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Methods for Estimating Selected Flow-Duration and Flood-Frequency Characteristics at Ungaged Sites in Central Idaho

Water-Resources Investigations Report 94–4120

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By L.C. Kjelstrom

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Boise, Idaho
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CONVERSION FACTORS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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By L.C. Kjelstrom

ABSTRACT

Methods for estimating daily mean discharges for selected flow durations and flood discharge for selected recurrence intervals at ungaged sites in central Idaho were applied using data collected at streamflow-gaging stations in the area. The areal and seasonal variability of discharge from ungaged drainage basins may be described by estimating daily mean discharges that are exceeded 20, 50, and 80 percent of the time each month. At 73 gaging stations, mean monthly discharge was regressed with discharge at three points—20, 50, and 80—from daily mean flow-duration curves for each month. Regression results were improved by dividing the study area into six regions. Previously determined estimates of mean monthly discharge from about 1,200 ungaged drainage basins provided the basis for applying the developed techniques to the ungaged basins. Estimates of daily mean discharges that are exceeded 20, 50, and 80 percent of the time each month at ungaged drainage basins can be made by multiplying mean monthly discharges estimated at ungaged sites by a regression factor for the appropriate region. In general, the flow-duration data were less accurately estimated at discharges exceeded 80 percent of the time than at discharges exceeded 20 percent of the time. Curves drawn through the three points for each of the six regions were most similar in July and most different from December through March.

Coefficients of determination of the regressions indicate that differences in mean monthly discharge largely explain differences in discharge at points on the daily mean flow-duration curve. Inherent in the method are errors in the technique used to estimate mean monthly discharge.

Flood discharge estimates for selected recurrence intervals at ungaged sites upstream or downstream from gaging stations can be determined by a transfer technique. A weighted ratio of drainage area times flood discharge for selected recurrence intervals at the gaging station can be used to estimate flood discharge at the ungaged site. Best results likely are obtained when the difference between gaged and ungaged drainage areas is small.

INTRODUCTION

Daily mean flow-duration data for individual months provide fish and wildlife managers, water-rights administrators, and other land- and water-use planners and managers information on areal and seasonal variations in runoff. Flow-duration information is required for central Idaho to aid in the adjudication of water rights based on fish habitat requirements. The study area includes the Salmon and Clearwater River Basins; upstream parts of the Weiser and Payette River Basins; and several small basins in Idaho that adjoin the western boundaries of the Weiser, Salmon, and Clearwater River Basins and drain to the Snake River (fig. 1).

Lipscomb (in press) identified and classified about 1,200 subbasins in the study area to provide input for fish habitat models. This study describes methods used to estimate flow-duration and flood-frequency charac-

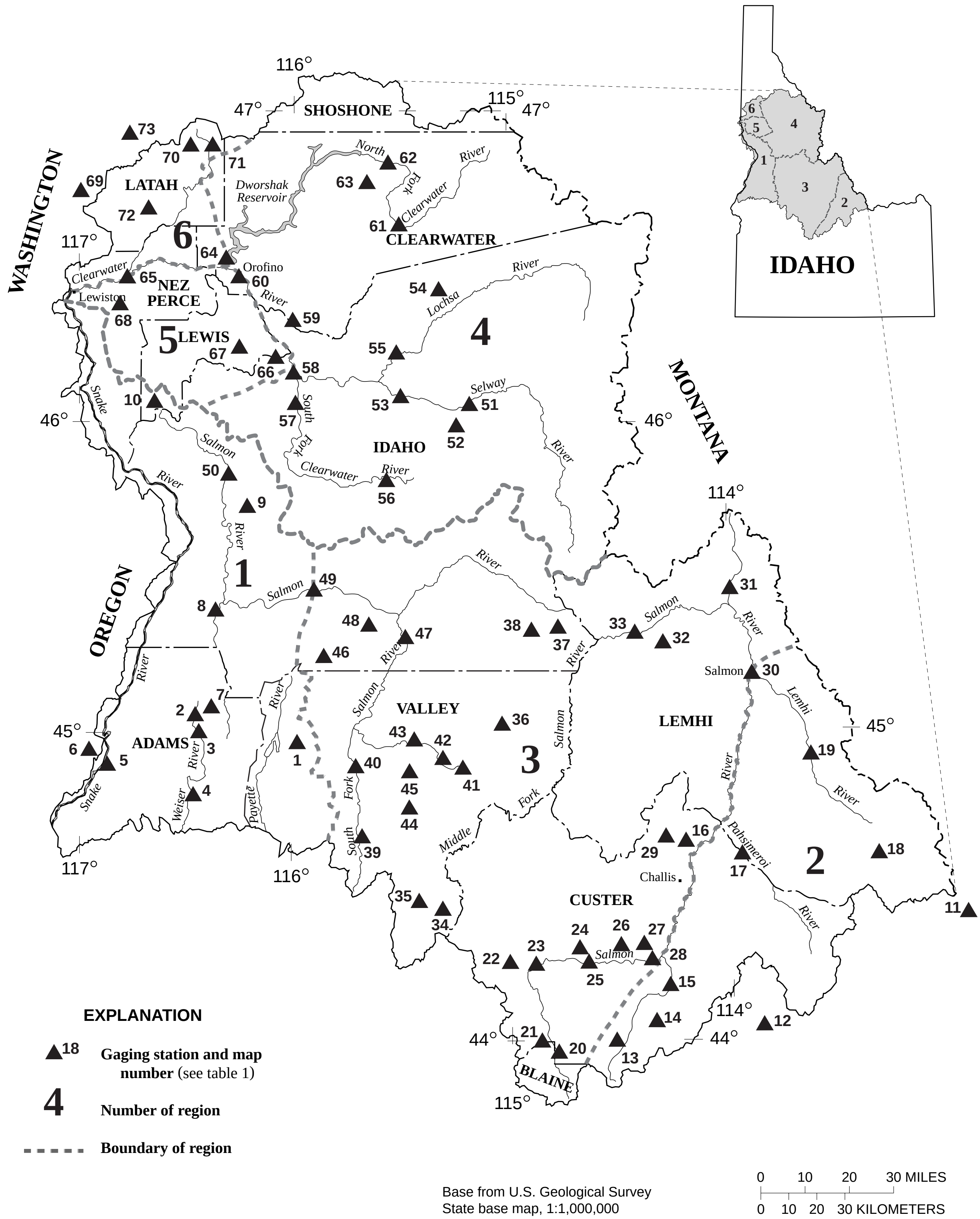

Figure 1. Locations of streamflow-gaging stations and regions used to estimate flow-duration curve values.

teristics of ungaged subbasins. Lipscomb also determined mean monthly discharges from the 1,200 ungaged drainage basins in the study area by using an existing technique (Quillian and Harenberg, 1982) and streamflow gaging-station records. This technique related several basin and climatic characteristics to mean annual discharge. The mean annual discharge was apportioned into monthly increments on the basis of gaging-station records selected to be characteristic of each subbasin.

Where adequate gaging-station records are available, a relation can be derived between the mean monthly discharge and discharges at selected points on the daily mean flow-duration curve for each month. These relations are similar for groups of gaging stations located in similar basins. The study area was divided into regions on the basis of such similarities (fig. 1).

In addition, peak discharge information was needed for fish habitat analysis at selected stream sites in central Idaho. Many of the basins selected did not include gaging stations at their outlets, but all included a station in the basin or on the same stream downstream from the basin of interest. Peak discharge estimates at ungaged sites need to be consistent with peak discharges at gaging stations. This can be done by adjusting the peak discharge at gaging stations on the basis of the intervening area between the station and the basin outlet.

The purpose of this report is to describe a method that was used to estimate daily mean discharges at selected points on the flow-duration curve and to indicate the reliability and limitations of the method. Daily mean discharges that are equaled or exceeded 20, 50, and 80 percent of the time during each month were selected to describe water-right claims. Another purpose is to describe a method to estimate peak discharges at ungaged sites that are located upstream or downstream from a gaging station.

FLOW DURATION

Monthly streamflow characteristics were computed from data collected at 73 gaging stations in or near the study area (table 1). All gaging stations had at least 5 years of record through 1991. Gaging stations on streams where discharges are substantially regulated or where large diversions substantially affect most discharges were not used in the analyses.

A statistical analysis can be made from gaging-station records to determine the percentage of time a discharge will be equaled or exceeded for a given duration period. For this study, the duration periods are each month of the year and are based on records of daily mean discharge. For about 1,200 ungaged sites in the study area, mean monthly discharge, a streamflow characteristic, has previously been estimated on the basis of basin characteristics. Flow-duration information obtained at a gaging station may be transferred to ungaged sites by regression with a streamflow characteristic, which, for this study, is mean monthly discharge.

Mean monthly discharge and daily mean flow-duration curves for each month were computed from the records of 73 gaging stations. The flow-duration curve is a cumulative frequency curve that expresses the magnitude of daily mean discharge that is equaled or exceeded as a percentage of the period of record at a gaging station. Length of record ranged from 5 to 77 years; 25 gaging stations had records of 30 years or more. Because short periods of record could be biased by wet and dry climatic cycles, data for gaging stations with fewer than 30 years of record were adjusted by using data for nearby gaging stations that had 36 to 77 years of record. For example, mean October discharge of the Salmon River near Obsidian (fig. 1, number 20) for 12 years of record (1942–53) was 41.4 ft^3/s. Mean October discharge of the Salmon River below Yankee Fork, near Clayton (fig. 1, number 25) for 70 years of record (1922–91) was 508 ft^3/s and, for the 1942–53 period, was 545 ft^3/s. The mean October discharge of the Salmon River near Obsidian was adjusted to 38.6 ft^3/s by using the ratio of 508/545, or 0.932. Duration data were adjusted in a similar manner.

Regression of adjusted mean monthly discharge with adjusted discharges at the 20-, 50-, and 80-percent points on the flow-duration curves showed a direct linear relation. A general linear model was used to determine the slope of the regression line, which defines the relation between mean monthly discharge and the flow-duration discharge. These slopes or factors were similar for stations in certain parts of the study area. Six regions were selected to define the dif-

Table 1. Streamflow-gaging stations used for regression analyses

[Gaging stations are in Idaho unless otherwise indicated; *, used for flood-frequency analyses]

Map No.	Gaging station No.	Gaging station name	Drainage area (square miles)	Period of record	Region
1	13240000*	Lake Fork Payette River above Jumbo Creek, near McCall	48.9	1946–91	1
2	13251300	West Branch Weiser River near Tamarack	3.96	1959–77	1
3	13251500	Weiser River at Tamarack	36.5	1936–71	1
4	13258500	Weiser River near Cambridge	605	1940–91	1
5	13289960	Wildhorse River at Brownlee Dam	177	1979–91	1
6	13290190	Pine Creek near Oxbow, Oregon	230	1968–91	1
7	13315500*	Mud Creek near Tamarack	15.8	1946–59	1
8	13316500*	Little Salmon River at Riggins	576	1952–54; 1957–91	1
9	13316800	North Fork Skookumchuck Creek near White Bird	15.3	1961–71	1
10	13317500	Deer Creek near Winchester	19.1	1952–56	1
11	13116000	Medicine Lodge Creek at Ellis Ranch, near Argora	165	1942–70	2
12	13120000	North Fork Big Lost River at Wild Horse, near Chilly	114	1945–91	2
13	13297450	Little Boulder Creek near Clayton	18.4	1971–86	2
14	13297597	Herd Creek below Trail Gulch, near Clayton	110	1980–84	2
15	13298000*	East Fork Salmon River near Clayton	532	1929–39; 1974–81	2
16	13299200	Challis Creek below Jeffs Creek, near Challis	91.2	1964–70	2
17	13302000*	Pahsimeroi River near May	845	1929–59; 1971–72	2
18	13303000	Texas Creek near Leadore	71.4	1956–63	2
19	13305000	Lemhi River near Lemhi	895	1956–91	2
20	13292500*	Salmon River near Obsidian	94.7	1942–53	3
21	13293000	Alturas Lake Creek near Obsidian	35.7	1942–52	3
22	13295000*	Valley Creek at Stanley	147	1912; 1922–71	3
23	13295500	Salmon River below Valley Creek, at Stanley	501	1926–60	3
24	13296000*	Yankee Fork Salmon River near Clayton	195	1922–49	3
25	13296500	Salmon River below Yankee Fork, near Clayton	802	1922–91	3
26	13297330	Thompson Creek near Clayton	29.1	1974–91	3
27	13297355	Squaw Creek below Bruno Creek, near Clayton	79.0	1974–91	3
28	13298500	Salmon River near Challis	1,800	1929–72	3
29	13299000	Challis Creek near Challis	85.0	1944–63	3
30	13302500*	Salmon River at Salmon	3,760	1913–91	3
31	13306000*	North Fork Salmon River at North Fork	214	1930–40	3
32	13306500	Panther Creek near Shoup	529	1945–77	3
33	13307000*	Salmon River near Shoup	6,270	1945–81	3
34	13308500*	Middle Fork Salmon River near Cape Horn	138	1929–72	3
35	13309000*	Bear Valley Creek near Cape Horn	180	1922–60	3
36	13309220	Middle Fork Salmon River at Middle Fork Lodge, near Yellow Pine	770	1973–81	3
37	13309500	Middle Fork Salmon River near Meyers Cove	2,020	1931–39	3
38	13310000*	Big Creek near Big Creek	470	1945–58	3
39	13310500	South Fork Salmon River near Knox	92.0	1929–60	3
40	13310700	South Fork Salmon River near Krassel Ranger Station	330	1967–82; 1985–86; 1989–91	3
41	13311000	East Fork South Fork Salmon River at Stibnite	19.6	1928–42; 1983–91	3
42	13311500	East Fork South Fork Salmon River near Stibnite	42.5	1928–41	3
43	13312000*	East Fork South Fork Salmon River near Yellow Pine	104	1928–43	3
44	13312500	Johnson Creek near Landmark Ranger Station	54.7	1943–49	3
45	13313000*	Johnson Creek at Yellow Pine	213	1929–91	3
46	13313500	Secesh River near Burgdorf	104	1943–52	3
47	13314000*	South Fork Salmon River near Warren	1,160	1931–43	3
48	13314500	Warren Creek near Warren	37.0	1943–49	3
49	13315000	Salmon River near French Creek	12,270	1945–56	3
50	13317000*	Salmon River at White Bird	13,550	1911–91	3
51	13336000	Selway River above Meadow Creek, near Lowell	1,550	1945–49	4
52	13336100	Meadow Creek near Lowell	241	1964–70	4
53	13336500*	Selway River near Lowell	1,910	1930–91	4
54	13336900	Fish Creek near Lowell	89.2	1958–67	4
55	13337000*	Lochsa River near Lowell	1,180	1911–12; 1930–91	4
56	13337500	South Fork Clearwater River near Elk City	261	1945–74	4
57	13338500*	South Fork Clearwater River at Stites	1,150	1966–91	4
58	13339000	Clearwater River at Kamiah	4,850	1911–65	4
59	13339500*	Lolo Creek near Greer	243	1980–91	4
60	13340000	Clearwater River at Orofino	5,580	1931–38; 1965–91	4

Table 1. Streamflow-gaging stations used for regression analyses—Continued

Map No.	Gaging station No.	Gaging station name	Drainage area (square miles)	Period of record	Region
61	13340500	North Fork Clearwater River at Bungalow Ranger Station	996	1945–69	4
62	13340600*	North Fork Clearwater River near Canyon Ranger Station	1,360	1968–91	4
63	13340615	Beaver Creek near Canyon Ranger Station	51.7	1984–88	4
64	13341000*	North Fork Clearwater River at Ahsahka	2,440	1927–68	4
65	13342500*	Clearwater River at Spalding	9,570	1911–13; 1926–71	4
66	13338800	Lawyer Creek near Nezperce	150	1968–74	5
67	13341128	Long Hollow Creek near Nezperce	17.7	1980–86	5
68	13342450	Lapwai Creek near Lapwai	235	1976–91	5
69	13346800	Paradise Creek at University of Idaho, at Moscow	17.7	1979–91	5
70	13341300	Bloom Creek near Bovill	3.15	1960–71	6
71	13341400	East Fork Potlatch River near Bovill	41.6	1960–71	6
72	13341500*	Potlatch River at Kendrick	425	1946–60	6
73	13345000	Palouse River near Potlatch	317	1974–91	6

ferences between regression estimates and measured discharge data. For some months, especially for discharge at the 20-percent point on the flow-duration curve, the factors are similar for two or more regions. However, for other months, differences between those regions are apparent. Graphical cluster analysis was used to establish the six regions, and analysis of residuals was used to determine boundaries.

Most of the boundaries for the six regions correspond to drainage basin boundaries; parts of the Clearwater and Salmon Rivers also serve as boundaries (fig. 1). The Clearwater River is the boundary between regions 5 and 6 and is part of the boundary between regions 4 and 5. Regression results of region 4 apply to the main stem of the Clearwater River. The Salmon River is part of the boundary between regions 2 and 3, and the downstream part of the Salmon River is in region 1. Regression results of region 3 apply to the main stem of the Salmon River. Data from gaging stations outside of regional boundaries were used in the regressions for all regions except 3 and 4. Regions 5 and 6 were originally one region. Because some large variations in regression results were apparent for some months, the region was divided into two regions. Although each of these regions is defined by only four gaging stations, the gaged and ungaged basins in both regions generally have similar basin characteristics.

A relation between mean monthly discharge and daily mean discharges at the 20-, 50-, and 80-percent points on the flow-duration curve for each month in the six regions (table 2) was developed on the basis of discharge at gaging stations. Estimates of discharge at the 20-, 50-, and 80-percent points can be computed by multiplying an appropriate factor times a previously determined mean monthly discharge for about 1,200 subbasins (Lipscomb, in press). Coefficients of determination (R^2) and standard errors, in percent, are shown so that the reliability of each factor can be assessed. The high R^2 values indicate that most differences in discharges at points on the flow-duration curves can be explained by differences in mean monthly discharges. Generally, standard errors show that discharges at the 20-percent point on the flow-duration curve are more strongly correlated to the mean monthly discharge than those at the 80-percent point, indicating that the lower end of the flow-duration curve is more difficult to estimate than the upper end (table 2). The relation between mean monthly discharge and points on the low-flow end of the duration curve can be greatly influenced by such factors as the amount of spring flow that enters the stream, leakage to ground water from the streambed, propensity for thunderstorms in some areas, and freezeouts and ice jams that are more frequent at some sites. Total error in discharge estimates is not known because mean annual discharge was adjusted and apportioned to mean monthly discharge as done by Lipscomb (in press).

The adjustment of discharges from gaging-station records of fewer than 30 years with discharges from records of more than 30 years was done to better represent long-term conditions. Adjustment of data for gaging stations with fewer than 30 years of record

Table 2. Summaries of regression analyses

[R^2, coefficient of determination]

Month	Discharge at 20-percent point			Discharge at 50-percent point			Discharge at 80-percent point		
	Factor	R^2	Standard error (percent)	Factor	R^2	Standard error (percent)	Factor	R^2	Standard error (percent)
Region 1									
Oct.	1.16	0.999	5	0.86	0.998	7	0.68	0.992	14
Nov.	1.16	.998	6	.77	.983	18	.56	.969	26
Dec.	1.21	.998	6	.57	.928	37	.39	.848	56
Jan.	1.18	.998	5	.61	.955	29	.38	.874	50
Feb.	1.34	.998	8	.64	.986	16	.35	.910	41
Mar.	1.40	.999	5	.80	.999	6	.42	.991	14
Apr.	1.40	.999	4	.89	.998	6	.55	.995	10
May	1.39	.999	5	.92	.999	4	.61	.995	10
June	1.45	.998	7	.95	.998	8	.52	.991	14
July	1.39	.999	5	.71	.992	15	.41	.985	21
Aug.	1.29	1.000	4	.92	.999	5	.68	.998	7
Sept.	1.28	.999	5	.94	.999	6	.68	.997	10
Region 2									
Oct.	1.23	0.994	9	0.99	0.998	6	0.78	0.994	10
Nov.	1.19	.998	7	.98	1.000	2	.83	.998	6
Dec.	1.17	.997	7	.99	1.000	2	.84	.995	10
Jan.	1.13	.994	9	.97	1.000	3	.84	.996	9
Feb.	1.15	.999	4	.97	1.000	2	.84	1.000	3
Mar.	1.14	.998	6	.99	1.000	3	.84	.999	4
Apr.	1.22	.990	9	.96	.981	15	.74	.975	19
May	1.31	.985	11	.75	.985	11	.48	.940	22
June	1.40	.998	5	.89	.999	4	.55	.994	9
July	1.43	.993	10	.75	.967	18	.44	.874	30
Aug.	1.32	.986	10	.92	.988	10	.66	.926	23
Sept.	1.26	.986	11	.92	.985	12	.70	.954	22
Region 3									
Oct.	1.19	1.000	5	0.96	1.000	4	0.81	0.999	7
Nov.	1.17	.999	6	.96	.999	5	.81	.998	9
Dec.	1.18	.999	9	.94	.999	6	.76	.997	11
Jan.	1.18	.999	5	.94	.999	6	.80	.999	7
Feb.	1.13	1.000	5	.95	.999	5	.80	.998	9
Mar.	1.17	.999	6	.92	.998	9	.75	.996	13
Apr.	1.41	1.000	4	.80	.999	6	.53	.995	16
May	1.45	1.000	3	.87	1.000	5	.59	.989	23
June	1.43	1.000	4	.92	1.000	2	.53	.998	9
July	1.40	.999	8	.79	.998	9	.47	.996	13
Aug.	1.29	1.000	5	.96	1.000	4	.67	.995	14
Sept.	1.22	1.000	3	.98	1.000	4	.76	.998	9
Region 4									
Oct.	1.27	0.999	4	0.78	0.998	6	0.53	0.994	9
Nov.	1.32	.998	5	.71	.992	10	.45	.993	10
Dec.	1.28	.996	8	.64	.998	6	.40	.993	10
Jan.	1.39	.998	6	.68	.998	6	.44	.994	10
Feb.	1.44	.998	6	.75	.997	7	.44	.990	12
Mar.	1.38	1.000	3	.85	.999	5	.51	.998	7
Apr.	1.46	.999	4	.88	.999	4	.55	.996	8
May	1.33	1.000	2	.92	1.000	2	.64	.999	4
June	1.50	.997	7	.89	.999	4	.50	.998	5
July	1.39	.999	4	.78	.997	7	.48	.983	14
Aug.	1.26	.999	4	.92	.999	3	.70	.995	8
Sept.	1.21	.998	5	.87	.998	5	.67	.998	12

Table 2. Summaries of regression analyses—Continued

Month	Discharge at 20-percent point			Discharge at 50-percent point			Discharge at 80-percent point		
	Factor	R^2	Standard error (percent)	Factor	R^2	Standard error (percent)	Factor	R^2	Standard error (percent)
Region 5									
Oct.	1.20	0.998	6	0.88	0.997	9	0.57	0.998	22
Nov.	1.22	.985	13	.87	.992	11	.63	.975	22
Dec.	.85	.962	22	.48	.995	8	.32	.986	17
Jan.	1.41	.994	7	.39	.915	26	.26	.811	44
Feb.	1.17	1.000	3	.56	1.000	2	.26	.914	26
Mar.	1.46	.994	8	.59	.775	60	.30	.863	43
Apr.	1.54	.954	24	.48	.963	21	.23	.720	65
May	1.40	1.000	2	.67	1.000	2	.34	.999	4
June	1.57	1.000	3	.60	.996	8	.39	1.000	2
July	1.37	.998	5	.85	1.000	3	.43	.998	6
Aug.	1.40	.991	11	.85	.993	10	.48	.976	15
Sept.	1.38	1.000	3	.83	.998	5	.58	.996	7
Region 6									
Oct.	1.29	0.997	5	0.65	0.943	18	0.39	0.813	29
Nov.	1.23	.999	4	.44	.962	18	.20	.787	35
Dec.	1.22	.994	9	.38	.965	20	.13	.899	26
Jan.	1.25	.984	13	.31	.976	14	.10	.897	26
Feb.	1.59	.979	16	.49	.992	9	.19	.994	8
Mar.	1.54	1.000	3	.77	.997	13	.39	.999	3
Apr.	1.47	.992	10	.87	.983	15	.47	.967	21
May	1.31	.998	4	.66	.995	7	.31	.989	10
June	1.29	.982	12	.59	.945	19	.34	.898	25
July	1.33	.978	13	.78	.961	16	.44	.892	31
Aug.	1.22	.948	17	.79	.970	12	.51	.963	12
Sept.	1.15	.907	23	.74	.887	24	.40	.678	53

resulted in reduced standard errors of 1 or 2 percent for many of the regression factors. However, for several of the regression factors, standard errors increased slightly when the adjusted data were used.

Dimensionless flow-duration curves were drawn using the flow-duration discharge to mean monthly discharge factors for 20, 50, and 80 exceedance percentages (fig. 2). Flow-duration curves for July, normally the warmest and driest month, are the most similar for each of the six regions (fig. 3). Curves for December through March are the most variable; curves for January (fig. 4) are representative of the period December through March.

The factor relating mean monthly discharge to the discharge that is exceeded 20 percent of the time for December in region 5 is less than 1. Although unusual, the available data show that streamflow is generally low but was high for a few days and significantly increased the mean monthly discharge.

FLOOD-FREQUENCY CHARACTERISTICS

Peak discharges having recurrence intervals of 2 and 100 years were required at 35 streamflow sites for analysis of the effect of floods on fish habitat. A gaging station is located at 13 of the 35 sites; therefore, peak discharge data are available at each of them. Peak discharges at the other 22 sites were determined by adjusting the peak discharges of 21 nearby upstream and downstream gaging stations.

Records of annual peak discharges at 26 gaging stations in table 1 were used for flood-frequency analyses. All gaging stations had 10 or more years of record and included data through 1990. Most annual peak discharges at the 26 gaging stations were not affected by regulation and diversion.

Techniques recommended by the U.S. Water Resources Council (1981) were used to fit the log-Pearson type III probability distribution to the annual peak discharges at gaging stations located at, upstream,

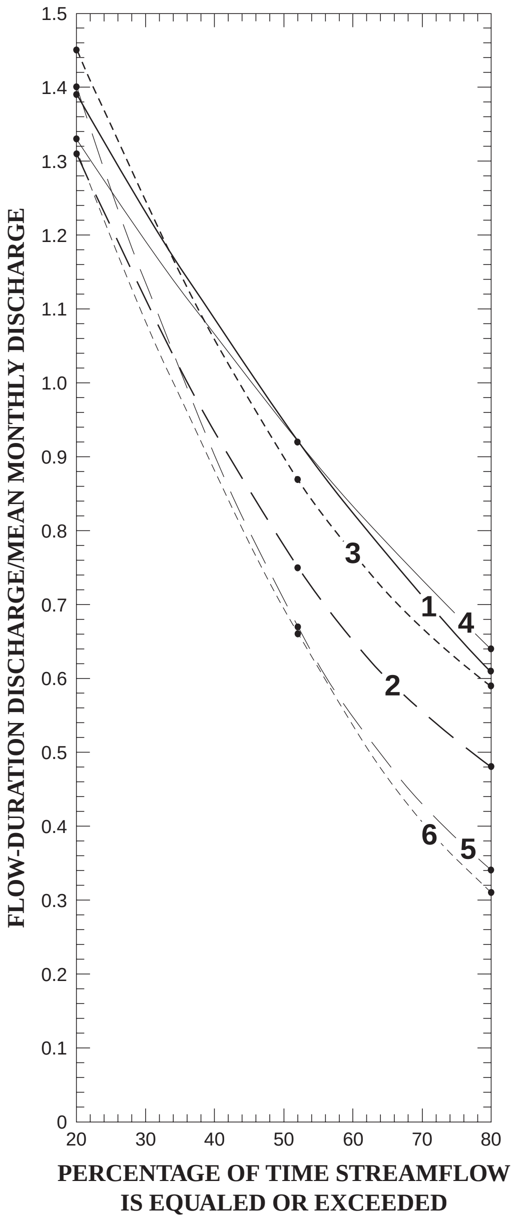

Figure 2. Dimensionless flow-duration curves for May in each of the six regions.

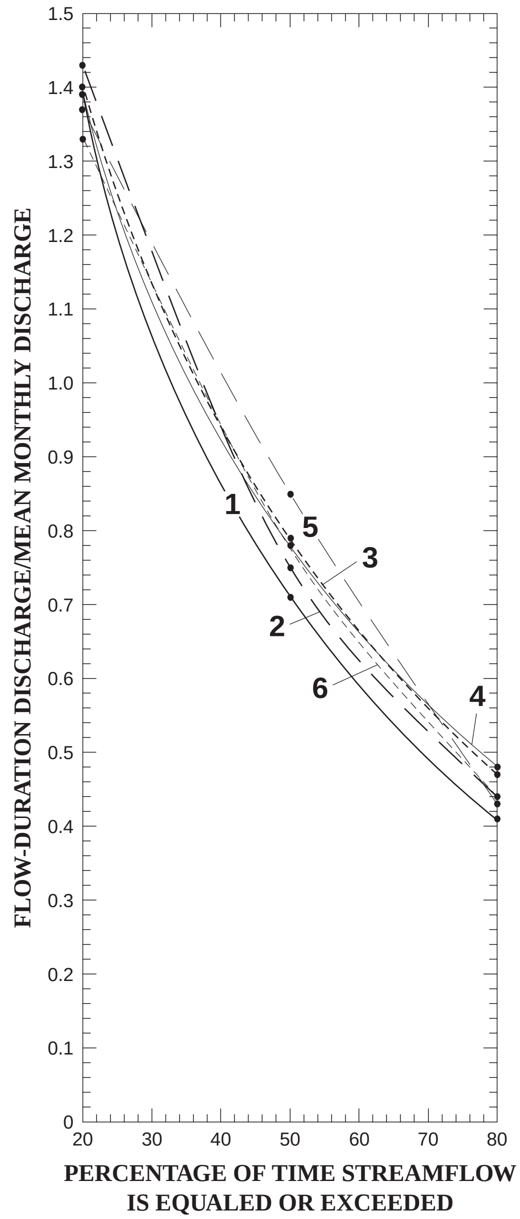

Figure 3. Dimensionless flow-duration curves for July in each of the six regions.

or downstream from selected sites. Regional skew coefficients were taken from a report by Kjelstrom and Moffatt (1981). Recurrence interval is the average time interval, in years, between occurrences for a flood of equal or greater magnitude.

Flood-frequency characteristics at a gaging station may be transferred to an upstream or downstream ungaged site by computing a weighted value of the flood magnitude at the gaging station (Omang and others, 1986; Blakemore and others, 1994). A drainage area ratio is used to weight the flood magnitude at the gaging station to the ungaged site as follows:

$$Qu = \left(\frac{Au}{Ag}\right)^{a} Qg ,$$

where

Qu is flood magnitude at the ungaged site,
Au is drainage area at the ungaged site,
Ag is drainage area at the gaging station,
a is exponent of the drainage area for the appropriate regional flood-frequency regression equation, and
Qg is flood magnitude at the gaging station.

The exponent (a) for drainage area is taken from regression equations (Kjelstrom and Moffatt, 1981) that were developed to estimate the mean annual peak discharge at ungaged sites. For the Clearwater River Basin, the value of the exponent is 0.99; for all other river basins in the study area, the exponent is 0.84.

The drainage area should be between approximately 0.5 and 1.5 for reliable results. Equations in a report by Kjelstrom and Moffatt (1981) can be used to estimate peak discharge if adequate gaging stations are not located upstream or downstream from the ungaged sites.

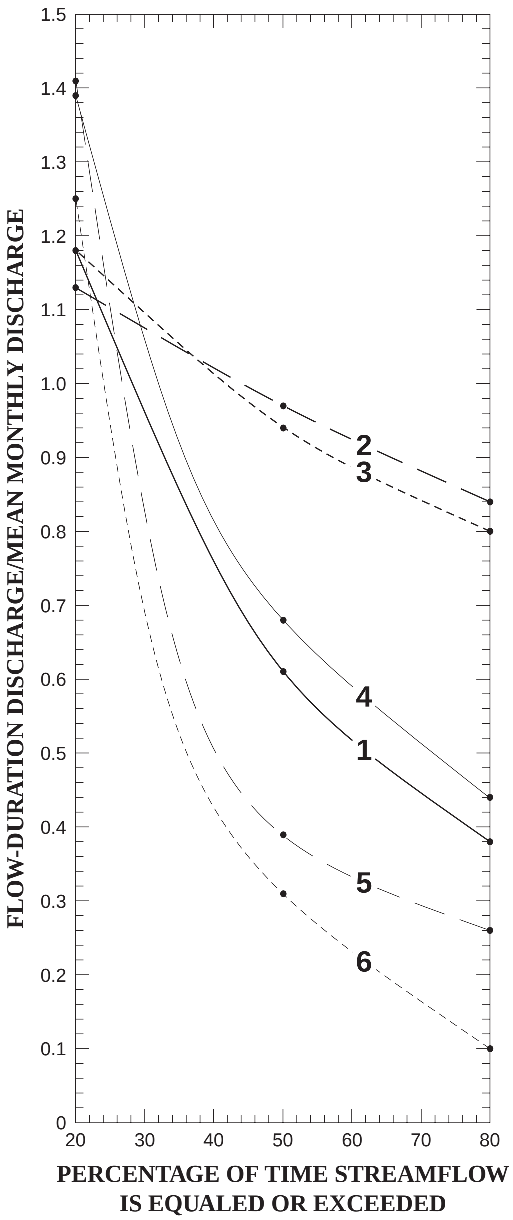

Figure 4. Dimensionless flow-duration curves for January in each of the six regions.

SUMMARY

Water-resource managers require quantified information to define the areal and seasonal variations in runoff from ungaged drainage basins in the Salmon and Clearwater River Basins; upstream parts of the Weiser and Payette River Basins; and several small drainage basins in Idaho that adjoin the western boundaries of the Weiser, Salmon, and Clearwater River Basins and drain to the Snake River. A previously developed technique based on basin and climatic characteristics was used in another study to estimate mean monthly discharge for ungaged drainage basins in central Idaho. Accuracy of the mean monthly discharges is unknown. This study relates mean monthly discharge to three points on the daily mean flow-duration curve for each month. Discharge data collected at 73 gaging stations were used to relate mean monthly discharge to daily mean discharges that are exceeded 20, 50, and 80 percent of the time. Further definition of areal and seasonal distribution of discharge was accomplished by dividing areas with similar streamflow data into six regions.

Estimates of daily mean discharge at the three points on the flow-duration curve can be made by multiplying a factor times mean monthly discharge. The factors can be used for ungaged drainage basins in the study area where discharge is not substantially affected by regulation or diversion and monthly mean discharge is known or estimated. Coefficients of determination indicate that differences in mean monthly discharge largely explain differences in discharges at points on the daily mean flow-duration curve. Standard errors generally increase from the correlation of discharges that are exceeded 20 percent of the time to those that are exceeded 80 percent of the time. The increase probably indicates that low discharges are influenced by spring flow, leakage to ground water, and ice formation during cold weather. Flow-duration curves drawn through the three points are most similar for the six regions in July and most different from December to March.

Flood magnitudes were required for selected recurrence intervals at ungaged sites upstream or downstream from gaging stations. Transfer of flood magnitude from a gaging station to an ungaged site can be made using a weighted ratio of the drainage area at the ungaged site and the drainage area at the gaging station. Best results are obtained when the difference between the ungaged and gaged drainage area is small.

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