern crossing of International Boundary	1909-86
06137400	Big Sandy Creek at reservation boundary, near Rocky Boy, Mont.	1982-86
06137570	Boxelder Creek near Rocky Boy, Mont.	1976-86
06137580	Sage Creek near Whitlash, Mont.	1977-82;1985-86
06138500	Big Sandy Creek near Box Elder, Mont.	1927-39
06139000	Big Sandy Creek near Laredo, Mont.	1918-20
06139500	Big Sandy Creek near Havre, Mont.	1946-54;1984-86
06140299	Beaver Creek above Lower Lake, near Havre, Mont.	1966-86
06140500	Milk River at Havre, Mont.	1906-23;1954-86
06141600	Little Boxelder Creek at mouth, near Havre, Mont.	--
06142000	Clear Creek near Bearpaw, Mont.	1918-22
06142400	Clear Creek near Chinook, Mont.	1984-86
06143000	Milk River at Lohman, Mont.	1918-21;1923-26;1934-51
06149500	Battle Creek at International Boundary	1917-86
06150000	Woodpile Coulee near International Boundary	1927-77
06150500	East Fork Battle Creek near International Boundary	1927-71;1973-77
06154100	Milk River near Harlem, Mont.	1960-69;1983-86
06154410	Little Peoples Creek near Hays, Mont.	1972-86
06154500	Peoples Creek near Dodson, Mont.	1918-22;1951-73;1982-86
06155030	Milk River near Dodson, Mont.	1983-86
06155500	Milk River at Malta, Mont.	1906-22
06156000	Whitewater Creek near International Boundary	1927-80
06164000	Frenchman River at International Boundary	1917-86
06164510	Milk River at Juneberg Bridge, near Saco, Mont.	1978-86
06164800	Beaver Creek above Dix Creek, near Malta, Mont.	1967-69;1976-82
06167500	Beaver Creek near Hinsdale, Mont.	1918-21
06168500	Rock Creek at International Boundary	1914-16;1927-62
06169000	Horse Creek at International Boundary	1914-17;1927-62
06170000	McEachern Creek at International Boundary	1924-77
06170200	Willow Creek near Hinsdale, Mont.	1965-73
06171000	Rock Creek near Hinsdale, Mont.	1906-07;1912-20
06172000	Milk River near Vandalia, Mont.	1915-25;1928-39;1970-73;1983-86
06172310	Milk River at Tampico, Mont.	1974-77;1987-86
06174000	Willow Creek near Glasgow, Mont.	1954-86
06174500	Milk River at Nashua, Mont.	1940-86
06175000	Porcupine Creek at Nashua, Mont.	1908-25;1982-86
06175540	Prairie Elk Creek near Oswego, Mont.	1976-85
06176500	Wolf Creek near Wolf Point, Mont.	1908-14;1950-53;1982-86
06177000	Missouri River near Wolf Point, Mont.	1929-86
06177500	Redwater River at Circle, Mont.	1929-72;1975-84;1986
06179000	East Fork Poplar River near Scobey, Mont.	1935-40;1975-80
06180000	West Fork Poplar River near Richland, Mont.	1935-49
06180500	Poplar River near Bredette, Mont.	1934-47
06181000	Poplar River near Poplar, Mont.	1908-25;1947-69;1975-79;1982-86
06182500	Big Muddy Creek at Daleview, Mont.	1947-72
06183450	Big Muddy Creek near Antelope, Mont.	1979-86
06185000	Big Muddy Creek near Culbertson, Mont.	1908-22
06334000	Little Missouri River near Alzada, Mont.	1911-25;1928-32;1935-69
06334500	Little Missouri River at Camp Crook, S. Dak.	1957-86
06334630	Boxelder Creek near Webster, Mont.	1961-73
06335000	Little Beaver Creek near Marmarth, N. Dak.	1938-79
06336500	Beaver Creek at Wibaux, Mont.	1938-69;1979-83
06336600	Beaver Creek near Trotters, N. Dak.	1921;1938-69;1979-83

Table 4. Results from the streamflow-record extension program

Streamflow-gaging station no.	Streamflow-gaging station name	Average standard error of prediction	No. of monthly flows estimated for 1937-86, except as noted
06132000	Missouri River below Fort Peck Dam, Mont.	--	[1]0
06140299	Beaver Creek above Lower Lake, near Havre, Mont.	27.8	400
06141600	Little Boxelder Creek at mouth, near Havre, Mont.	77.2	600
06142400	Clear Creek near Chinook, Mont.	95.5	583
06151500	Battle Creek near Chinook, Mont.	78.3	588
06154400	Peoples Creek near Hays, Mont.	75.1	362
06164000	Frenchman River at International Boundary	176.5	349
06164590	Beaver Creek near Zortman, Mont.	26.6	559
06166000	Beaver Creek below Guston Coulee, near Saco, Mont.	144.3	561
06169500	Rock Creek below Horse Creek, near International Boundary	38.3	328
06177825	Redwater River near Vida, Mont.	92.0	480
06178000	Poplar River at International Boundary	86.5	192
06178500	East Poplar River at International Boundary	54.7	148
06185500	Missouri River near Culbertson, Mont.	18.6	[1]75
06334500	Little Missouri River at Camp Crook, S. Dak.	100.0	240
06334630	Boxelder Creek near Webster, Mont.	90.9	444
06335000	Little Beaver Creek near Marmarth, N. Dak.	135.9	84
06336600	Beaver Creek near Trotters, N. Dak.	71.8	507

[1]Number of estimates for 1943-86.

estimated using the streamflow-record extension program.

To determine the effect that a large average standard error of prediction coupled with a short record length might have on monthly streamflow characteristics based on a long extended record, the streamflow-record extension program was tested at one station. As shown in table 4, Little Beaver Creek near Marmarth, N. Dak. (06335000) had a large standard error of prediction (135.9 percent) but a relatively long record length (only 84 out of 600 monthly flows estimated during the 1937-86 base period). The period of record at station 06335000 used for the test was 1939-79. Monthly mean flows exceeded 90, 50, and 20 percent of the time (Q.90, Q.50, and Q.20, respectively) were calculated based on the 1943-79 period (excluding the 48 months of recorded flows prior to 1943). Then, assuming that the only recorded flows available for use in the streamflow-record extension program were the 48 monthly values for the 1939-42 period, all flows for station 06335000 during the 1943-79 period were estimated using the streamflow-record extension program. Q.90, Q.50, and Q.20 were then calculated based on the estimated flows for the 1943-79 period and compared to those calculated from the actual 1943-79 record. This test was considered to represent a situation similar to that for station 06141600 wherein a relatively small number of recorded flows (48) were available only for a period outside the selected base period. In one sense, the test represents a "worst case" situation because the standard error of prediction for station 06335000 (135.9 percent) is substantially larger than that for station 06141600 (77.2 percent).

The results of the test are displayed in figure 2. Figure 2A shows the comparison between a low-flow characteristic (Q.90) calculated from the actual 1943-79 record and that calculated from the extended record. For most months, the differences between Q.90 from the actual record and Q.90 from the extended record are within 1.0 cubic foot per second or less. The single exception is for the high-runoff month of June where the difference is about 4.0 cubic feet per second. For a medium-flow characteristic (Q.50), figure 2B shows that the only two months having a significant difference between Q.50 from the actual record and Q.50 from the extended record are the high-runoff months of March and June. The largest difference occurs in June and is about 30 cubic feet per second. Figure 2C shows the comparison for a high-flow characteristic (Q.20). Again, the only months having a significant difference between Q.20 from the actual record and Q.20 from the extended record are the high-runoff months of March and June. The largest difference in Q.20 is about 120 cubic feet per second in March. Overall, figure 2 indicates that, for the test station, monthly flow characteristics based on a period (1943-79) containing only estimated flows generally are very close to characteristics based entirely on recorded flows for the same

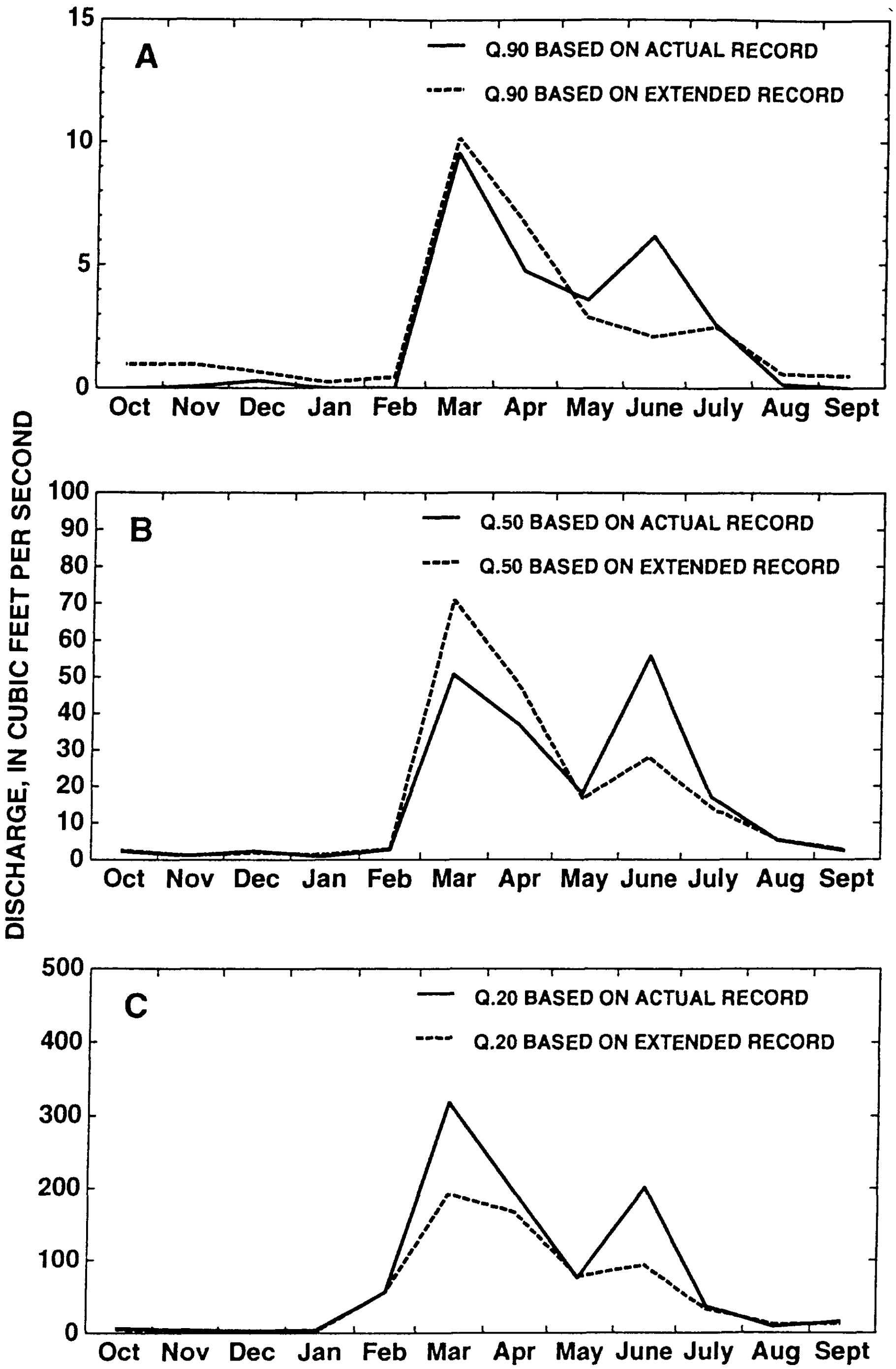


Figure 2. Monthly mean discharge exceeded 90, 50, and 20 percent of the time (Q.90, Q.50, and Q.20) for Little Beaver Creek near Marmarth, N. Dak. (06335000) as determined from actual 1943-79 record and 1943-79 extended record.

period. Flow characteristics calculated from a completely extended record are significantly different from those calculated from actual record only for months of generally high runoff, presumably because flow characteristics for those months are sensitive to a few, large recorded flows that were not duplicated by the streamflow-record extension program.

Concurrent-measurement method

One method for estimating streamflow characteristics at an ungaged site requires a series of discharge measurements at the site. The measured discharges are correlated with concurrent discharges at some nearby, hydrologically similar, gaged site, and the relation between the discharges at the two sites is used to transfer the desired long-term streamflow characteristic at the gaged site to the ungaged site. This estimation method, referred to in this report as the concurrent-measurement method, was used to estimate monthly streamflow characteristics for the 1937-86 base period at two sites (sites 15 and 16). Although Poplar River at Fort Peck Reservation boundary, near Scobey, Mont. (site 15) has no continuous-record of streamflow, 67 miscellaneous measurements of discharge were made from 1977 to 1981 at a site several miles downstream. The measured discharges were considered to be equivalent to discharges at the boundary and were used as a basis for the estimation of monthly streamflow characteristics at the boundary. Similarly, nine miscellaneous measurements of discharge made from 1975 to 1976 at West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes, Mont., (site 16) were used to estimate monthly streamflow characteristics at that ungaged site. The measured discharges at each site were presumed to be equivalent to daily mean discharges and were paired with concurrent daily mean discharges at the streamflow-gaging station Poplar River at International Boundary (station 06178000). The MOVE.1 curve-fitting technique described by Parrett and others (1989, p. 10-13) was used to develop a relation between discharge at each ungaged site and discharge at the gaged site. The relations, expressed in the form of linear equations, are as follows:

$$\log y_{15} = 0.899 + 0.743 \log x \qquad (1)$$

$$\log y_{16} = 0.520 + 0.673 \log x \qquad (2)$$

where

$\log y_{15}$ is the base 10 logarithm of discharge at site 15 in cubic feet per second,

$\log x$ is the base 10 logarithm of discharge at station 06178000 in cubic feet second, and

$\log y_{16}$ is the base 10 logarithm of discharge at site 16 in cubic feet per second.

The correlation coefficient between discharges at the correlating station (station 06178000) and sites 15 and 16 were 0.89 and 0.93, respectively. The standard errors of estimate (standard deviations of the residuals) for equations 1 and 2 were 0.368 log units and 0.188 log units, respectively. The MOVE.1 equations and the scatter about the lines described by the equations are illustrated by the graphs in figure 3. The relations for concurrent daily mean discharges were presumed to be applicable also for monthly streamflow characteristics, and equations 1 and 2 were used to calculate monthly streamflow characteristics at sites 15 and 16 from monthly streamflow characteristics at station 06178000.

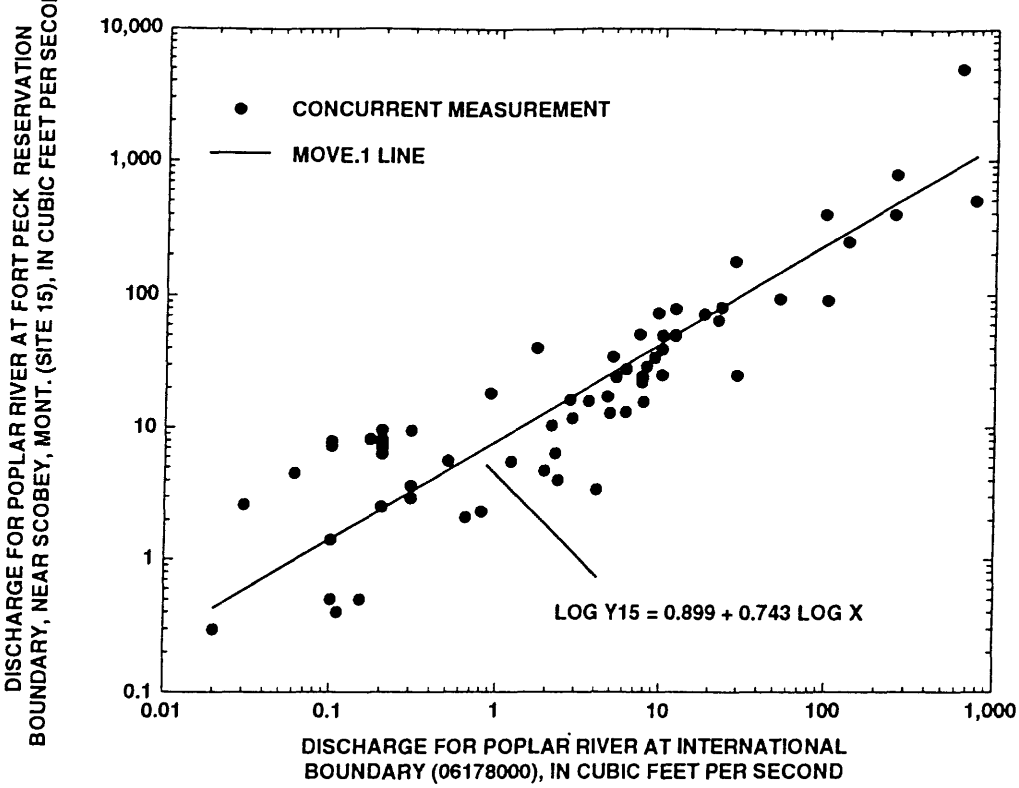
Drainage-area-ratio-adjustment method

A second method for estimating streamflow characteristics at an ungaged site requires continuous-record streamflow data from a gaged site on the same stream as the ungaged site. Long-term streamflow characteristics at the gaged site are transferred to the ungaged site by multiplying the values of the characteristics at the gaged site by the ratio of the drainage area at the ungaged site to the drainage area at the gaged site. For example, if the drainage areas at the ungaged and gaged sites are 150 and 100 square miles, respectively, each desired long-term streamflow characteristic for the ungaged site would be calculated by multiplying the value of that characteristic at the gaged site by (150/100), or 1.5.

This method for estimating streamflow characteristics at ungaged sites, termed the drainage-area-ratio-adjustment method in this report, was used to estimate monthly streamflow characteristics for 12 sites. The sites and data used for the drainage-area-ratio adjustments are shown in table 5. For the Frenchman River at mouth, near Saco (site 7), the drainage-area-ratio adjustment was applied to recorded flows at the upstream gaging station, Frenchman River at International Boundary (06164000), after subtraction of flows in the Frenchman Canal near Saco (06164500).

ESTIMATES OF REPRESENTATIVE DOMINANT-DISCHARGE HYDROGRAPHS

Dominant discharges for 14 selected sites were estimated based on recorded data at the site or at a streamflow-gaging station located on the same stream. Representative hydrographs having a maximum daily discharge equal to the dominant discharge were estimated from visual examination of selected recorded



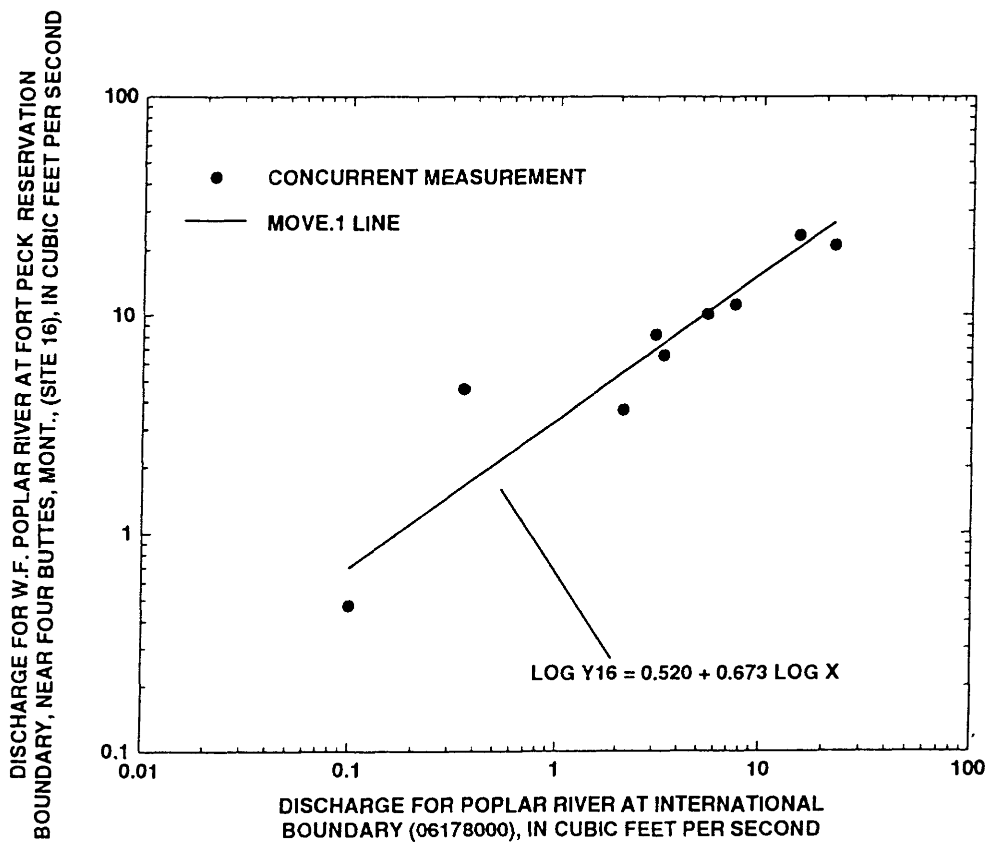


Figure 3. Relation between measured discharge at ungaged sites and concurrent discharge at gaged site, defined by the MOVE.1 curve-fitting technique.

Table 5. Estimation sites where drainage-area-ratio-adjustment method was used to estimate monthly streamflow characteristics

[mi^2, square miles]

Site no.	Stream name	Drainage area (mi^2)	Streamflow-gaging station used for estimation: No.	Streamflow-gaging station used for estimation: Drainage area, (mi^2)	Drainage-area ratio
3	Little Boxelder Creek at Clear Creek Road, near Havre, Mont.	53.2	06141600	95.9	0.56
4	Clear Creek at Clear Creek Road crossing, near Lohman, Mont.	91.3	06142400	135	.68
5	Battle Creek at mouth, near Chinook, Mont.	1,710	06151500	1,623	1.05
6	Peoples Creek at Barney Olsen Road, near Dodson, Mont.	90.6	06154400	220	.41
7	Frenchman River at mouth, near Saco, Mont.	2,565	06164000	2,299	[1]1.12
8	Beaver Creek at Fort Belknap Indian Reservation, near Zortman, Mont.	5.5	06164590	10.1	.54
9	Beaver Creek at mouth, near Saco, Mont.	1,798	06166000	1,200	1.50
10	Rock Creek at mouth, near Hinsdale, Mont.	1,376	06169500	328	4.20
11	Redwater River above confluence of East Fork Redwater River, near Vida, Mont.	1,706	06177825	1,974	.86
12	Redwater River near Vida, Mont.	2,113	06177825	1,974	1.07
13	Poplar River above confluence of East Poplar River, near Scobey, Mont.	572	06178000	365	1.57
14	East Poplar River at mouth, near Scobey, Mont.	755	06178500	541	1.40

[1]Flows at Frenchman Canal near Saco (06164500) were subtracted from station 06164000 before applying drainage-area-ratio adjustment factor.

hydrographs at the site or at a gaged site on the same stream.

Dominant discharge

The dominant discharge generally has been defined as the bankfull discharge (Montana Department of Fish, Wildlife and Parks, 1981; Reiser and others, 1985). The bankfull discharge, an index discharge generally considered to be important for channel formation, has been found to have a recurrence interval of 1 to 2 years for most alluvial streams (Leopold and others, 1964). Although the recurrence interval for the bankfull discharge has considerable site-to-site variability, the peak discharge having a recurrence interval of 2 years was used as the dominant discharge for all sites in this study. In this report, the term dominant discharge is used in place of the peak discharge having a recurrence interval of 2 years.

For each streamflow-gaging station used to estimate dominant discharge (table 6), the dominant discharge was based on recorded annual peak-flow data. For most stations, dominant discharges were obtained from a flood-frequency report by Omang (1992). For those stations not included in the flood-frequency report, dominant discharges were determined by fitting a log-Pearson Type 3 probability distribution to recorded annual peak discharges using procedures of the Interagency Advisory Committee on Water Data (1982) as described by Omang (1992, p. 4-8).

For each ungaged estimation site and for one gaged site (site 21) where recorded peak-discharge data were considered to be generally unrepresentative of long-term hydrologic conditions, dominant discharge was estimated by applying a drainage-area-ratio adjustment described by Omang (1992, p. 12-13) to the dominant discharge at a gaged site on the same stream. The drainage-area-ratio adjustment developed by Omang (1992) is similar to the drainage-area-ratio-adjustment method used to estimate monthly streamflow characteristics, except that the drainage-area-ratio for dominant discharge is taken to some power less than 1.0. For sites in the lower Missouri River Basin, the exponent on the drainage-area ratio is 0.69, and for sites in the Little Missouri River Basin, the exponent is 0.55 (Omang, 1992, table 2). For example, if the dominant discharge for a gaged site in the lower Missouri River Basin having a drainage area of 300 square miles was 400 cubic feet per second, and if the ungaged site on the same stream had a drainage area of 500 square miles, the estimated dominant discharge for the ungaged site would be $400 \times (500/300)^{0.69}$, or 569 cubic feet per second.

Although Omang (1992) suggested that the use of a regional equation for estimation of dominant discharge might be better than the use of the drainage-area-ratio adjustment for drainage-area ratios less than

Table 6. Dominant-discharge hydrograph estimation sites and associated streamflow-gaging station data

Site no.	Stream name	Station used to estimate dominant discharge	Period of peak-flow record	Drainage-area ratio
5	Battle Creek at mouth, near Chinook, Mont.	06151500	1906-21; 1952; 1986-90	1.05
7	Frenchman River at mouth, near Saco, Mont.	06164000	1917-90	1.11
9	Beaver Creek at mouth, near Saco, Mont.	06164800	1967-69; 1974-82; 1986	1.94
10	Rock Creek at mouth, near Hinsdale, Mont.	06169500	1917-90	4.20
11	Redwater River above confluence of East Fork Redwater River, near Vida, Mont.	06177825	1976-85	.86
12	Redwater River near Vida, Mont.	06177825	1976-85	1.07
13	Poplar River above confluence of East Poplar River, near Scobey, Mont.	06178000	1931-90	1.58
14	East Poplar River at mouth, near Scobey, Mont.	06178500	1931-90	1.40
15	Poplar River at Fort Peck Reservation boundary, near Scobey, Mont.	06181000	1909; 1915; 1921; 1923; 1946; 1948-1963; 1965-1969; 1975-1979; 1982-1989	.54
16	West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes, Mont.	06180000	1935-49; 1990	1.71
18	Little Missouri River at Montana-South Dakota border[1]	06334500	1904-06; 1957-90	--
19	Boxelder Creek near Webster, Mont.	06334630	1960-75	--
20	Little Beaver Creek at Montana-North Dakota border[2]	06335000	1938-79	--
21	Beaver Creek at Montana-North Dakota border[3]	06336500	1872; 1921; 1929; 1938-1969; 1979-1983	1.75

[1]Name of streamflow-gaging station is Little Missouri River at Camp Crook, S. Dak.
[2]Name of streamflow-gaging station is Little Beaver Creek near Marmarth, N. Dak.
[3]Name of streamflow-gaging station is Beaver Creek near Trotters, N. Dak.

0.5 or greater than 1.5, the adjustment was used in this study for drainage-area ratios as large as 4.20 (table 6). Because the regional equation for the estimation of dominant discharge developed by Omang (1992) had a relatively large standard error (equivalent to having only 3 years of gaged record), the authors believe that the drainage-area-ratio adjustments provided more reliable estimates of dominant discharge than did a regional equation.

Development of Representative Hydrograph

After the dominant discharge was estimated for each site, a representative runoff hydrograph of daily mean discharge was developed (fig. 4). Although dominant discharge estimated in this study is for an instantaneous peak, the dominant discharge was also used for the maximum daily discharge for each representative hydrograph to be consistent with previous work for DFWP (Montana Department of Fish, Wildlife and Parks, 1979; 1981). In addition, each representative hydrograph developed in this study had a duration of either 14 or 21 days to be consistent with representative hydrographs previously developed for DFWP (Montana Department of Fish, Wildlife and Parks, 1979). Limiting representative hydrograph durations to just two values is intended to simplify administration of the water reservations.

To estimate reasonable runoff hydrographs having these characteristics, flow records for each gaged site used to determine the dominant discharge were examined, and annual hydrographs having maximum daily discharges relatively close to the dominant discharge at the estimation site were selected for further analysis. For the 14 selected sites, runoff hydrographs

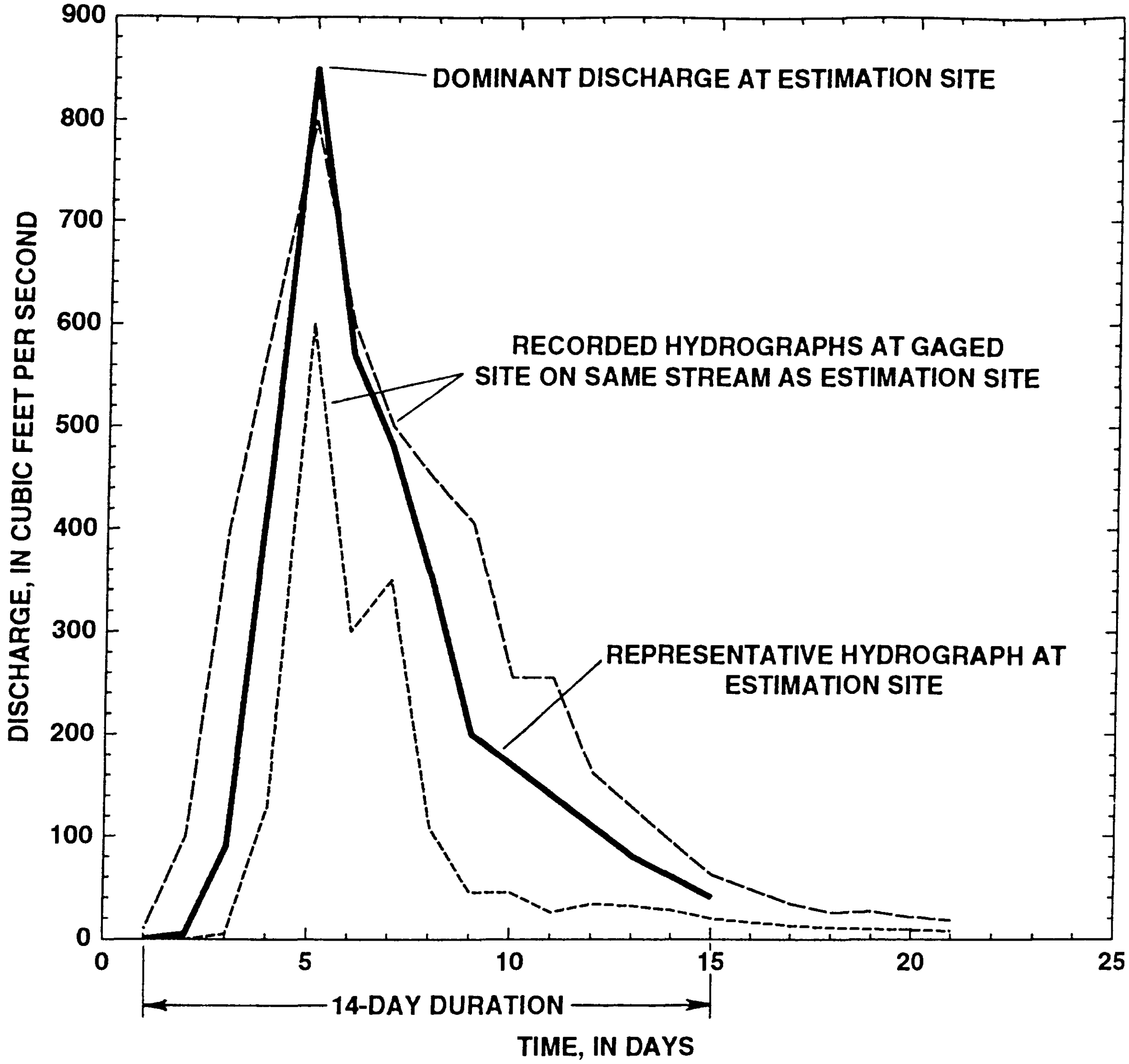


Figure 4. Development of a representative hydrograph using recorded hydrographs.

resulting from summer thunderstorms generally have durations that are shorter than 14 days. These runoff hydrographs were excluded from the analysis regardless of the maximum daily discharge value. Although the use of either 14- or 21-day durations for typical runoff hydrographs may seem overly restrictive, most recorded annual snowmelt runoff hydrographs that were analyzed had durations reasonably close to either 14 or 21 days.

Selected hydrographs were plotted together with their maximum daily discharges in alignment on a common day so that hydrograph durations and shapes could be more easily compared (fig. 4). The dominant discharge for the estimation site was also plotted on the same day as the maximum daily discharges for the recorded hydrographs. Visual examination was used to estimate values of daily discharge on either side of the dominant discharge such that the slopes of the rising and recession limbs of the representative hydrograph were in close agreement with the average slopes of the recorded hydrographs. In some instances, one or more recorded hydrographs may have had shapes that were significantly different from other recorded hydrographs. In these instances, the atypical recorded hydrographs either were not used to develop representative hydrographs or were given less weight in developing representative hydrographs.

On many recorded hydrographs, generally smooth hydrograph recession curves were interrupted by storm runoff. The resultant sudden increases in flow on the recession curves were ignored in the determination of representative discharge values. The representative values of daily discharge generally were visually determined average values of several recorded hydrographs. In some instances, however, the representative values of discharge were determined largely from one recorded hydrograph that was considered to be most representative of normal, long-term runoff conditions. The choice of a 14- or 21-day duration for the representative hydrograph was somewhat arbitrary, but was largely based on the following criteria: (1) the discharge values for the first and last day had to be close to base flow, and (2) the slope of the recession limb of the hydrograph had to be fairly constant so that successive values of discharge near the end of the duration were not repeated. In some instances, the first criterion was not fully met because the best value for a representative hydrograph duration was probably greater than 21 days. In some instances, the second criterion was not fully met because the best value for a representative hydrograph duration was probably less than 14 days.

The estimated dominant discharge, hydrograph duration (either 14 or 21 days), and values of discharge on the rising and recession limbs of the hydrograph were used to plot a dominant-discharge hydrograph for each site. From the plot, daily discharges were determined for each day of the selected duration period. Dominant-discharge hydrographs for two sites are compared to the selected recorded hydrographs from which they were developed in figure 5. Recorded hydrographs in figure 5 are shown on the actual days of occurrence. The dates on the dominant discharge hydrographs in figure 5 are arbitrary and were selected so that all hydrographs could be easily compared. Because estimated discharges were rounded, the dominant-discharge hydrographs shown in figure 5 are not completely smooth throughout the rising and recession limbs. As indicated in figure 5, the dominant-discharge hydrographs are similar in shape to the recorded hydrographs and are considered to be reasonably representative of general runoff conditions at the gaged sites where the data were recorded. In one instance, Rock Creek at mouth, near Hinsdale (site 10), the selected recorded hydrographs used to develop the dominant-discharge hydrograph were for a gaged site having a drainage area less than one-fourth that of the estimation site. Although the dominant discharge was estimated based on a drainage-area-ratio adjustment, no such adjustments are available for hydrograph characteristics such as duration and slopes of the rising and recession limbs. Natural hydrographs at ungaged estimation sites thus may have different durations and shapes from those of the estimated dominant-discharge hydrographs, particularly if the difference in drainage area between the gaged and ungaged sites is large.

RELIABILITY OF ESTIMATES

Although the reliability of the estimates of monthly flow characteristics and dominant-discharge hydrographs cannot be directly measured, some inferences can be made based on findings of the previous study for the upper Missouri River Basin (Parrett and others, 1989) and the results of the test of the streamflow-record extension method described earlier. As described by Parrett and others (1989), estimates of monthly flow characteristics at gaged sites generally are the most accurate and, if the record spans the base period, the only error is measurement error. Measurement error is generally small and, for purposes of this report, will be ignored. On that basis, the estimated flows for the Missouri River below Fort Peck Dam (site 1) are considered to be virtually error free because the recorded flow record for the 1943-86 period is complete. For the other gaged sites, the error of estimation is due solely to the error of the record-extension method. The error of the record-extension method depends on the length of record and the average standard error of prediction. The shorter the length of actual record and the larger the average standard error of prediction, the greater the error.

The test of the streamflow-record extension method that was described earlier in this report found that the error of record extension was significant only during months of generally high runoff. Although the test was not rigorous, it did represent a probable "worst-case" situation wherein the standard error of prediction for the streamflow-record extension method was relatively large and all flows during the selected base period were estimated. The test results suggest that record-extension errors probably are not significant for most monthly streamflow characteristics for most months at streamflow-gaging stations used in the study. Parrett and others (1989) found that record-extension errors in the upper Missouri River Basin generally were less, even for record lengths as short as 5 years, than the errors resulting from estimation based on regional regression equations or the concurrent-measurement method at ungaged sites.

For the two ungaged sites where the concurrent-measurement method was used, the error of estimation depends upon the number of concurrent measurements and the degree of correlation between the estimation site and the nearby gaged site. Because of the greater number of measurements spanning a greater range in flow, the estimated monthly flow characteristics for Poplar River at Fort Peck Reservation boundary, near Scobey (site 15) are considered to be more reliable than the estimated monthly flow characteristics for West Fork Poplar River at Fort Peck Reservation boundary,

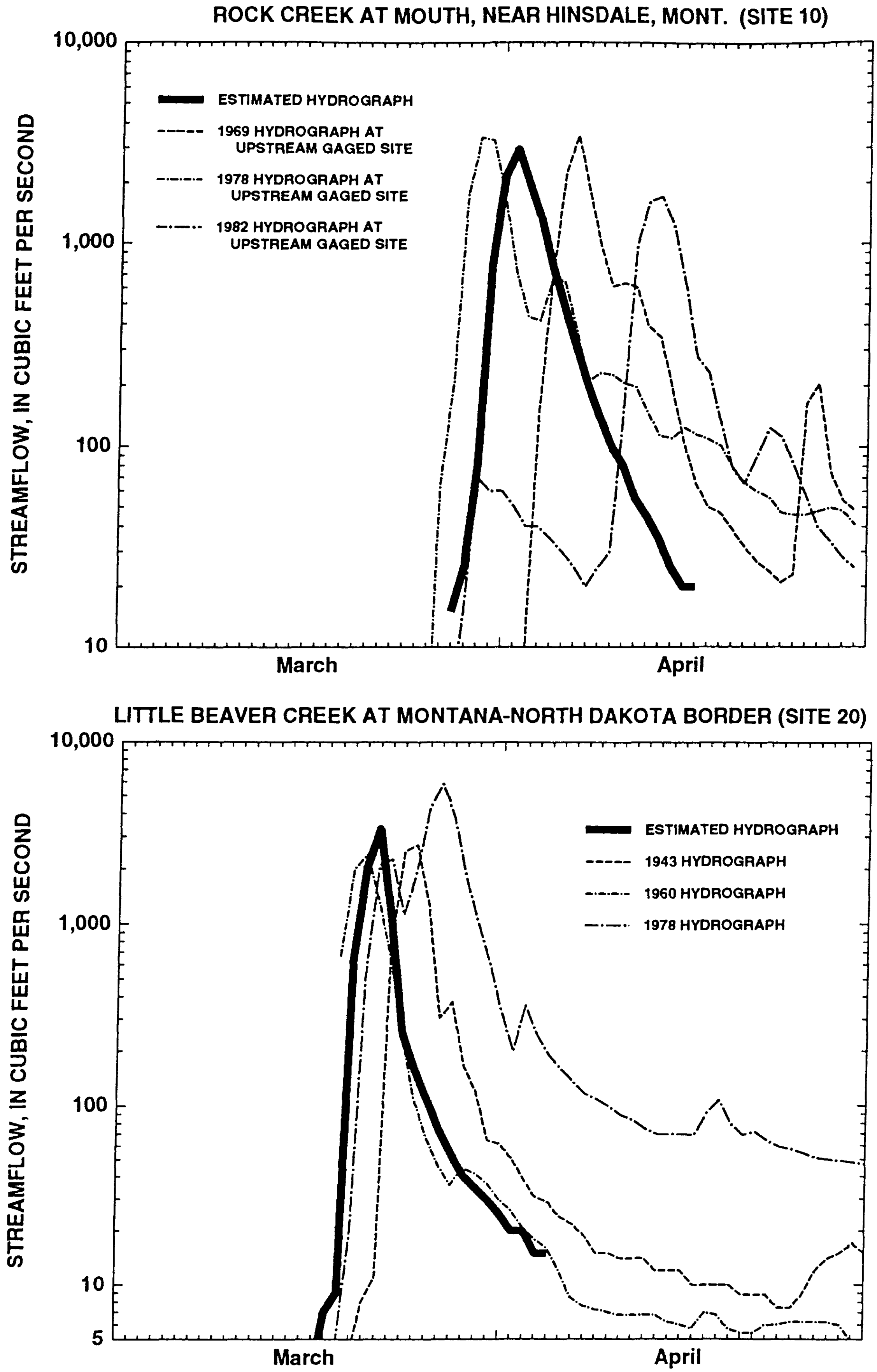


Figure 5. Dominant-discharge hydrographs and selected recorded hydrographs at selected streams in Montana.

near Four Buttes (site 16). Based on the value of the correlation coefficient, the degree of correlation between the estimation site and the gaged site was considered to be relatively good.

The reliability of the estimated monthly flow characteristics for sites where the drainage-area-ratio-adjustment factor was used is primarily dependentupon the difference in hydrologic characteristics between the gaged and ungaged sites. To the degree that the difference in hydrologic characteristics is related to drainage area difference, the reliability depends upon the drainage-area ratio. For sites where the drainage-area ratio is close to 1.0, the reliability of flow estimates is considered to be almost as good as for gaged sites. For sites where the ratio is less than about 0.5 or greater than about 1.5, the reliability is considered to be significantly less than for gaged sites.

The reliability of the estimated dominant-discharge hydrographs is difficult to determine because there is no single runoff hydrograph to which each dominant-discharge hydrograph can be compared. Statements about the reliability of dominant-discharge hydrograph estimates thus are more general than for estimates of monthly flow characteristics. In general, the estimated dominant-discharge hydrographs for gaged sites are considered to be more reliable than those for ungaged sites. As noted previously, however, the dominant-discharge hydrograph for site 21 (Beaver Creek near Trotters, N. Dak.), was based on a different streamflow-gaging station than the one near the site. In this instance, considering the site to be ungaged and using the drainage-area-ratio adjustment provided a more reliable dominant-discharge hydrograph than did the gaged record.

For ungaged sites in general, the closer the drainage-area ratio is to 1.0, the more reliable is the estimated dominant discharge. On that basis, the estimated dominant discharges for Battle Creek at mouth, near Chinook (site 5) and Redwater River near Vida (site 12) are considered to be the most reliable, and the estimated dominant-discharge for Rock Creek at mouth, near Hinsdale (site 10) is considered to be the least reliable. The reliability of the dominant-discharge hydrographs is also related to the number of recorded hydrographs used for visual comparison and the degree of similarity among them. On that basis, the dominant-discharge hydrograph for Redwater River near Vida, although having one of the more reliable dominant discharge estimates, is one of the least reliable hydrographs overall because the recorded hydrographs used for visual comparison had widely varying shapes. On the other hand, the dominant-discharge hydrograph for West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes (site 16) is considered to be one of the most reliable because the recorded hydrographs on which it is based had fairly consistent hydrograph shapes.

SUMMARY

To establish an instream-flow reservation in the lower Missouri River and Little Missouri River Basins for fish, wildlife, and recreation purposes, DFWP requires information about various streamflow characteristics. USGS, in cooperation with DFWP, conducted a study to determine streamflow characteristics at 17 sites in the lower Missouri River Basin and 4 sites in the Little Missouri River Basin in Montana. Mean monthly and annual streamflow and monthly mean streamflow exceeded 90, 80, 50, and 20 percent of the time was estimated for all 21 sites. Streamflow-gaging stations were located at 7 of the selected sites, and the streamflow record was used as a basis for determining the monthly streamflow characteristics. For each of the 14 ungaged sites, streamflow records from nearby gaging stations were used as a basis for estimating streamflow characteristics.

For all sites but two on the Missouri River mainstem, the streamflow estimates were based on a common 1937-86 base period. For the two Missouri River sites, streamflow characteristics were estimated based on the period of record since Fort Peck Lake was substantially filled and became operational (1943-86). A streamflow record-extension program was used to estimate missing values of monthly flow during the 1937-86 base period at streamflow-gaging stations used to estimate flow characteristics at the selected sites.

For two ungaged sites in the Poplar River Basin, miscellaneous measurements of discharge were correlated with concurrent daily mean discharges at the streamflow-gaging station Poplar River at International Boundary (station 06178000) using the MOVE.1 curve-fitting technique. The resultant log-linear equations relating discharge at the ungaged sites to discharge at the Poplar River at International Boundary were used to estimate monthly streamflow characteristics at the ungaged sites.

For each of the other 12 ungaged sites, monthly streamflow characteristics at a streamflow-gaging station located on the same stream were used to estimate monthly streamflow characteristics at the ungaged site using a drainage-area-ratio-adjustment method. The ratio of the drainage area at the ungaged site to the drainage area at the gaged site was multiplied by the value of each monthly streamflow characteristic at the gaged site to estimate the value of the characteristic at the ungaged site. An adaptation of the drainage-area-ratio-adjustment method was used to estimate monthly streamflow characteristics for Frenchman River at mouth, near Saco. For this site, the drainage-area-ratio adjustment was applied to streamflow characteristics developed from flow records at Frenchman River at International Boundary (station 06164000) minus flow records for Frenchman Canal near Saco (station 06164500).

Dominant-discharge hydrographs were estimated for 10 ungaged sites in the lower Missouri River Basin and 4 gaged sites in the Little Missouri River Basin. The dominant discharge was considered to be equivalent to the peak discharge having a recurrence interval of 2 years and, for 3 of the 4 gaged sites, was determined from recorded data at the streamflow-gaging stations. For each of the 10 ungaged sites and 1 gaged site, the dominant discharge was determined by multiplying the dominant discharge at a gaged site on the same stream by a drainage-area-ratio adjustment. Dominant discharges at all gaged sites were obtained from a USGS flood-frequency report or by fitting a log-Pearson Type 3 probability distribution to the recorded data.

For each of the 14 selected sites, the dominant discharge was used as the maximum daily discharge for the dominant-discharge hydrograph. Visual examination of selected recorded hydrographs from each gaged site used to determine dominant discharge was used to determine the duration and daily mean discharges on the rising and recession limbs of the dominant-discharge hydrograph.

Based on results of a previous study for the upper Missouri River Basin, the estimates of monthly streamflow characteristics are considered to be most reliable for gaged sites. Ignoring measurement error, estimates for one Missouri River site (site 1) are virtually error free because the estimates are based on gaged records with no months of missing flow data. The reliability of the monthly streamflow estimates for two sites (sites 15 and 16) using the concurrent-measurement method is considered to be almost as good as that for gaged sites. Likewise, the estimates of monthly streamflow based on the drainage-area-ratio-adjustment method for sites where the drainage-area ratios are close to 1.0 are considered to be almost as reliable as those for gaged sites.

The reliability of the estimated dominant-discharge hydrographs is difficult to assess. In general, the estimates made at gaged sites are better than those made for ungaged sites except for Beaver Creek at Montana-North Dakota border (site 21). At ungaged sites, the closer the drainage-area ratio is to 1.0 the more reliable is the estimate for dominant discharge. The reliability of representative hydrographs developed from recorded hydrographs generally is related to the degree of similarity of the recorded hydrographs and the distance from the estimation site to the gaged site.

REFERENCES CITED

Alley, W.M., and Burns, A.W., 1983, Mixed-station extension of monthly streamflow records: American Society of Civil Engineers, Journal of Hydraulic Engineering, v. 109, no. 10, p. 1,272-1,284.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency--Bulletin 17B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination, 183 p.

Leopold, L.B., Wolman, M.G., and Miller, J.P., 1964, Fluvial processes in geomorphology: San Francisco, W.H. Freeman and Co., 522 p.

Montana Department of Fish, Wildlife and Parks, 1979, Instream flow evaluation for selected streams in the upper Missouri River basin: Helena, Mont., 254 p.

Montana Department of Fish, Wildlife and Parks, Ecological Services and Fisheries Divisions, 1981, Instream flow evaluation for selected waterways in western Montana: Helena, Mont., Contract No. 53-0343-0-305, 340 p.

Omang, R.J., 1992, Analysis of the magnitude and frequency of floods and the peak-flow gaging network in Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4048, 70 p.

Parrett, Charles, Johnson, Dave R., and Hull, J.A., 1989, Estimates of monthly streamflow characteristics at ungaged sites in the upper Missouri River Basin, Montana, base period water years 1937-86: U.S. Geological Survey Water-Resources Investigations Report 89-4082, 103 p.

Reiser, D.W., and Ramey, M.P., 1985, Review of flushing flow requirements in regulated streams: San Ramon, California, Pacific Gas and Electric Company, Dept. of Engineering Research, 97 p.

SUPPLEMENTAL DATA

Table 7. Estimated monthly and annual streamflow characteristics

[Q.XX, monthly mean streamflow exceeded XX percent of the time, in cubic feet per second; QM, mean streamflow for specified month, or mean annual streamflow when Annual is specified, in cubic feet per second]

Site no.	Stream name	Month	Q.90	Q.80	Q.50	Q.20	QM
1	Missouri River below Fort Peck Dam, Mont.	October	5,200	6,060	11,500	19,100	12,600
		November	4,590	5,800	9,210	13,200	9,460
		December	5,150	6,880	10,100	11,300	9,040
		January	4,470	6,640	10,900	13,000	9,620
		February	2,130	5,500	10,900	14,100	9,600
		March	1,250	4,130	7,740	11,200	7,620
		April	2,120	4,430	7,520	10,500	7,440
		May	2,800	5,500	7,380	12,000	8,310
		June	2,500	4,170	7,900	12,700	8,420
		July	3,640	5,770	10,000	13,200	10,300
		August	5,980	7,720	12,100	18,900	13,000
		September	5,900	7,020	11,900	18,800	13,000
		Annual	--	--	--	--	9,870
2	Beaver Creek above Lower Lake, near Havre, Mont.	October	3	4	7	12	9
		November	4	4	7	12	9
		December	2	2	6	11	7
		January	4	5	7	8	7
		February	7	7	8	13	10
		March	7	8	18	33	20
		April	12	14	23	39	27
		May	17	18	23	126	54
		June	14	19	38	74	49
		July	3	4	11	31	18
		August	2	3	5	13	8
		September	2	2	4	10	7
		Annual	--	--	--	--	19
3	Little Boxelder Creek at Clear Creek Road, near Havre, Mont.	October	0	0	.2	3	1
		November	0	0	.3	3	1
		December	0	0	.3	2	1
		January	0	0	.2	1	2
		February	0	0	.7	6	4
		March	.4	3	6	18	11
		April	.6	1	5	17	11
		May	.1	1	3	18	15
		June	.1	.4	3	15	11
		July	0	0	1	7	5
		August	0	0	.2	2	1
		September	0	0	.2	1	1
		Annual	--	--	--	--	5
4	Clear Creek at Clear Creek Road crossing, near Lohman, Mont.	October	0	0	.2	2	1
		November	0	.1	.5	3	2
		December	0	.1	.6	3	2
		January	0	0	.5	1	2
		February	0	.1	.9	6	6
		March	.5	.8	9	34	23
		April	.7	1	6	23	16
		May	.2	2	6	32	29
		June	.1	.5	6	27	20
		July	0	.1	2	10	5
		August	0	0	.1	2	1
		September	0	0	0	.7	1
		Annual	--	--	--	--	9

Table 7. Estimated monthly and annual streamflow characteristics (Continued)

Site no.	Stream name	Month	Q.90	Q.80	Q.50	Q.20	QM
5	Battle Creek at mouth, near Chinook, Mont.	October	0	0	.5	16	7
		November	0	0	.3	10	5
		December	0	0	.3	7	4
		January	0	0	.1	2	2
		February	0	0	1	14	12
		March	0	.1	15	93	54
		April	0	4	31	85	146
		May	0	.5	34	116	75
		June	0	.1	21	47	40
		July	0	.1	12	26	14
		August	0	.1	.5	8	6
		September	0	0	3	7	24
		Annual	--	--	--	--	32
6	Peoples Creek at Barney Olsen Road, near Dodson, Mont.	October	0	0	.5	2	1
		November	0	0	.5	2	1
		December	0	0	.4	2	.9
		January	0	0	.4	1	1
		February	0	0	1	6	4
		March	.5	2	7	18	13
		April	3	4	7	18	11
		May	.6	1	4	17	12
		June	.4	1	6	20	12
		July	0	0	2	8	4
		August	0	0	.2	2	1
		September	0	0	0	.9	1
		Annual	--	--	--	--	5
7	Frenchman River at mouth, near Saco, Mont.	October	0	0	3	13	10
		November	.7	2	5	11	7
		December	0	.1	2	7	3
		January	0	0	.3	3	2
		February	0	0	.8	7	17
		March	3	13	76	199	151
		April	23	52	239	755	460
		May	10	17	59	195	139
		June	0	1	21	94	58
		July	0	0	13	37	41
		August	0	0	4	13	9
		September	0	0	2	8	6
		Annual	--	--	--	--	75
8	Beaver Creek at Fort Belknap Indian Reservation, near Zortman, Mont.	October	.2	.3	.4	.5	.4
		November	.2	.3	.5	1	.3
		December	.1	.2	.3	.5	.3
		January	0	0	.2	.3	.2
		February	0	.1	.2	.3	.2
		March	.2	.3	.5	.5	.5
		April	.2	.3	.5	1	.5
		May	.2	.2	.5	2	1
		June	.1	.2	1	3	2
		July	.1	.3	.5	1	1
		August	.1	.1	.5	1	.5
		September	.2	.2	.4	.5	.5
		Annual	--	--	--	--	.6

Table 7. Estimated monthly and annual streamflow characteristics (Continued)

Site no.	Stream name	Month	Q.90	Q.80	Q.50	Q.20	QM
9	Beaver Creek at mouth, near Saco, Mont.	October	0	.2	5	38	27
		November	2	2	5	18	11
		December	2	2	5	13	8
		January	1	2	3	8	7
		February	2	2	9	58	47
		March	6	21	80	339	204
		April	2	5	25	225	198
		May	3	18	91	643	329
		June	4	7	35	207	133
		July	2	3	27	129	85
		August	1	2	14	29	18
		September	.2	.2	2	21	48
		Annual	--	--	--	--	93
10	Rock Creek at mouth, near Hinsdale, Mont.	October	1	2	7	13	8
		November	3	4	7	10	8
		December	2	2	3	5	3
		January	0	0	.8	3	2
		February	0	0	2	11	16
		March	1	18	151	738	354
		April	39	59	239	1130	508
		May	16	20	46	164	84
		June	9	14	34	115	70
		July	2	5	13	59	36
		August	0	0	.4	6	15
		September	0	0	.4	6	15
		Annual	--	--	--	--	93
11	Redwater River above confluence of East Fork Redwater River, near Vida, Mont.	October	.7	1	3	6	4
		November	2	2	3	4	4
		December	.6	1	3	4	3
		January	0	0	.6	2	2
		February	.6	1	3	67	52
		March	7	14	77	221	213
		April	5	9	24	62	109
		May	4	5	11	34	21
		June	2	4	13	101	70
		July	.6	2	6	52	35
		August	.6	.7	2	6	4
		September	1	1	1	4	3
		Annual	--	--	--	--	43
12	Redwater River near Vida, Mont.	October	.9	1	3	7	4
		November	2	2	4	5	4
		December	.7	2	3	4	3
		January	0	0	.9	2	2
		February	.7	2	4	83	64
		March	10	17	95	274	263
		April	6	12	30	77	135
		May	5	6	14	43	27
		June	2	5	16	125	87
		July	.7	2	7	64	43
		August	.7	.9	2	7	5
		September	1	1	2	4	4
		Annual	--	--	--	--	53

Table 7. Estimated monthly and annual streamflow characteristics (Continued)

Site no.	Stream name	Month	Q.90	Q.80	Q.50	Q.20	QM
13	Poplar River above confluence of East Poplar River, near Scobey, Mont.	October	.3	1	4	6	4
		November	1	2	4	6	4
		December	0	.7	2	4	2
		January	0	0	.4	2	1
		February	0	0	.6	4	4
		March	.4	13	62	207	115
		April	14	18	60	353	168
		May	8	11	20	47	32
		June	3	5	13	31	26
		July	.5	1	4	10	12
		August	.2	.2	.5	3	3
		September	.2	.2	.7	3	2
		Annual	--	--	--	--	31
14	East Poplar River at mouth, near Scobey, Mont.	October	2	3	4	4	4
		November	2	3	4	4	4
		December	2	3	4	4	3
		January	2	2	4	4	3
		February	2	3	4	5	4
		March	4	4	5	74	33
		April	4	4	9	163	68
		May	5	9	15	37	20
		June	4	4	5	26	18
		July	3	3	4	6	5
		August	3	3	4	5	5
		September	3	3	4	4	4
		Annual	--	--	--	--	14
15	Poplar River at Fort Peck Reservation boundary, near Scobey, Mont.	October	2	7	16	21	17
		November	5	8	16	22	17
		December	0	0	9	15	11
		January	0	0	2	9	8
		February	0	0	4	15	16
		March	3	39	122	298	192
		April	41	50	119	443	255
		May	27	34	52	99	74
		June	13	20	39	73	64
		July	3	6	16	31	35
		August	1	1	3	14	12
		September	1	1	4	13	11
		Annual	--	--	--	--	59
16	West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes, Mont.	October	1	3	6	8	7
		November	2	3	6	8	7
		December	0	2	4	6	4
		January	0	0	1	4	3
		February	0	0	2	6	6
		March	1	14	40	89	60
		April	15	17	39	127	77
		May	10	12	18	33	25
		June	5	8	14	25	22
		July	1	3	6	12	13
		August	.7	.7	1	6	5
		September	.7	.7	2	5	4
		Annual	--	--	--	--	19

Table 7. Estimated monthly and annual streamflow characteristics (Continued)

Site no.	Stream name	Month	Q.90	Q.80	Q.50	Q.20	QM
17	Missouri River near Culbertson, Mont.	October	5,520	6,430	11,500	18,900	12,800
		November	4,610	6,320	9,290	13,100	9,800
		December	5,380	6,960	9,620	11,600	8,950
		January	4,620	6,160	11,000	12,700	9,490
		February	2,390	6,020	11,200	14,400	10,200
		March	4,150	5,420	10,700	14,400	10,400
		April	4,950	7,470	10,900	16,900	11,900
		May	3,270	6,050	9,260	14,800	10,000
		June	4,480	5,440	8,620	13,800	9,780
		July	5,160	6,430	9,940	13,500	11,000
		August	6,470	7,670	12,200	19,200	13,000
		September	6,620	7,420	12,100	19,100	13,200
		Annual	--	--	--	--	10,900
18	Little Missouri River at Montana-South Dakota border[1]	October	2	3	4	18	55
		November	3	3	5	8	8
		December	2	3	5	7	5
		January	1	1	3	6	6
		February	1	2	6	39	68
		March	15	38	192	613	359
		April	8	26	72	532	282
		May	9	17	71	639	319
		June	9	22	230	790	418
		July	5	14	46	119	86
		August	1	4	16	71	38
		September	2	2	5	53	40
		Annual	--	--	--	--	140
19	Boxelder Creek near Webster, Mont.	October	2	2	5	12	32
		November	3	4	6	8	7
		December	2	2	4	6	5
		January	2	2	3	6	4
		February	.9	1	5	48	44
		March	15	21	95	398	211
		April	11	17	58	285	257
		May	7	15	48	255	149
		June	13	25	123	263	174
		July	3	6	32	72	50
		August	1	2	10	37	22
		September	.9	2	5	27	21
		Annual	--	--	--	--	81
20	Little Beaver Creek at Montana-North Dakota border[2]	October	0	.4	2	6	10
		November	.3	1	3	4	3
		December	0	.5	2	3	3
		January	0	0	1	4	4
		February	0	.3	3	46	27
		March	9	14	52	266	149
		April	5	9	28	133	113
		May	5	6	16	49	42
		June	5	15	53	138	83
		July	2	4	15	37	29
		August	.2	1	4	9	10
		September	0	.3	3	14	13
		Annual	--	--	--	--	41

Table 7. Estimated monthly and annual streamflow characteristics (Continued)

Site no.	Stream name	Month	Q.90	Q.80	Q.50	Q.20	QM
21	Beaver Creek at Montana-North Dakota border[3]	October	0	0	.3	2	1
		November	0	0	.4	2	3
		December	0	.2	1	2	1
		January	0	0	.6	2	2
		February	.1	.7	5	63	39
		March	8	14	71	429	181
		April	4	7	23	140	111
		May	.8	1	8	24	14
		June	.9	3	10	55	35
		July	.1	.6	5	25	39
		August		0	0	.3	3
		September	0	0	.3	2	.7
		Annual	--	--	--	--	36

[1]Name of streamflow-gaging station is Little Missouri River at Camp Crook, S. Dak.
[2]Name of streamflow-gaging station is Little Beaver Creek near Marmarth, N. Dak.
[3]Name of streamflow-gaging station is Beaver Creek near Trotters, N. Dak.

Table 8. Daily mean discharges from the estimated dominant-discharge hydrographs

Site no.	Stream name	Day	Daily mean discharge, in cubic feet per second
5	Battle Creek at mouth, near Chinook, Mont.	1	40
		2	90
		3	210
		4	470
		5	1,520
		6	710
		7	260
		8	130
		9	100
		10	85
		11	70
		12	60
		13	55
		14	45
7	Frenchman River at mouth, near Saco, Mont.	1	10
		2	30
		3	50
		4	70
		5	150
		6	290
		7	450
		8	740
		9	1,320
		10	1,010
		11	760
		12	580
		13	470
		14	360
		15	280
		16	200
		17	160
		18	120
		19	90
		20	70
		21	60
9	Beaver Creek at mouth, near Saco, Mont.	1	10
		2	190
		3	880
		4	2,210
		5	1,750
		6	1,180
		7	640
		8	500
		9	390
		10	300
		11	210
		12	180
		13	150
		14	120
		15	100
		16	80
		17	60
		18	40
		19	20
		20	10
		21	10

Table 8. Daily mean discharges from the estimated dominant-discharge hydrographs (Continued)

Site no.	Stream name	Day	Daily mean discharge, in cubic feet per second
10	Rock Creek at mouth, near Hinsdale, Mont.	1	15
		2	25
		3	80
		4	780
		5	1,900
		6	2,560
		7	1,750
		8	1,260
		9	760
		10	480
		11	310
		12	200
		13	140
		14	100
		15	80
		16	55
		17	45
		18	35
		19	25
		20	20
		21	20
11	Redwater River above confluence of East Fork Redwater River, near Vida, Mont.	1	0
		2	20
		3	60
		4	180
		5	370
		6	780
		7	540
		8	340
		9	230
		10	120
		11	100
		12	80
		13	60
		14	40
12	Redwater River near Vida, Mont.	1	5
		2	70
		3	110
		4	300
		5	490
		6	900
		7	700
		8	480
		9	290
		10	180
		11	150
		12	130
		13	110
		14	90

Table 8. Daily mean discharges from the estimated dominant-discharge hydrographs (Continued)

Site no.	Stream name	Day	Daily mean discharge, in cubic feet per second
13	Poplar River above confluence of East Poplar River, near Scobey, Mont.	1	40
		2	150
		3	670
		4	1,000
		5	670
		6	320
		7	160
		8	110
		9	80
		10	60
		11	50
		12	30
		13	20
		14	20
14	East Poplar River at mouth, near Scobey, Mont.	1	2
		2	6
		3	10
		4	60
		5	280
		6	540
		7	330
		8	200
		9	80
		10	60
		11	20
		12	9
		13	7
		14	5
15	Poplar River at Fort Peck Reservation boundary, near Scobey, Mont.	1	50
		2	200
		3	880
		4	1,930
		5	1,530
		6	1,000
		7	820
		8	600
		9	400
		10	300
		11	220
		12	170
		13	120
		14	70
16	West Fork Poplar River at Fort Peck Reservation boundary, near Four Buttes, Mont.	1	5
		2	90
		3	450
		4	850
		5	570
		6	480
		7	350
		8	200
		9	170
		10	140
		11	110
		12	80
		13	60
		14	40

Table 8. Daily mean discharges from the estimated dominant-discharge hydrographs (Continued)

Site no.	Stream name	Day	Daily mean discharge, in cubic feet per second
18	Little Missouri River at Montana-South Dakota border[1]	1	10
		2	15
		3	20
		4	75
		5	290
		6	1,450
		7	2,540
		8	2,320
		9	1,670
		10	1,150
		11	940
		12	760
		13	600
		14	430
		15	280
		16	240
		17	200
		18	280
		19	240
		20	200
		21	150
19	Boxelder Creek near Webster, Mont.	1	6
		2	25
		3	55
		4	170
		5	340
		6	850
		7	1,910
		8	1,480
		9	1,220
		10	860
		11	640
		12	380
		13	160
		14	120
		15	55
		16	35
		17	15
		18	10
		19	5
		20	4
		21	3

Table 8. Daily mean discharges from the estimated dominant-discharge hydrographs (Continued)

Site no.	Stream name	Day	Daily mean discharge, in cubic feet per second
20	Little Beaver Creek at Montana-North Dakota border[2]	1	2
		2	3
		3	7
		4	9
		5	620
		6	2,050
		7	3,310
		8	1,080
		9	250
		10	160
		11	110
		12	75
		13	55
		14	41
		15	35
		16	30
		17	25
		18	20
		19	20
		20	15
		21	15
21	Beaver Creek at Montana-North Dakota border[3]	1	10
		2	15
		3	35
		4	130
		5	390
		6	790
		7	1,050
		8	660
		9	330
		10	130
		11	65
		12	53
		13	40
		14	35

[1]Name of streamflow-gaging station is Little Missouri River at Camp Crook, S. Dak.
[2]Name of streamflow-gaging station is Little Beaver Creek near Marmarth, N. Dak.
[3]Name of streamflow-gaging station is Beaver Creek near Trotters, N. Dak.