ANALYSIS OF THE MAGNITUDE AND FREQUENCY OF FLOODS AND THE PEAK-FLOW GAGING NETWORK IN MONTANA

By R.J. Omang

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
cubic foot per second per square mile	0.01093	cubic meter per second per square kilometer
foot (ft)	0.3048	meter
foot per mile	0.1894	meter per kilometer
inch (in.)	25.4	millimeter
mile	1.609	kilometer
square mile (mi^2)	2.59	square kilometer

Temperatures in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by the equation:

$$°C = 5/9\ (°F - 32)$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Flood magnitudes and frequencies were updated by log-Pearson type III analysis for 522 crest-stage and streamflow-gaging stations on unregulated streams in Montana, adjoining States, and Canada. These flood magnitudes were related to basin characteristics using ordinary least-squares multiple-regression techniques. On the basis of preliminary analysis, data from the regression were used to divide the State into eight hydrologic regions.

Generalized least-squares regression procedures were used on data from each region to relate the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence interval flood magnitude to the basin characteristics determined to be significant by ordinary least-squares regression. The resulting regression equations can be used to estimate flood magnitude and frequencies at ungaged sites. Drainage area, mean annual precipitation, mean basin elevation, and percentage of basin above 6,000 feet elevation were determined to be the most significant basin characteristics. Different basin characteristics are significant for the eight regions involved. Contributing drainage area was the most significant characteristic in all regions. The standard error of estimate for equations that estimate floods having a 100-year recurrence interval ranged from 32 to 63 percent. The standard error of prediction for the 100-year recurrence interval ranged from 38 to 67 percent. The standard errors of estimate were generally an improvement over previous studies.

Techniques are described for estimating annual flood magnitude and frequency at ungaged sites based on data from gaged stations on the same stream. Curves relating peak flow to drainage area can be used to determine flood magnitudes for seven major streams in the State.

A generalized least-squares regression model was also used to analyze the peak-flow gaging network of crest-stage stations in terms of cost effectiveness of supplying regional flood information. Peak flows having recurrence intervals of 2, 10, and 50 years were used in the network analysis to ensure that the information supplied by the network was representative of a wide range of flood magnitudes. The analysis considered three planning horizons: current water year (1988) conditions, 5-year horizon, and 20-year horizon. The network's effectiveness was assessed by evaluating changes in the network's average sampling mean-square error by adding or deleting crest-stage stations in each region. New stations were added to the network on the basis of the effect that each station would have on the regression results using drainage-basin characteristics. A composite ranking was developed using the rankings for the 20-year planning horizon.

Network analysis indicates that the most cost-effective peak-flow gaging network would result from discontinuing numerous crest-stage stations in most regions and adding at least two new stations in each region. The result would be a decrease in average sampling mean-square error of about 4 percent, an increase in the quantity of regional information of about 4 percent, and a savings in operation and maintenance costs of about 30 percent.

INTRODUCTION

Reliable estimates of magnitude and frequency of floods are essential for proper design of engineering projects such as levees, bridges, and culverts. Flood-frequency information also is used by planners and managers for land-use management of flood plains and the establishment of actuarial flood-insurance rates. These uses necessitate that flood-frequency information be the most accurate possible.

Several studies completed in Montana since 1970 have resulted in reports that describe methods for estimating flood magnitudes of various recurrence intervals using drainage-basin characteristics (Boner and Buswell, 1970; Dodge, 1972; Johnson and Omang, 1976; Parrett and Omang, 1981; Omang and others, 1986). A report by Parrett and others (1987) described methods for estimating flood magnitude using channel-geometry characteristics from streamflow-gaging stations having at least 10 years of record through 1983. The flood-frequency information was updated in this report on the basis of an additional 5 years of record.

An important objective of a peak-flow gaging network is the collection of regional information. Regional information is used to estimate streamflow characteristics at ungaged sites and to improve estimates at gaged sites. The U.S. Geological Survey (USGS), in cooperation with the Montana Department of Transportation, has operated a peak-flow gaging network consisting of crest-stage (partial-record) stations since 1955 to supplement data collected at streamflow-gaging (continuous-record) stations under cooperative agreements with other Federal, State, and local agencies. The initial network consisted of 45 stations. The program was expanded to 152 stations in 1959 and to 216 stations in 1963. In 1974 and 1975, 111 new stations were established and some stations were discontinued. The present (1988) statewide network consists of 158 stations. Data collected at these crest-stage stations, supplemented by data collected at streamflow-gaging stations, constitute the basis for the regional information on peak flows available for streams within the State. Because of increased costs of operation, constraints on funding, and the need to maximize regional flood information, the peak-flow gaging network of crest-stage stations was evaluated so that the Montana Department of Transportation could decide whether to continue supporting the current number of crest-stage stations. This study was conducted by the USGS in cooperation with the Montana Department of Transportation; the U.S. Department of Transportation, Federal Highway Administration; and the U.S. Department of Agriculture, Forest Service.

Purpose and Scope

This report describes the results of analyzing the magnitude and frequency of floods and the peak-flow gaging network of crest-stage stations. The report presents updated flood magnitude and frequency data for stations and describes improved techniques for estimating flood magnitudes and frequencies at ungaged sites for recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. Estimating equations were developed by relating drainage-basin characteristics to the flood magnitudes of the various recurrence intervals.

The flood magnitude and frequency analysis is based on data from 476 crest-stage and streamflow-gaging stations in Montana, 11 in Idaho, 13 in North Dakota, 3 in South Dakota, 7 in Wyoming, and 12 in Canada (pl. 1 and table 1--all tables are in the Supplemental Information section at the back of the report). The station data are from unregulated streams having at least 10 years of streamflow record through water year[1] 1988 and having drainage areas that range from 0.04 to 2,554 mi^2. Some stations in Montana having 10 or more years of record were excluded from the analysis because the data were considered to be inadequate or unrepresentative of the region owing to unknown regulation, poorly defined ratings for the station, or too many years of zero flow.

The peak-flow gaging network of crest-stage stations was analyzed by assessing its ability to provide maximum regional information through the continued operation of present-network stations or by modification of the number of network stations operated in cooperation with the Montana Department of Transportation. Peak flows with recurrence intervals of 2, 10, and 50 years were analyzed on the basis of

[1]A water year is the 12-month period October 1 through September 30. It is designated by the calendar year in which it ends.

value of present and future information. One method considered all current (currently active in 1988) stations in the network as eligible for discontinuance whereas another method considered addition of some stations and discontinuance of others.

General Hydrologic Conditions

Montana, with an area of about 147,100 mi^2, is the fourth largest State. Because of its size, the State has widely varying geographic and climatic conditions. The western half is characterized by rugged mountains with large intermontane valleys, whereas the eastern half is generally flat or rolling prairie with large, deeply incised streams. The western and southwestern parts of Montana are in the Northern Rocky Mountains physiographic province, and the central and eastern parts are in the northern Great Plains province.

The climate is affected largely by the topography. In the western mountainous region, most precipitation occurs as snow produced by moist airmasses originating over the Pacific Ocean. Peak flows in mountain streams can result from either spring snowmelt or spring snowmelt combined with rain. Along the east slope of the mountains, severe flooding has resulted from rains produced by humid airmasses originating over the Gulf of Mexico. Mountains generally protect the west slope from storms moving northward along the east slope. At times, however, intense rainstorma cross the divide and cause severe flooding along the west slope (Boner and Stermitz, 1967, p. B16-B44.)

Although much of the precipitation in the eastern plains region falls as snow during the winter, intense rainstorms during the summer also can add substantial quantities of precipitation in a short time. Flows of plains streams, which are more variable than those of mountain streams, result from snowmelt or rainfall.

The State was divided into eight regions for flood-frequency analysis. The boundaries of the regions, which generally conform to the different physiographic areas described above, are shown on plate 1.

The West Region includes the mountainous area west of the Continental Divide. In this area, streams are perennial and runoff generally results from snowmelt. Annual precipitation ranges from about 12 to 120 in. (U.S. Soil Conservation Service, 1980). Unit flood discharges (discharges per unit of drainage area) range from 0 to several hundred cubic feet per second per square mile of drainage area.

The Northwest Region includes the northern part of the Continental Divide, where severe runoff is caused by intense rainfall from airmasses that originate over the Gulf of Mexico. Annual precipitation ranges from 14 to 120 in. and unit flood discharges range from 0 to several thousand cubic feet per second per square mile of drainage area.

The Southwest Region is also a mountainous region, with runoff generally resulting from snowmelt. Precipitation is generally less (annual precipitation of about 10 to 60 in.) than in the West Region. Unit flood discharges consequently are smaller than in the West Region.

The Upper Yellowstone-Central Mountain Region is a mountainous area similar to the West Region. Runoff generally results from snowmelt. Annual precipitation ranges from about 12 to 70 in., but generally is more variable than in the West Region. Storms may originate from the north or south as well as from the west. Unit flood discharges range from zero to several hundred cubic feet per second per square mile of drainage area.

The Northwest Foothills Region is an area of rolling plains just east of the mountains of the Northwest Region. Runoff is generally from rainfall or rainfall combined with snowmelt. Annual precipitation ranges from about 12 to 20 in. Unit flood discharges generally are larger than in similar plains areas farther east, probably because the area is partly affected by intense rainfall that causes large floods in the Northwest Region.

The Northeast Plains Region is flat land predominantly north but also south of the Missouri River. Runoff is variable, with most smaller streams flowing only intermittently. Floods are produced by snowmelt and rainfall. Annual precipitation generally ranges from about 12 to 20 in., except in the area around Lewistown where precipitation can be as much as 40 in. Unit flood discharges range from zero to several hundred cubic feet per second per square mile of drainage area.

The East-Central Plains Region, which is also predominantly flat plains, is the area most affected by intense thunderstorms. Annual precipitation ranges from about 12 to 40 in. Flood discharges generally are more variable than in the Northeast Plains Region, with annual unit flood discharges ranging from zero to several hundred cubic feet per second per square mile of drainage area.

The Southeast Plains Region is similar in topography to both the Northeast Plains and the East-Central Plains Regions. In the Southeast Plains Region, flood peaks from intense thunderstorms are not as prevalent as in the East-Central Plains Region. Annual precipitation (about 12 to 16 in.) generally is more variable and somewhat less than in the Northeast Plains Region. Unit flood discharges are more variable than in the Northeast Plains Region, but not as large or as variable as in the East-Central Plains Region.

ANALYSIS OF MAGNITUDE AND FREQUENCY OF FLOODS

Standard hydrologic methods were used to analyze the magnitude and frequency of floods at each crest-stage and streamflow-gaging station. Flood magnitude and frequency characteristics developed for each station were related to drainage-basin characteristics using multiple-regression techniques to define regional flood-frequency relations. These flood-frequency relations can be used to estimate annual flood magnitudes and frequencies at ungaged sites.

Station Flood Analysis

Flood magnitudes for selected recurrence intervals were determined at each station from a flood-frequency curve based on a log-Pearson type III probability distribution. Interagency Advisory Committee on Water Data (1982), formerly U.S. Water Resources Council, guidelines were followed. A flood-frequency curve relates the magnitude of annual peak flows to annual exceedance probability. Annual exceedance probability can be expressed as the chance, in percent, that a given flood magnitude will be exceeded in any 1 year. Recurrence interval is the reciprocal of annual exceedance probability multiplied by 100 and is the average interval, in years, within which the given flood is expected to be equaled or exceeded once. For example, a 1-percent-chance flood has an exceedance probability of 1 percent and a recurrence interval of 100 years. However, probability describes only the likelihood of occurrence of a random event, and a flood magnitude of a given recurrence interval may be exceeded in a much shorter time. In this report, the term "recurrence interval" is used.

Flood-frequency curves were developed for 522 crest-stage and streamflow-gaging stations on unregulated streams having at least 10 years of peak-flow data. Data through water year 1988 were used in the analysis. Historic adjustments to the recorded station data were used where applicable and low outliers were deleted using the low-outlier test recommended by the Interagency Advisory Committee. A low outlier is a data point that departs significantly from the trend of the remaining data. Flood-frequency curves for stations near the Montana borders that were developed by neighboring States may differ from the curves developed for this analysis, because of the use of a different skew-coefficient map or the deletion of different low outliers.

In the Northwest Region, flood-frequency-curve determination was complicated by a few extreme rain-caused floods within a population of small floods caused by snowmelt or snowmelt mixed with rain. Because the rain-caused floods are substantially larger than the more prevalent snowmelt-caused floods, the log-Pearson type III probability distribution did not fit the data well when all floods were considered together. Accordingly, the maximum discharges at each site in the region were separated by cause--those caused by intense rains and those caused by snowmelt or snowmelt mixed with rain. Frequency curves then were fitted to each set of maximum discharges, and the separate frequency curves were combined using procedures developed by the U.S. Army Corps of Engineers (1958). Fitting a frequency curve to the rain-caused floods was complicated by the paucity of events. Rainfall-frequency curves were prepared for all long-term rain gages in the area and were used as a guide in assigning reasonable probabilities of occurrence to the few rain-caused floods. Flood reports documenting the severity and rarity of the large rain-caused floods also were used to help assign probabilities of occurrence to rain-caused floods (Boner and Stermitz, 1967; U.S. Army Corps of Engineers, 1969, 1973). A sample frequency curve determined by this method is shown in figure 1.

In the East-Central Plains Region, flood-flow records also were examined to determine if rain-caused floods needed to be separated from snowmelt-caused floods. Because the two types of floods were not clearly distinct nor sufficiently independent, separation was not warranted.

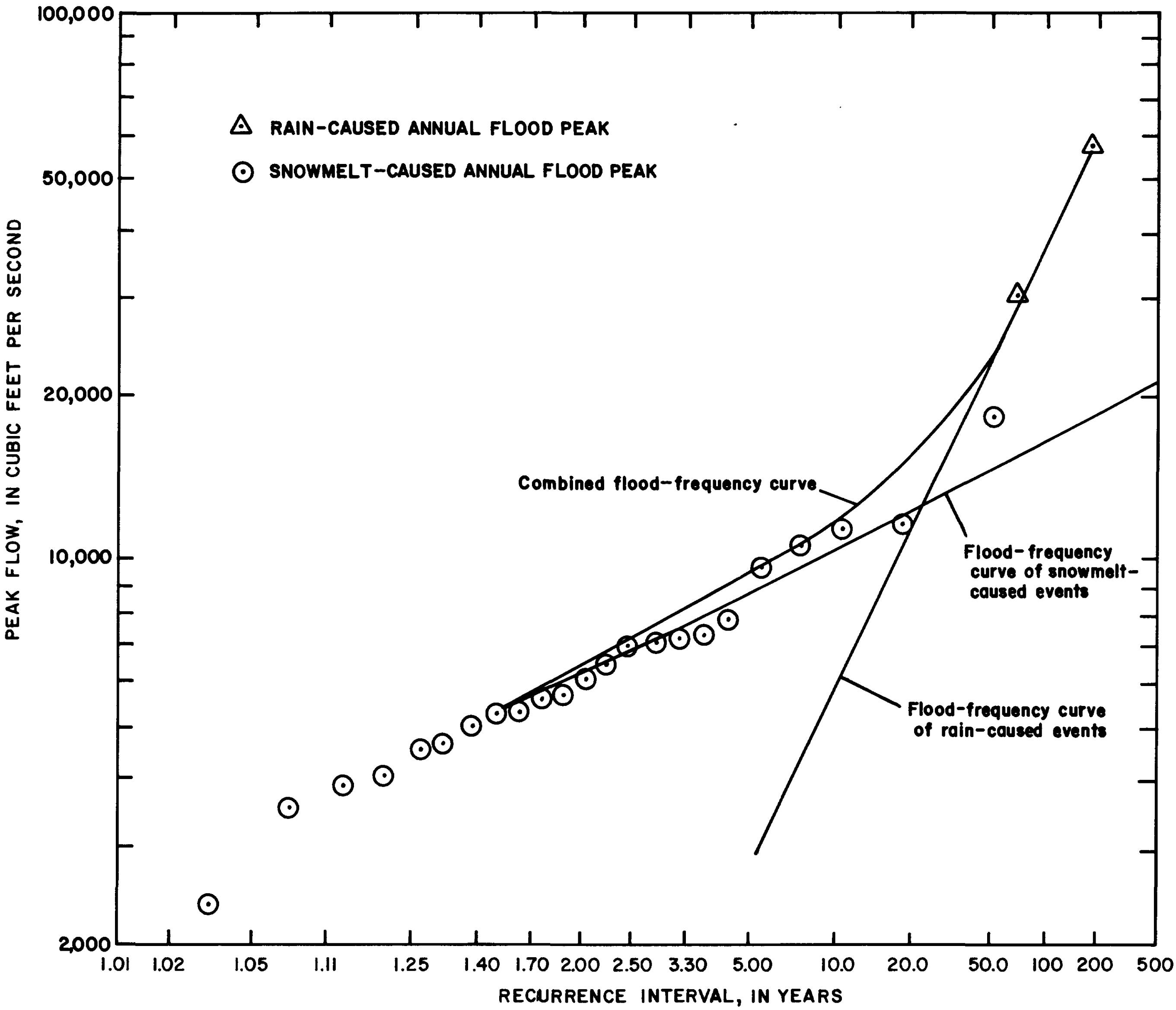


Figure 1.--Flood-frequency curve for the Sun River near Augusta, Montana (station 06080000).

Generalized skew coefficients of logarithms of annual maximum streamflow were used in the log-Pearson analysis. For most of the State, the generalized skew map (fig. 2) was used for this analysis. The skew coefficient at each station was a

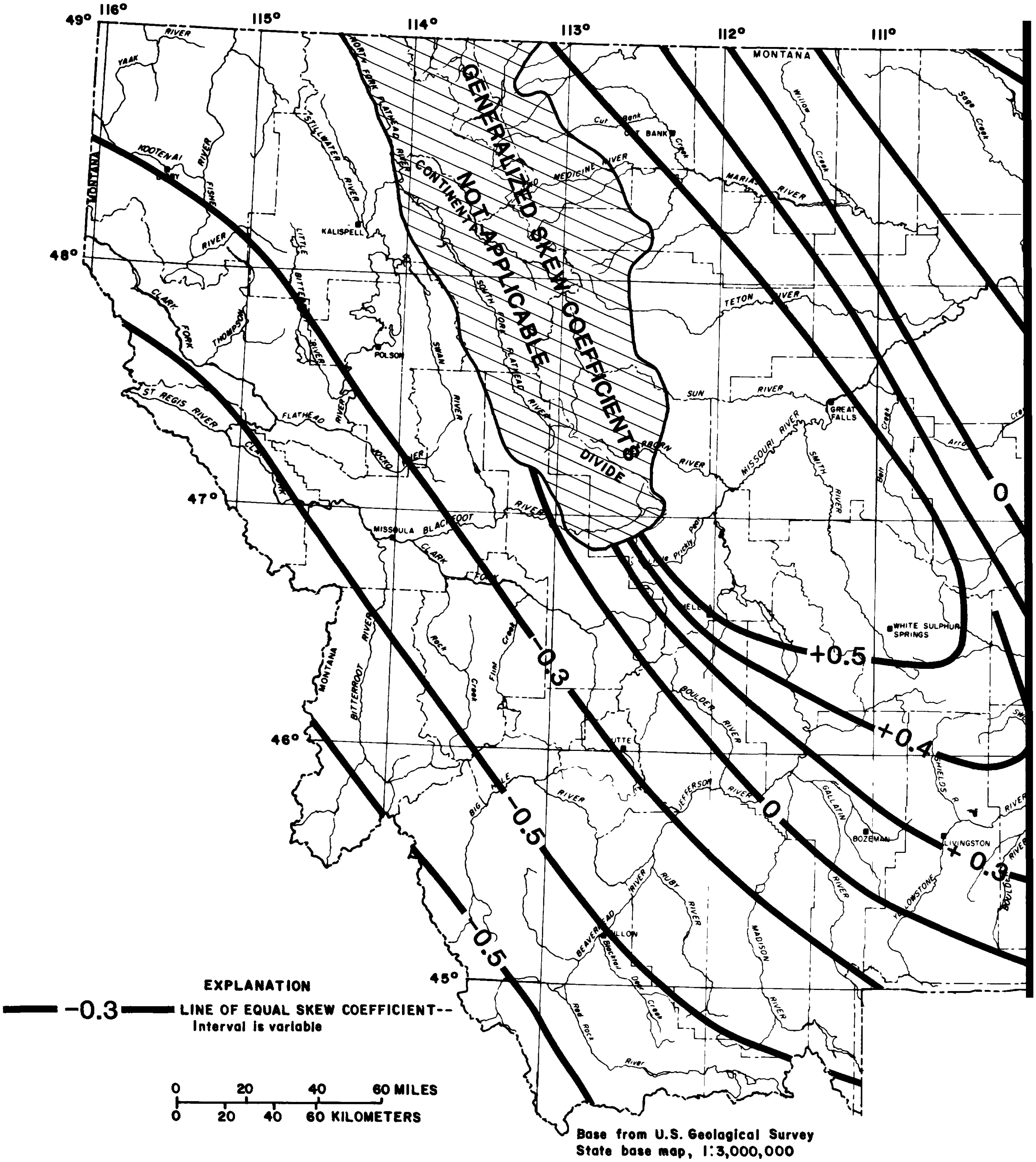
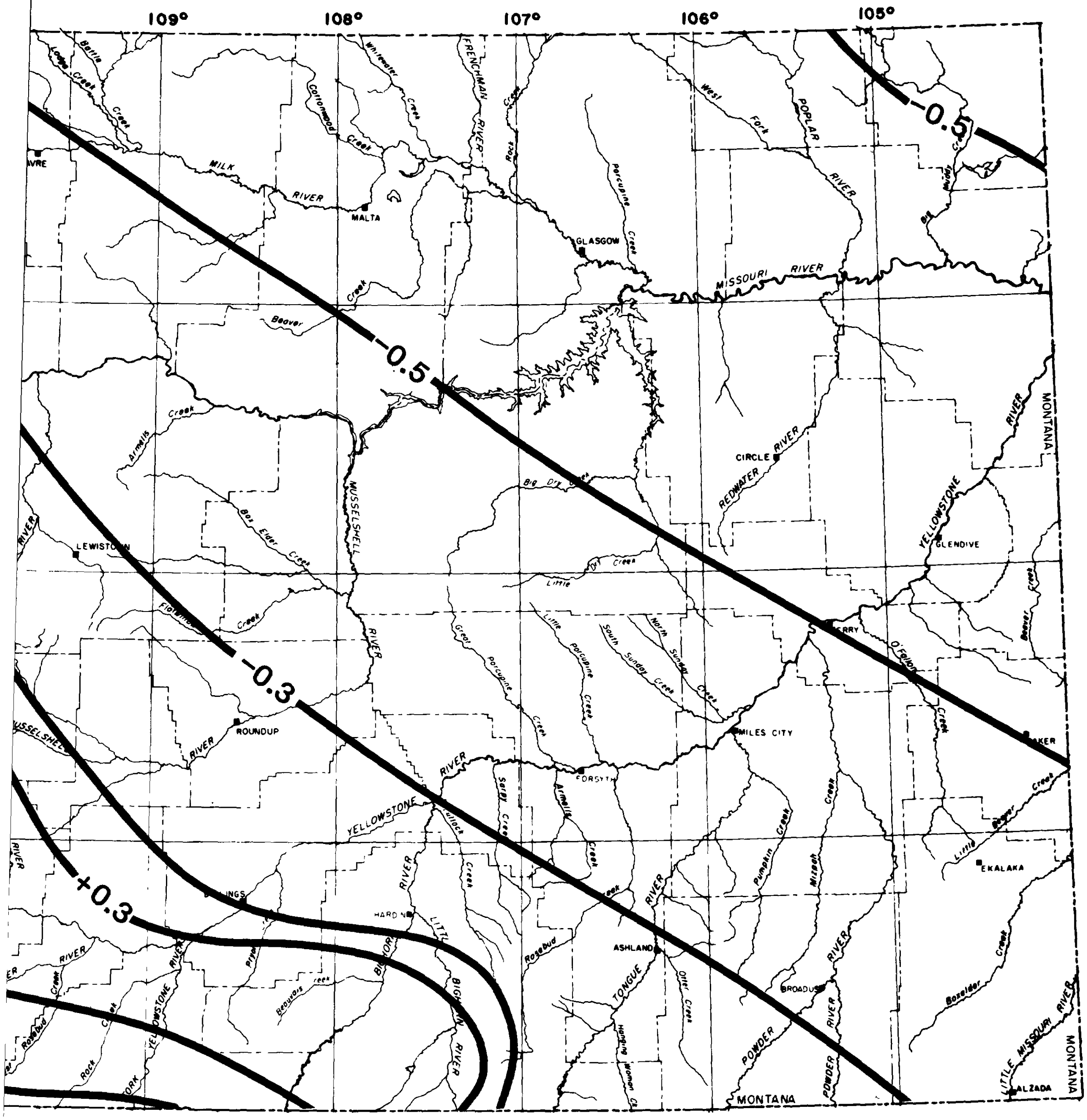


Figure 2.--Generalized skew coefficients of

combination of station skew and regional skew determined by weighting the two values in inverse proportion to their mean-square error. Because of the mixed-population frequency analysis made for the Northwest Region, generalized skew coefficients were not applicable in that region.



Map from S.M. Hamilton (U.S. Soil Conservation Service, Bozeman, Montana, written commun., 1982)

the logarithms of annual maximum streamflow.

The flood magnitudes for selected recurrence intervals that were determined from flood-frequency curves for each station are listed in table 1. Included are data for recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years.

The flood-frequency curves determined from the log-Pearson analysis are an improvement over previous flood-frequency curves, because the period of record is longer at most stations. An example plot from the analysis for Deep Creek near Fortine (station 12300800) is shown in figure 3.

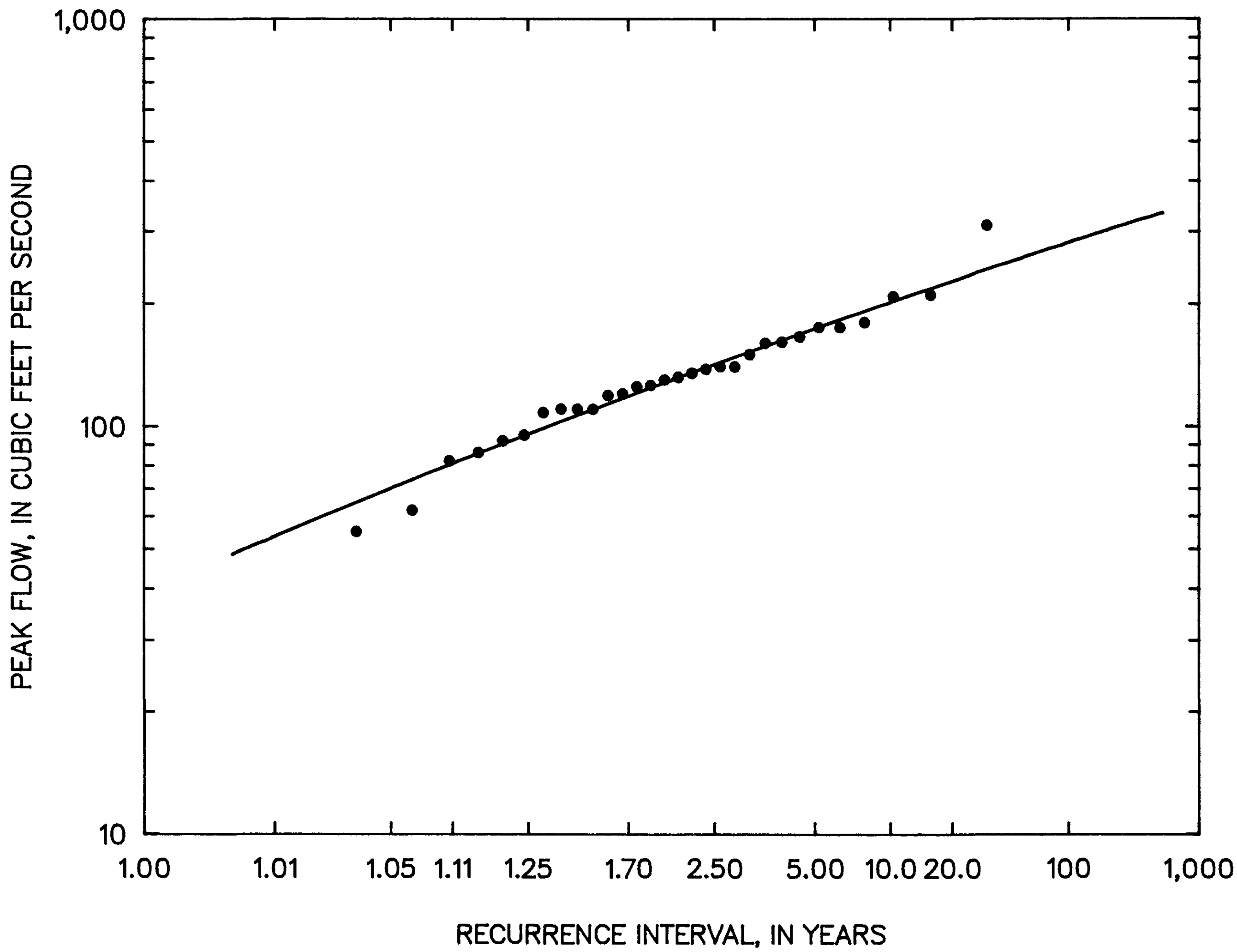


Figure 3.--Flood-frequency curve for Deep Creek near Fortine, Montana (station 12300800).

Regional Flood Analysis

Flood-frequency characteristics developed for crest-stage and streamflow-gaging stations were related to drainage-basin characteristics using multiple-regression techniques to define regional flood-frequency relations. Relations were developed for estimating flood magnitudes for ungaged streams in Montana for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence-interval flood.

Multiple Regression and Drainage-Basin Characteristics

Mathematical equations expressing flood magnitude as a function of drainage-basin characteristics were developed by multiple-regression techniques. The data were transformed to logarithms to help ensure a linear relation between flood magnitude and drainage-basin characteristics. Regression equations of the following form were derived:

$$\text{Log } Q_t = \log K + a \log A + b \log B + \ldots n \log N, \quad (1)$$

where

Q_t, the response variable, is the estimated flood magnitude, in cubic feet per second, having a t-year recurrence interval, where t equals 2, 5, 10, 25, 50, 100, or 500;
K is a multiple-regression constant;
a, b, ... n are regression coefficients; and
A, B, ... N, the explanatory variables, are values of drainage-basin characteristics.

After taking antilogarithms, the resulting equations are of the form:

$$Q_t = K\, A^a\, B^b \ldots N^n. \quad (2)$$

Drainage-basin characteristics that were evaluated for inclusion as explanatory variables in the regression equations include:

A	contributing drainage area, in square miles;
P	mean annual precipitation, in inches;
I_{24-2}	precipitation intensity, in inches per 24 hours;
F	percentage of forest cover;
E	mean basin elevation, in feet above sea level;
HE	percentage of basin above 6,000 ft elevation;
JANMIN	mean minimum January temperature, in degrees Fahrenheit;
S	main channel slope, in feet per mile;
L	main channel length, in miles;
SI	soils storage index, in inches; and
LAKE	percentage of basin occupied by lakes and ponds.

Combinations of these explanatory variables were evaluated using ordinary least-squares multiple-regression techniques for computing the response variable. Ordinary least-squares multiple-regression analyses were performed using Minitab[2] (Minitab, Inc., 1986), a general purpose, data-analysis system that involves statistical procedures including stepwise regression. The stepwise method of regression adds explanatory variables, one at a time, to the basic regression model (equation 1) until all statistically significant variables have been included. The significance of certain variables already in the model may change as other variables are added. Consequently, variables may be added at one step only to be removed at a later step. The goals of stepwise regression are to include all the explanatory variables that contribute significantly to the response variable and to exclude all the variables that have little effect on the response variable.

Initially, the same regional boundaries for the eight regions used in the study by Omang and others (1986) were used in this analysis. These boundaries were determined by plotting on a map the regression residuals (difference between the Q_t predicted from the regression equation and the Q_t determined from the station data-frequency curve). The plotted residuals were examined for groupings of similar magnitude and then were used, along with topographic maps, to delineate final boundaries of the eight regions. Drainage divides were used as regional bounda-

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[2]Use of the trade name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

ries where feasible. Some of the boundaries changed slightly from the previous analysis. Separate multiple-regression analyses were then made for each of the eight regions using ordinary least-squares techniques. The final selection of explanatory variables was based not only on the ordinary least-squares regression but also on the premise that the choice of the explanatory variables, as well as the signs and magnitudes of their associated regression coefficients, conform to sound hydrologic reasoning.

Drainage-basin characteristics determined to be important in the regression equations were drainage area, mean annual precipitation, mean basin elevation, and percentage of basin above 6,000 ft elevation. Drainage area was the most significant basin characteristic in all regions. Drainage area, in square miles, is determined for ungaged sites by planimetering the area outlined on 7 1/2-minute USGS topographic maps.

Mean annual precipitation is the basin average, in inches. Its magnitude is determined from maps prepared by the U.S. Soil Conservation Service (1980).

Mean basin elevation is the mean elevation of the basin, in feet above sea level. Mean basin elevation can be determined by the transparent grid method from a topographic map having a practical scale by laying a grid over the map, recording the elevation at each grid intersection, and averaging those elevations. The values for mean basin elevation are divided by 1,000 (E/1000) to avoid large numbers in the equations.

The basin above 6,000 ft elevation is the percentage of the total basin area above an elevation of 6,000 ft. The percentage of basin above 6,000 ft elevation can be determined by planimetering the drainage area above the 6,000-ft contour on a topographic map, multiplying by 100, and dividing the result by the total drainage area. The value 10 is then added to the final percentage (HE+10) to ensure that a value of zero does not occur in the equations. Values of the drainage-basin characteristics for each crest-stage and streamflow-gaging station used in the analysis are listed in table 1.

Generalized Least-Squares Regression

After acceptable drainage-basin characteristics were determined and the eight regions were delineated using ordinary least-squares techniques, generalized least-squares regression was performed. Using this approach, the regression coefficients are estimated by considering the time-sampling error in the streamflow characteristics and the cross correlation between sites. Generalized least-squares regression also can be used to determine the effect of current or proposed stations on the accuracy of the regression equations. The regression equations that are developed using the generalized least-squares technique relate drainage-basin characteristics to peak flows by using a weighting matrix to account for the different reliabilities and cross-correlations of concurrent peak-flow records of the various stations.

Stedinger and Tasker (1985) found that the generalized least-squares procedure provides more accurate estimates of the regression coefficients, better estimates of the accuracy of the regression model, and almost unbiased estimates of the model-error variance. Another valuable feature of the generalized least-squares technique is its use in a network analysis to provide a reliable estimate of the regression sampling error.

The generalized least-squares analysis was performed using ANNIE/WDM, a set of programs designed for analyzing hydrologic data (Lumb and others, 1989). The final regression equations developed for each region using this analysis and the standard errors of estimate and prediction are given in table 2.

Limitations of Regression Equations

The regression equations provide a method for determining flood magnitudes having selected recurrence intervals for sites on ungaged streams and for sites on gaged streams in Montana where the drainage area at the site is less than 0.5 times the gaged drainage area or greater than 1.5 times the gaged drainage area. The equations are valid where floodflows are virtually unaffected by urbanization, regulation, or diversion.

The regression equations are not valid where unique, local geohydrologic features affect floods. These features would include springs or seeps that contribute a large part of the streamflow and soils that are so permeable that unusually large volumes of runoff are absorbed.

The regression equations are not valid for determining Q_{50}, Q_{100}, and Q_{500} in the Northwest Foothills Region for any stream that originates in the Northwest Region. Streams that originate in the Northwest Region have large Q_{50}, Q_{100}, and Q_{500} as a result of intense rains from airmasses having southern sources. As these streams drain from the mountains and enter the relatively flat plains area of the Northwest Foothills Region, the high flows are largely attenuated by ground-water recharge and storage. Thus, the peak flows at downstream locations commonly are the same as, or less than, the peak flows at upstream locations. The Q_{50}, Q_{100}, and Q_{500} contribution from the Northwest Region can be calculated by using basin characteristics at the region boundary. However, determining whether Q_{50}, Q_{100}, and Q_{500} increase, remain constant, or decrease with increasing downstream drainage area requires careful, individual study of the stream in question.

The derived regression equations in this report are defined only within the range of the explanatory variables tested or sampled. For this study, the range in values of basin characteristics tested is given in table 3. Use of the regression equations for basin-characteristic values outside the range tested may not provide valid flood estimates.

The regression equations yield estimates of flood magnitude based on records of gaged streams. The designer or hydrologist responsible for making flood estimates needs to be aware of unusual circumstances wherein the regression equations might provide unreliable results. In these instances, additional study, knowledge of hydrologic conditions in a specific area including historic floods and streamflow measured at the site, or onsite visits and conversations with long-time residents are needed to decide between alternative estimating techniques and to determine whether an estimate is sufficiently accurate.

The regression equations presented in this report provide more reliable estimates of flood magnitudes than those of previous studies. Because of extremely high peak flows in 1991, however, the equations could be updated and improved by including data through water year 1991. Also, regression equations previously developed for estimating flood magnitudes from channel-width measurements could be updated using the same data base, and the two estimating methods could be weighted inversely proportional to their variances and averaged to yield a single estimate that would probably be more reliable than an individual estimate from either method.

Accuracy of Regression Equations

The accuracy of a regression equation generally is assessed in terms of the standard error of estimate, the average standard error of prediction, and the equivalent years of record. The standard error of estimate is a measure of the standard deviation of the distribution of residuals about the regression line and usually is expressed in percentage of the estimated value when log-transformed variables are used. The regression value is within the range of error (standard error of estimate) at about two of every three sites and is within twice this range at about 19 of every 20 sites. The standard error of estimate is a measure of how well the observed peak flows agree with the regression estimate of the peak flows and is not necessarily a measure of how well the equation can be used to estimate or predict from data not used in the regression analysis.

The average standard error of prediction at an ungaged site is a measure of the expected accuracy with which the regression model can estimate the t-year flood. The true value of the t-year flood, in log units, will be within plus or minus one standard error of prediction from the predicted value about two of every three times. The average standard error of prediction reported in table 2 is the average of the standard errors of prediction computed for sites with basin characteristics identical to the basin characteristics of the gaging stations in the region. The average standard error of prediction was determined in log units and was converted to percent standard error of prediction by methods described by Hardison (1971).

The equivalent years of record represents an estimate of the number of years of actual streamflow record required at a site to achieve an accuracy equivalent to the regional regression estimate. The equivalent years of record is computed as part of the generalized least-squares analysis using the method described by Hardison (1971).

The standard error of estimate, standard error of prediction, and equivalent years of record for each regression equation are given in table 2. The largest standard errors are generally in the Southwest, East-Central Plains, and Southeast Plains Regions. Conversely, the smallest standard errors are in the Northwest Region. In all regions, except the West and Northwest Regions, the largest standard error occurs in the prediction equation for the 2-year recurrence interval. In the West and Northwest Regions, the largest standard errors occur in the prediction equation for the 500-year recurrence interval.

The standard errors of estimate in table 2 represent an improvement for most of the recurrence intervals in all regions compared to the results of Omang and others (1986). The best improvements were in the East-Central Plains and Southeast Plains Regions.

Sensitivity Tests

The regression equations for the 100-year recurrence interval in all regions were tested for sensitivity. The test was performed by assuming that all variables except the one being tested for sensitivity remain constant. A variable was considered to be sensitive if a 10-percent change in the variable resulted in a 10-percent or larger difference in the computed 100-year peak-flow estimate. None of the explanatory variables was found to be sensitive.

The constancy of residual variance was tested by plotting the regression residuals against the corresponding values of each explanatory variable used for each region. The equations presented in this report have a constant residual variance (characterized by a relatively uniform band of points around the line corresponding to the zero residual), which indicates that the residuals are not a function of the explanatory variables used; thus, the regression equations are equally applicable for the full ranges of the explanatory variables used in the regression analysis.

Intercorrelation of the explanatory variables was also tested. The results indicated no discernible intercorrelation of the explanatory variables used for the final equations.

Estimating Magnitude and Frequency of Floods

The flood characteristics defined by frequency analysis of crest-stage and streamflow-gaging station records listed in table 1 enable the flood magnitude to be estimated directly for ungaged sites near a streamflow-gaging station on the same stream, particularly where long-term records are available. These flood magnitudes can be estimated directly at that ungaged site if the ungaged drainage area is between 0.5 and 1.5 times the gaged drainage area. The estimate can be computed using the following equation, which is based on the drainage-area ratio of the ungaged site to that of the gaged site:

$$Q_{tu} = \left(\frac{Au}{Ag}\right)^{a} \cdot Q_{tg}, \qquad (3)$$

where

Q_{tu} is the flood magnitude being estimated at the ungaged site, with recurrence interval t;
Au is the drainage area at the ungaged site;
Ag is the drainage area at the gaged site;
a is the exponent of drainage area for the appropriate region and desired recurrence interval, as given in table 2; and
Q_{tg} is the flood magnitude at the gaged site based on the appropriate recurrence interval from table 1.

On large streams having several gaged sites or at sites where flood magnitude has been estimated for National Flood Insurance Studies, flood magnitudes at points of interest between the sites can be interpolated from curves relating flood magnitude to drainage area. The relation of flood magnitude to drainage area for all major streams in Montana where interpolation was considered to be applicable is presented in figures 4-10. For ungaged sites having drainage areas smaller than those shown in figures 4-10, the appropriate regression equation needs to be used to estimate the flood magnitude. Diversions and regulation that occur between some stations on these streams could affect some of the flows. For example, on the Milk (fig. 6), Missouri (fig. 7), and Musselshell (fig. 8) Rivers, Q_2 decreases between two stations having increasing drainage area.

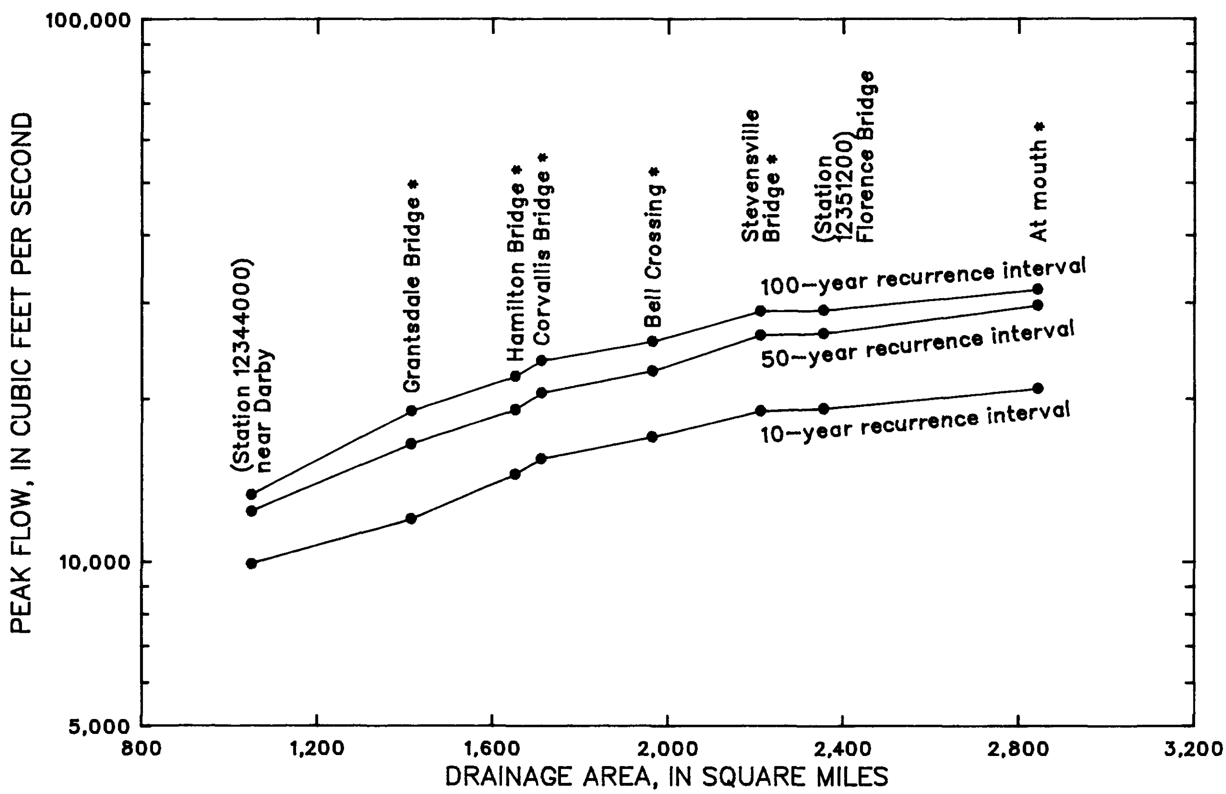


Figure 4.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Bitterroot River. Asterisk denotes flood magnitude determined for National Flood Insurance Study by the Federal Emergency Management Agency (1982, p. 8).

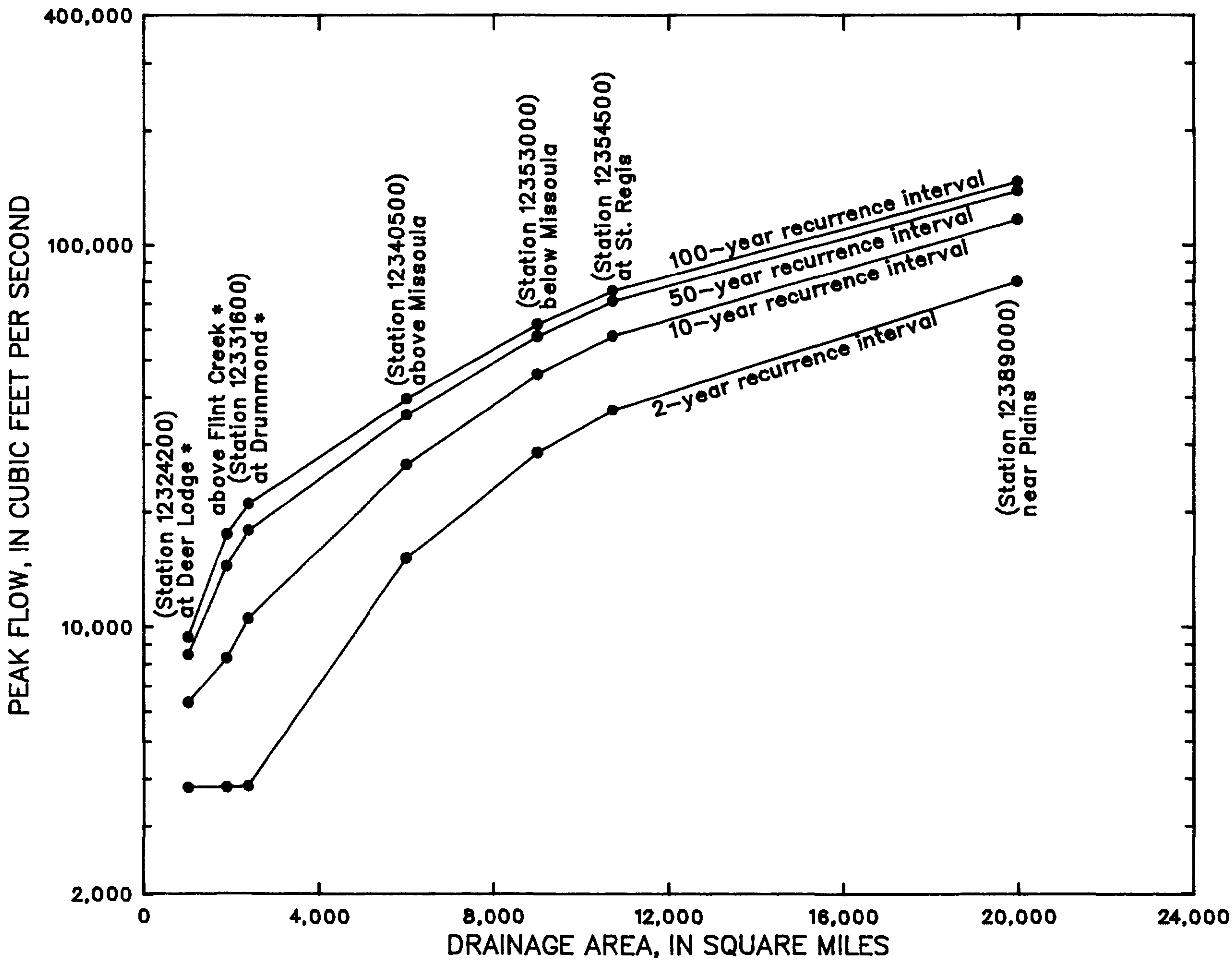


Figure 5.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Clark Fork. Asterisk denotes flood magnitude determined for National Flood Insurance Study by the Federal Insurance Administration (1980, p. 14).

To determine flood magnitudes for selected recurrence intervals for any ungaged site in Montana, locate the site on the map (pl. 1), determine in which region it is located, and determine if it is on a gaged stream.

1. If the site is on the Bitterroot, Clark Fork, Milk, Missouri, Musselshell, Powder, or Yellowstone River, interpolate the desired flood magnitudes from the applicable curves in figures 4-10.

2. If the site is on a gaged stream and has a drainage area within 5 percent of that of the nearest gage, use the flood magnitudes for the gage given in table 1.

3. If the site is on a gaged stream and has a drainage area between 0.5 and 0.95 times the gaged drainage area, or between 1.05 and 1.5 times the gaged drainage area, use equation 3 to determine the desired flood magnitude.

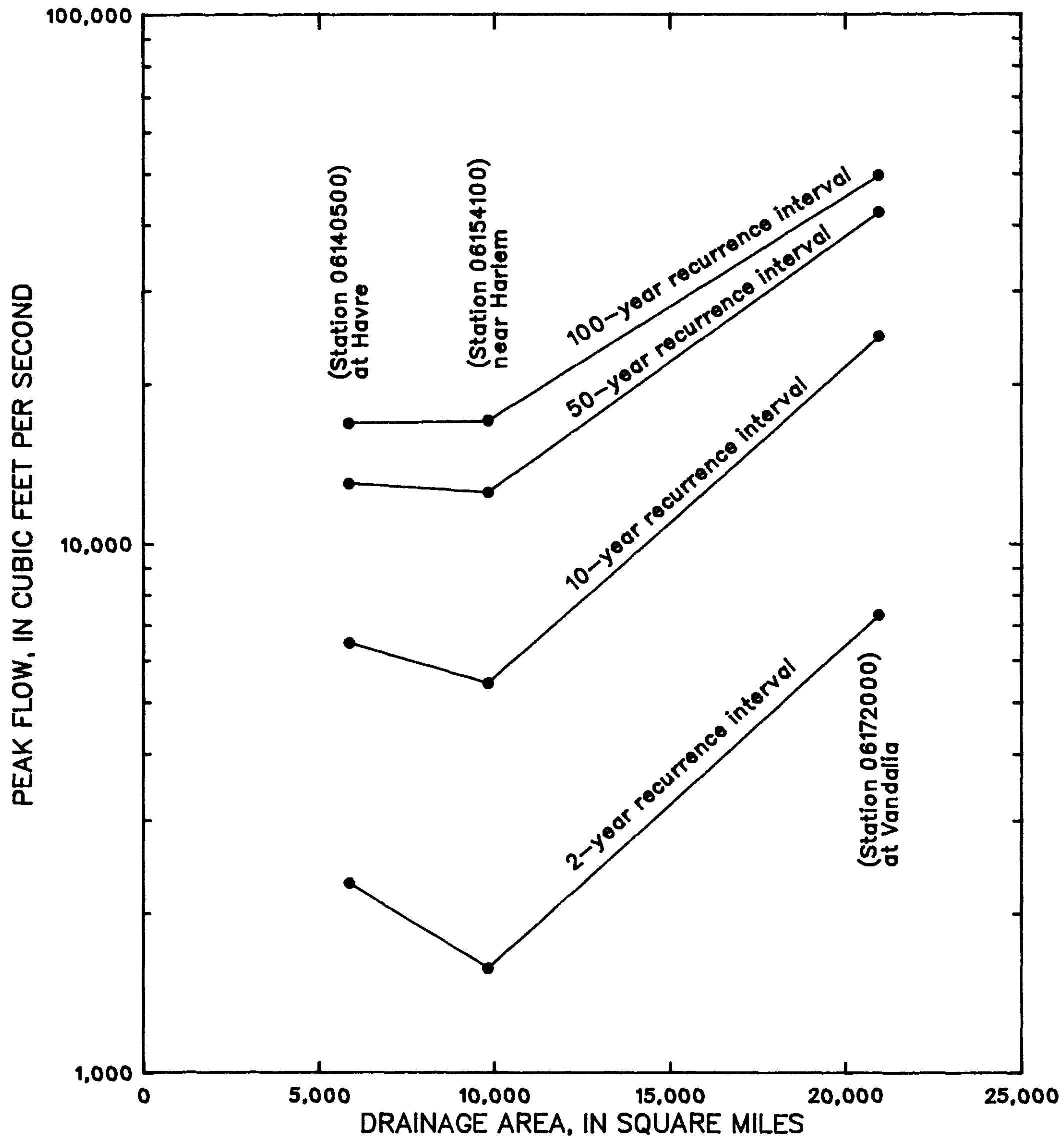


Figure 6.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Milk River.

4. If the site is on an ungaged stream, or on a gaged stream where the drainage area at the site is less than 0.5 times the gaged drainage area, or greater than 1.5 times the gaged drainage area, use the appropriate regression equation to calculate flood magnitude as follows:

   a. Select the appropriate regression equation from table 2, on the basis of which region the site is in; and

   b. Determine the required drainage-basin characteristics from the best available topographic map and from precipitation data of the U.S. Soil Conservation Service (1980).

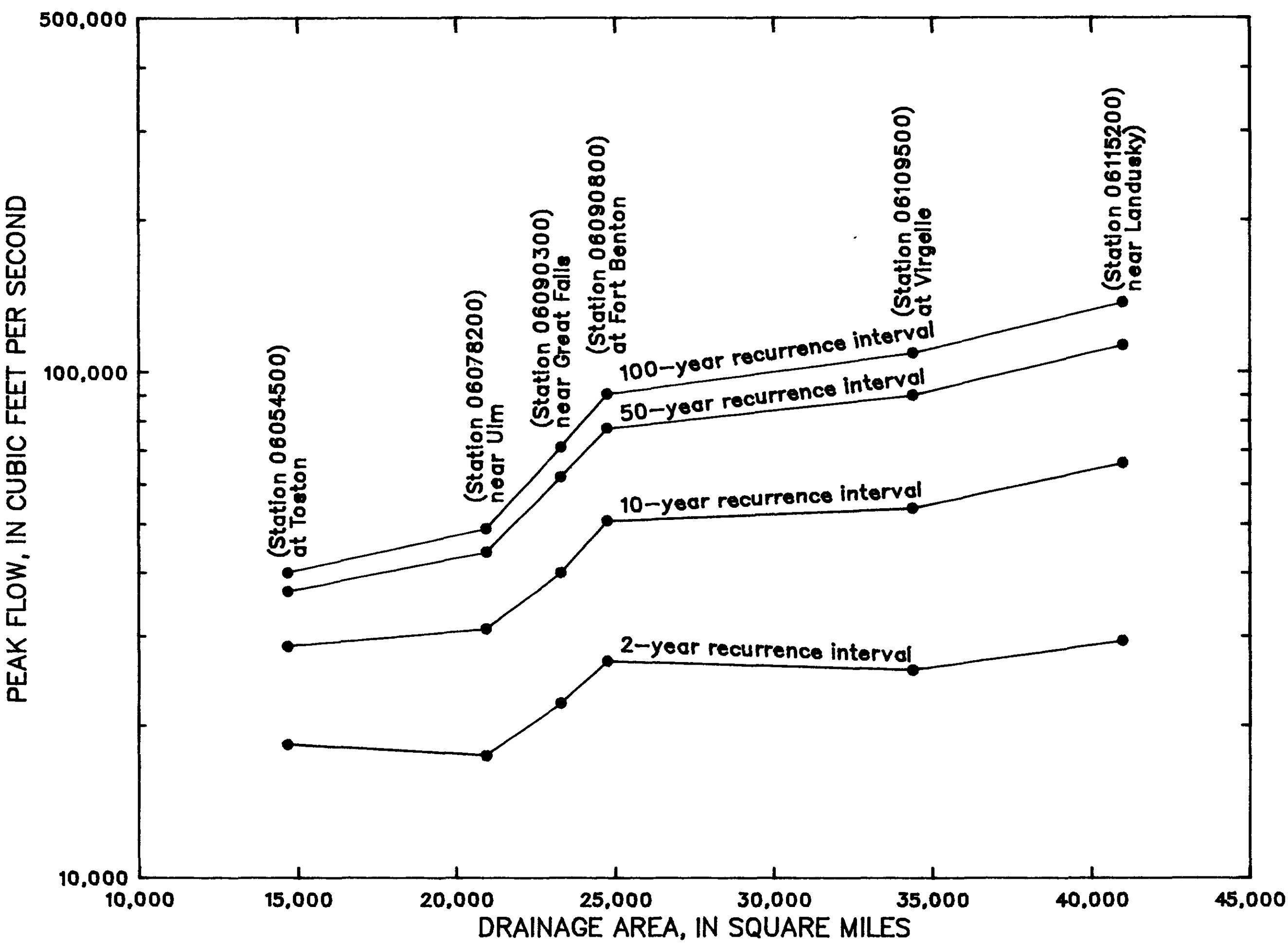


Figure 7.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Missouri River.

5. If the drainage basin for the site of needed flood magnitude lies in two adjoining regions, determine a weighted-average flood magnitude as follows:

   a. Using the total drainage area and the appropriate regression equation, determine the flood magnitude that would result if the entire drainage basin were located within each of the two regions;

   b. Measure the part of the total drainage area that lies in each of the two adjoining regions; and

   c. Multiply the flood magnitude determined in step 5a. for each region by the ratio of the drainage area within that region to the total drainage area and add the two results to obtain a weighted-average flood magnitude.

Procedure 5 is valid for boundaries between all regions in Montana except between the Northwest Region and the Northwest Foothills Region (see section "Limitations of Regression Equations"). The procedure is valid between those two regions only for determining Q_2, Q_5, Q_{10}, and Q_{25}.

Use of the regression equations to estimate flood magnitudes at ungaged sites is shown by the following examples. The technique is similar for all regions and all recurrence intervals for which equations are provided.

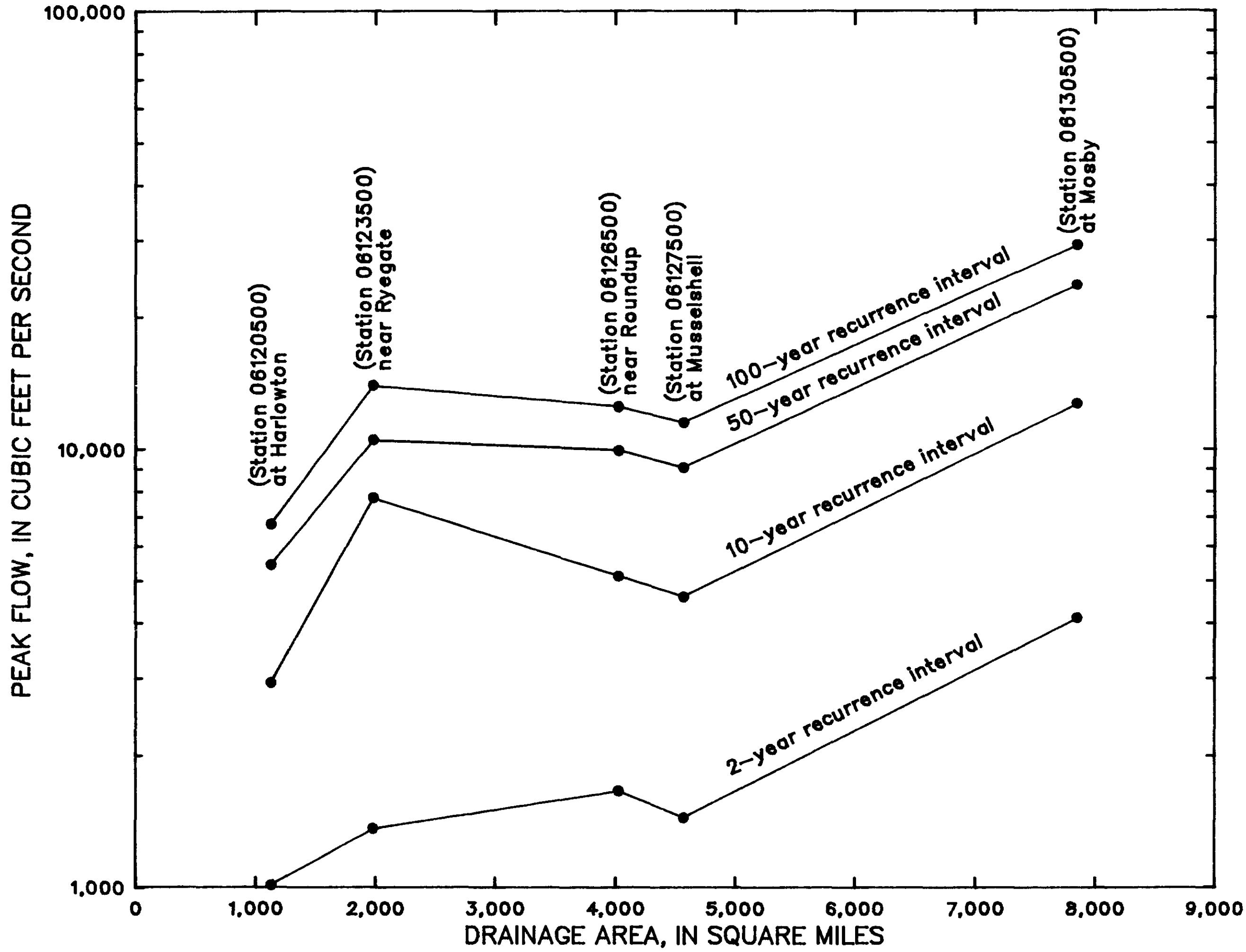


Figure 8.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Musselshell River.

<u>Example 1. (Using the regression equations when the drainage basin is in one region)</u>

Determine the flood magnitude for a recurrence interval of 100 years for an ungaged site in the Southwest Region where the contributing drainage area (A) is 16.4 mi^2 and the percentage of basin above 6,000 ft elevation (HE) is 75.

From the Southwest Region equations (table 2), the flood magnitude for a 100-year recurrence interval is:

$$Q_{100} = 1,520\ A^{0.68} (HE+10)^{-0.74}$$

$$= (1,520)(16.4)^{0.68}(85)^{-0.74}$$

$$= (1,520)(6.70)(0.0373)$$

$$= 380\ ft^3/s$$

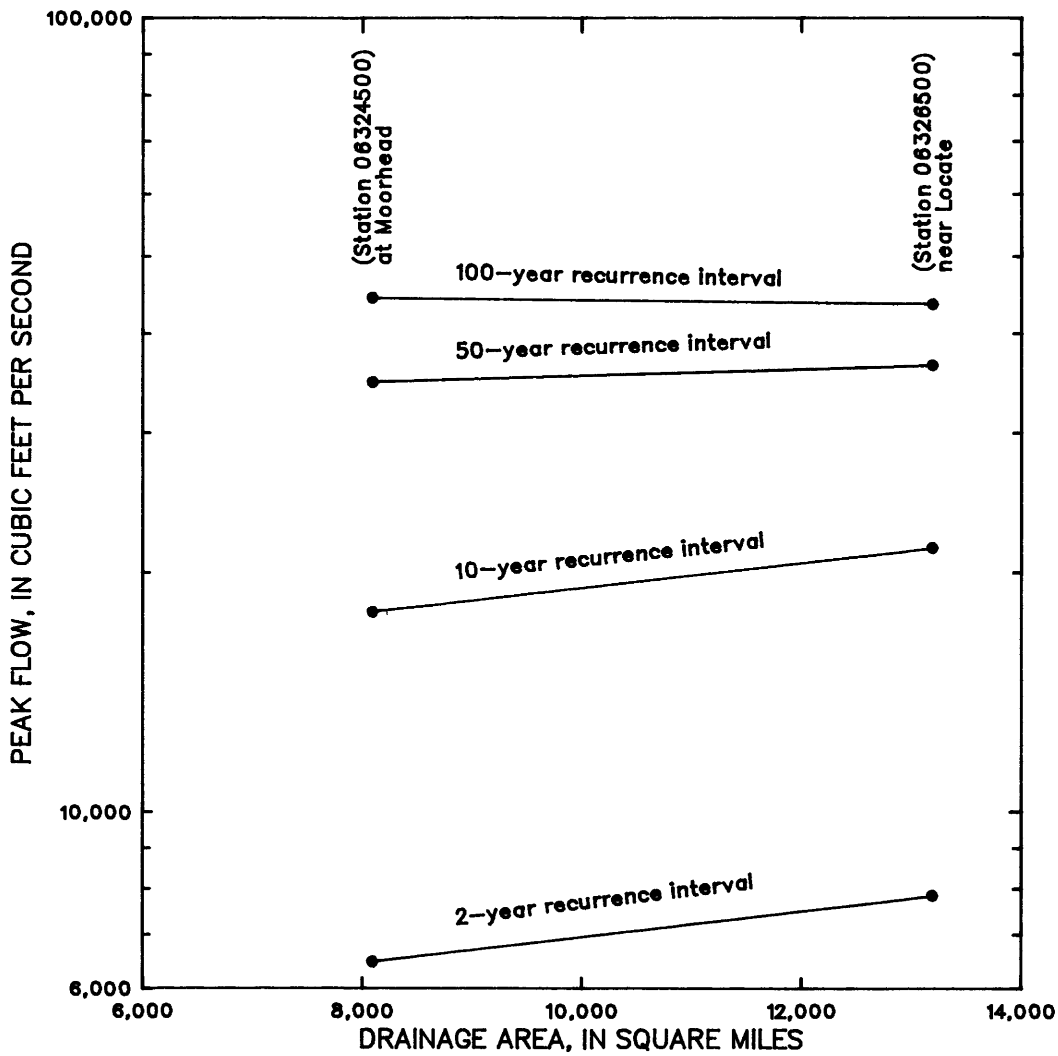


Figure 9.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Powder River.

<u>Example 2. (Using the regression equations when the drainage basin is in two regions)</u>

Determine the flood magnitude for a recurrence interval of 50 years for a site in northeastern Montana where 12.5 mi^2 of the total drainage area is in the Northeast Plains Region and 35.2 mi^2 of the total drainage area is in the East-Central Plains Region. That part of the drainage basin in the Northeast Plains Region has a mean basin elevation (E) of 3,120 ft. That part of the drainage basin in the East-Central Plains Region has a mean basin elevation (E) of 2,780 ft.

From the Northeast Plains Region equations, the flood magnitude for a 50-year recurrence interval is:

$$Q_{50} = 543\ A^{0.60}\ (E/1000)^{-1.09}$$

$$= (543)(47.7)^{0.60}\ (3.12)^{-1.09}$$

$$= (543)(10.17)(0.289)$$

$$= 1{,}600\ ft^3/s$$

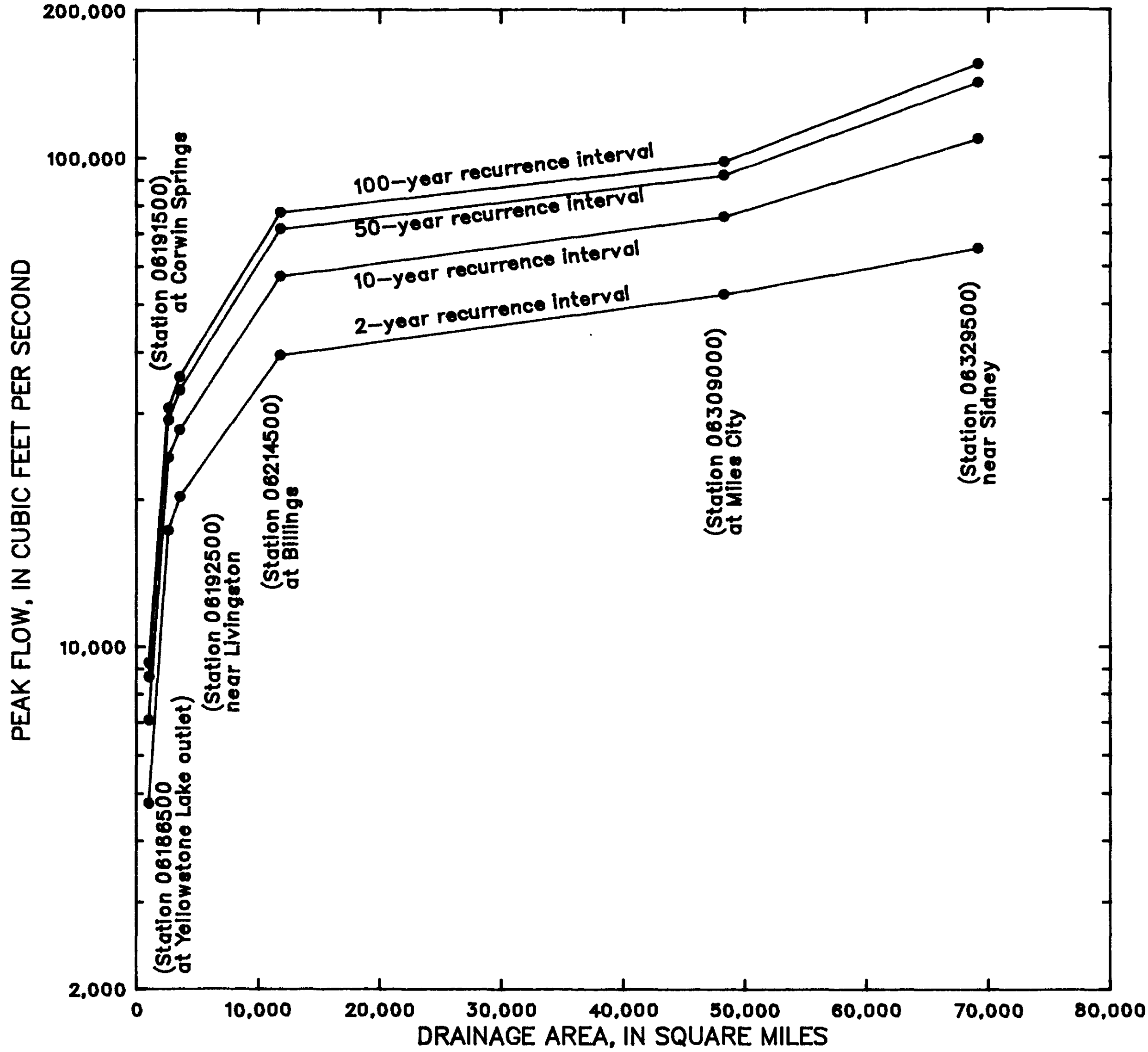


Figure 10.--Relation of peak flow to drainage area for selected flood frequencies along the mainstem of the Yellowstone River.

From the East-Central Region equations, the flood magnitude for a 50-year recurrence interval is:

$$
\begin{aligned}
Q_{50} &= 2{,}100\ A^{0.49}\ (E/1000)^{-1.72} \\
&= (2{,}100)(47.7)^{0.49}\ (2.78)^{-1.72} \\
&= (2{,}100)(6.64)(0.172) \\
&= 2{,}400\ ft^3/s
\end{aligned}
$$

The weighted average flood magnitude for a 50-year recurrence interval is:

$$Q_{50} = 1,600 \left(\frac{12.5}{47.7}\right) + 2,400 \left(\frac{35.2}{47.7}\right)$$

$$= 419 + 1,771$$

$$= 2,190 \text{ ft}^3/\text{s}$$

Example 3. (Transferring data from a gaged site)

Determine the flood magnitude for a recurrence interval of 100 years for the Tobacco River near Eureka, Montana, at an ungaged site where the drainage area is 310 mi^2. From table 1 (West Region), the drainage area of the gaged site (station 12301300) is 440 mi^2 and the 100-year recurrence interval flood is 3,220 ft^3/s. Because the ungaged drainage area (310 mi^2) is between 0.5 and 1.5 times the gaged drainage area (440 mi^2), equation 3 can be used to calculate the flood magnitude. From the equations for the West Region (table 2), the exponent for drainage area (A) for a 100-year recurrence interval flood is 0.85. Using equation 3, the flood magnitude for a 100-year recurrence interval at the site is:

$$Q_{100} = \left(\frac{310}{440}\right)^{0.85} (3,220)$$

$$= (0.743)(3,220)$$

$$= 2,390 \text{ ft}^3/\text{s}$$

ANALYSIS OF PEAK-FLOW GAGING NETWORK

The peak-flow gaging network of crest-stage stations operated in cooperation with the Montana Department of Transportation (fig. 11) was analyzed to assess the effect of adding or deleting stations and thereby improve the cost effectiveness of supplying regional flood information. Owing to the simplicity of a crest-stage station, most of the cost of operation is for record compilation, which is fairly uniform for all stations. Consequently, a uniform cost for operation and maintenance was assumed for all stations. For those stations that have already been discontinued, the cost is irrelevant. Therefore, the cost of obtaining data from stations in the network is directly proportional to the number of stations in the network at a given time.

Procedure

The network that was analyzed in this report consists of eight sub-networks corresponding to the eight regions determined by the flood-frequency analysis. The streamflow-gaging stations operated by the U.S. Geological Survey were assumed to remain in operation throughout the period of analysis. The streamflow characteristic used in the analysis was the annual peak flow for each station during the period of record; that flow is assumed to represent current conditions and to be unaffected by regulation.

The drainage-basin characteristics used in the network analysis were those identified in the ordinary least-squares regression analyses for computing t-year recurrence-interval floods. The characteristics were drainage area, mean annual precipitation, mean basin elevation, and percentage of basin above 6,000 ft elevation (table 1). For this analysis, only those stations having drainage areas of less than 2,555 mi^2 were used.

The peak-flow gaging network was analyzed using a generalized least-squares regression model proposed by Stedinger and Tasker (1985) and documented by Tasker and Stedinger (1989) that relates selected drainage-basin characteristics to t-year recurrence-interval peak flows. The process accounts for the time-sampling error (variance) in the streamflow characteristic and the cross correlations of concurrent peak-flow records between various sites (Tasker and others, 1986). A feature of the generalized least-squares technique that makes it particularly valuable for peak-flow-gaging-network analysis is that it provides a reliable estimate of the regression sampling error. The regression sampling error is the error due to estimating the true regression parameters from observed data. The sampling error is affected by record length at the stations, variability of the peak-flow data, cross correlation with data from other stations, and a combination of drainage-basin characteristics at the stations. Only the sampling error is affected by increases in record length or by the inclusion of new stations, so the network analysis is limited to this component. The generalized least-squares analysis recognizes the correlation between data at stations that have concurrent periods of record. The individual station covariances are adjusted for the effect of interstation correlation in the computation of the average sampling mean-square error.

Analyses were performed using peak flows having recurrence intervals of 2, 10, and 50 years to ensure that the information supplied by each sub-network was representative of a wide range of flood magnitudes. Each flow characteristic was analyzed by two methods on the basis of value of present and future information. One method considered all current crest-stage stations in the sub-network as eligible for discontinuance, whereas the other considered the addition of new stations to the sub-network as well as the discontinuance of all current stations. Because the Northwest Region contains only two current crest-stage stations, the evaluation for this region was based only on the second method.

Hypothetical new stations were evaluated on the basis of relative effect of the stations on the regression results. One of the statistics in the output of the generalized least-squares regression model represents the extent to which the data for a particular station and the combination of drainage-basin characteristics affect the results. Generally, the values of the basin characteristics that have the greatest effect are at or approach the extremes of the values used in the regression. Therefore, stations to be added to the network were selected on the basis of their having basin characteristics near the extremes.

The revision of a data network needs to involve consideration of the length of future operations to permit assessment of its future effectiveness. The quantity of regional information that is available is related to the time and cost of collecting the data. Hardison (1969) showed that the reliability of estimating flood magnitude for selected recurrence intervals at a particular site increases with the number of years of data collected. This increase in reliability becomes smaller as additional years of data are collected. The time period during which a peak-flow gaging network will be operated is thus an important factor in the evaluation of network reliability. This analysis considered three time periods (planning horizons) for network operation. The 0-year horizon depicts the reliability of current network operation based on data collected through water year 1988. The 5-year and 20-year horizons showed the reliability of various network configurations for an additional 5 and 20 years of data collection, respectively. The 5-year horizon represents the additional reliability to be gained from a short-term continuation of the network, and the 20-year horizon represents the additional reliability to be gained from a long-term continuation of the network.

Using these planning horizons, generalized least-squares regression determined which current crest-stage stations contributed most to decreasing the average sampling mean-square error of the regression equation and how additional data collection at these stations would further decrease the average sampling mean-square error. Generalized least-squares regression was also used to evaluate the decrease in average sampling mean-square error that resulted from adding stations to the network using each planning horizon. The greater the decrease in the error, the more a station would continue to contribute information and be effective in the future network. Conversely, a small decrease in the error indicates that the station contributes little information to the network and could be discontinued.

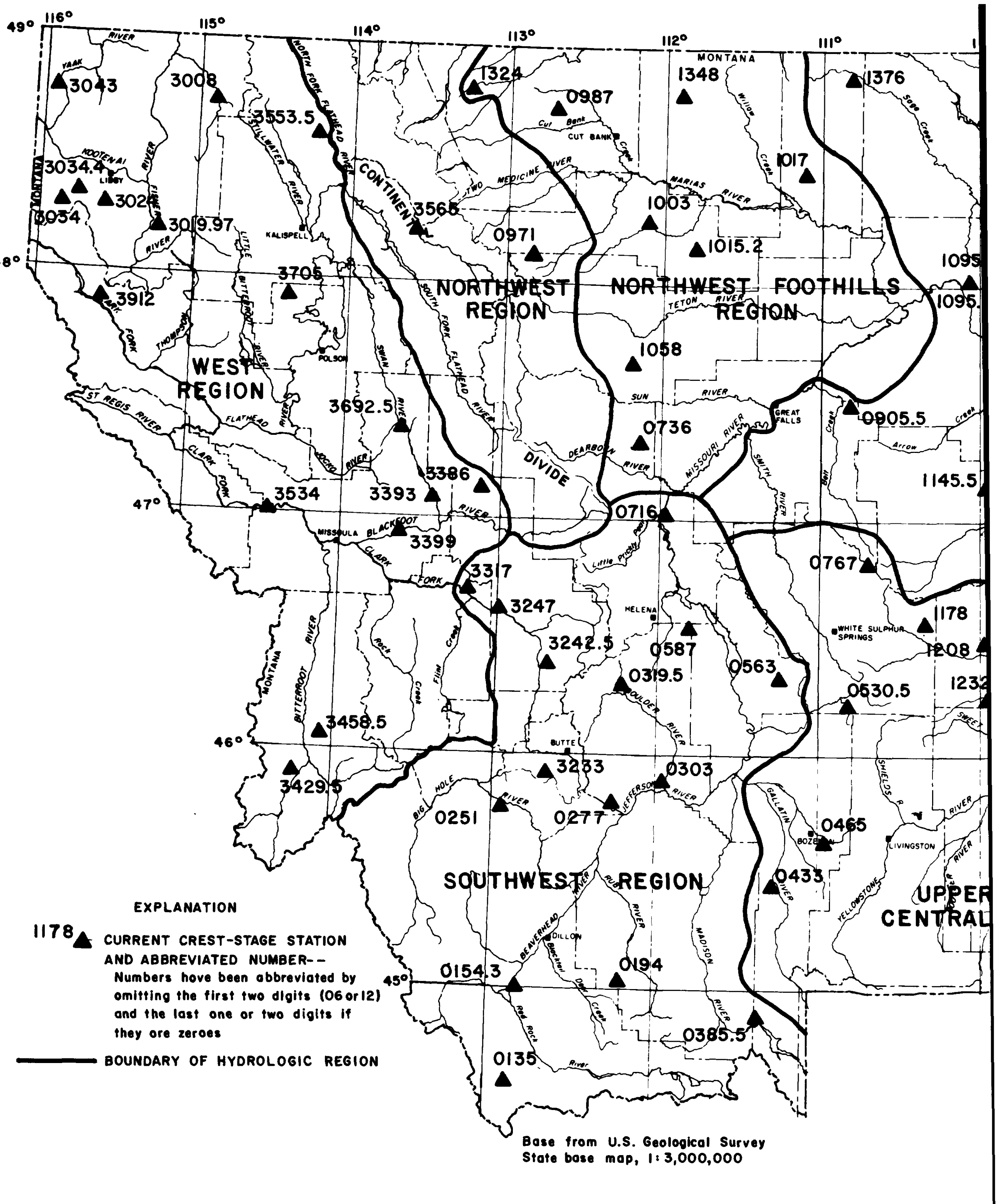
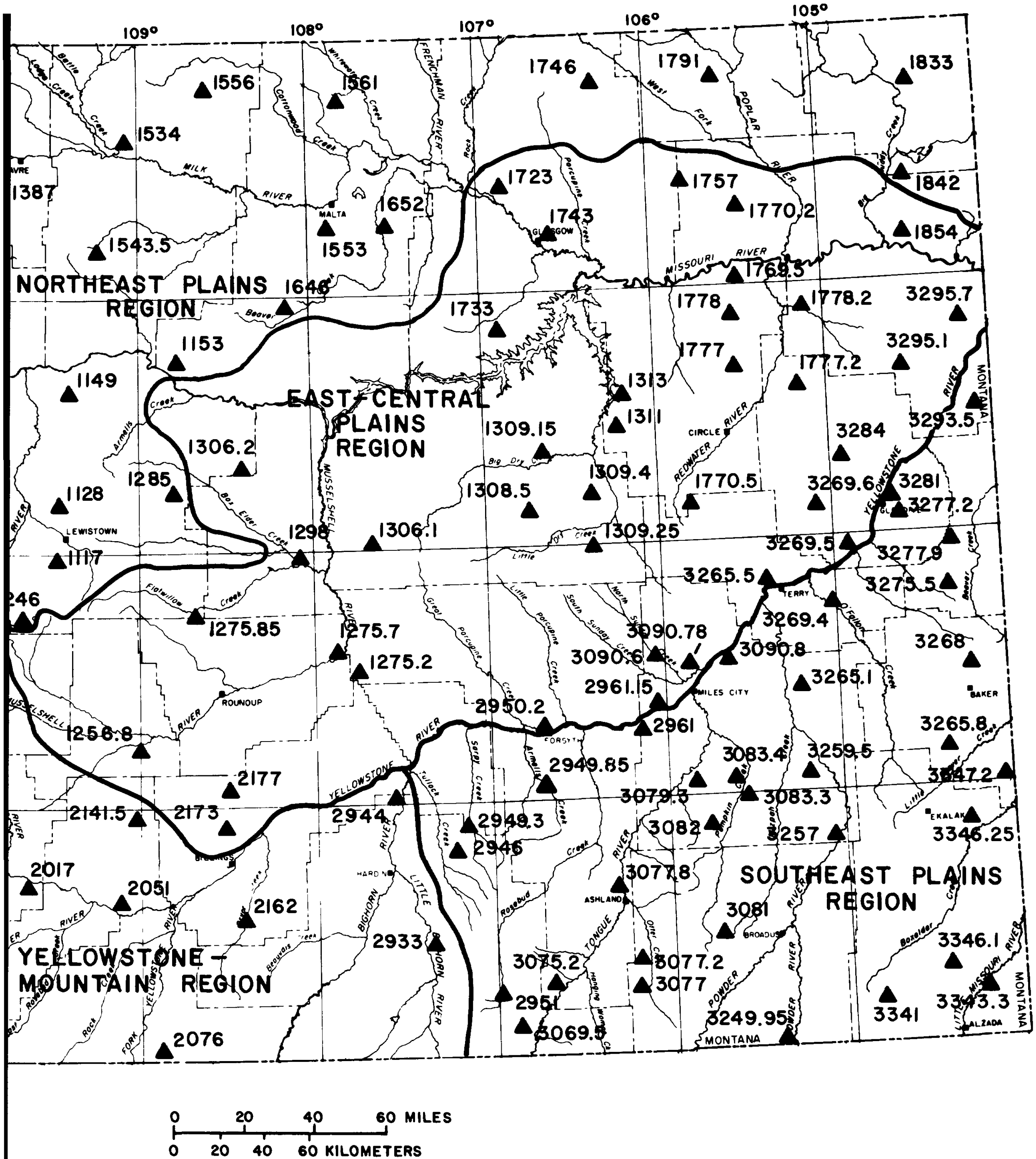


Figure 11.--Boundaries of hydrologic regions and location of



current crest-stage stations in the peak-flow gaging network.

Results of Network Analysis

The results of the network analysis are presented in figures 12-19 and tables 4-11. Figures 12-19 summarize the results using the 50-year recurrence-interval peak flow for each network strategy and planning horizon. The graphs show stations plotted as points of average sampling mean-square error (vertical axis) versus the number of stations (horizontal axis) remaining in the network. The points are arranged on the graphs so that the station exerting the maximum effect is plotted to the left, and each station toward the right is progressively less effective. The stations to the left of the most effective station are not plotted individually but are considered as a group that needs continued operation. These are streamflow-gaging stations that are not operated in cooperation with the Montana Department of Transportation but are operated for other cooperating agencies and thus would not be discontinued on the basis of this analysis. All stations plotted individually are crest-stage stations that could be discontinued. Tables 4-11 rank the stations in order of importance in providing regional peak-flow information. Stations are ranked according to 5- and 20-year planning horizons and 2-, 10-, and 50-year recurrence intervals.

The series of points plotted on each graph (figs. 12-19) are referred to as "curves" even though lines have not been drawn. The slope of the curve indicates the change in the average sampling mean-square error between the plotted points representing stations. Where the slope is steep, the curve represents stations that are the most effective in decreasing the average sampling mean-square error. These stations provide considerable regional information for the network. In most regions, the most-effective stations are nearly all new stations added to the network. Conversely, where the slope is flat, the curve represents stations that would contribute very little to decreasing the average sampling mean-square error, and the station would have little effect on the quantity of regional information being provided by the network. These stations could be discontinued.

Although the average sampling mean-square error resulting from the analysis of the 2-, 10-, and 50-year peak flows is different for each recurrence interval, the interpretation of results for each recurrence interval is similar. Therefore, the results are discussed collectively, yet examples are shown only for the 50-year recurrence interval. The effects of operating the network for 0, 5, and 20 years for each of the eight regions are shown in figures 12-19. The relatively flat slopes of the curves for the 5-year planning horizon indicate that very little information would be gained by operating most of the stations for an additional 5 years. The Northwest Foothills (fig. 16A), East-Central Plains (fig. 18A), and Southeast Plains (fig. 19A) Regions each have about five current stations that form a slightly downward-trending curve and thus would result in a decreased error during the 5-year planning horizon. For the 20-year planning horizon, the Northwest Foothills (fig. 16A), Northeast Plains (fig. 17A), East-Central Plains (fig. 18A), and Southeast Plains (fig. 19A) Regions would each benefit from retention of at least five stations. The size of the network could be decreased in these four regions by about 50 percent, and the average sampling mean-square error would decrease by about 3 percent from the 0-year to the 20-year planning horizon. However, by adding stations to every region, the average sampling mean-square error would be decreased even more (figs. 12B, 13, 14B-19B).

The results shown in figures 12-19 can be used to determine how many sites could be continued and how many sites could be added to the network to meet goals for providing regional information. Tables 4-11 then can be used to identify the stations and, in conjunction with table 1, can assist in identifying drainage-basin characteristics at the extremes of the values used in the regression that would be desirable for stations added to the network. As an example of this procedure for the Northwest Foothills Region, determine from figure 16B that three sites could continue to be operated and that four stations added to the network would be effective in decreasing the average sampling mean-square error. The three stations that could be continued are determined by the slope of the curve. Then, by using table 8, the station numbers are determined from the appropriate columns or from the composite station ranking.

The composite ranking for the current crest-stage stations in each sub-network and stations added to the network is based on the relative ranking of the station

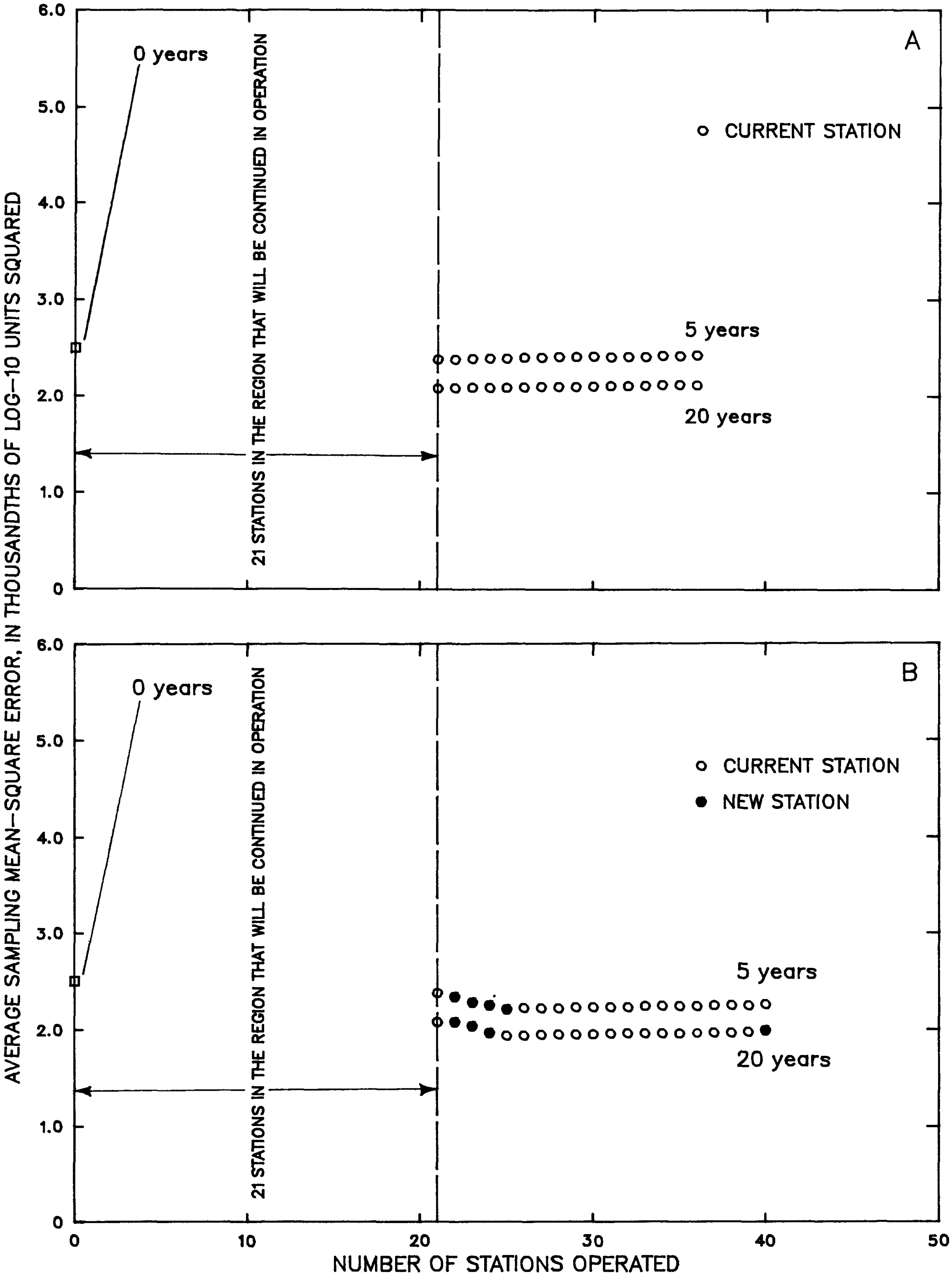


Figure 12.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the West Region. A, Continued operation of all current stations. B, Addition of four stations.

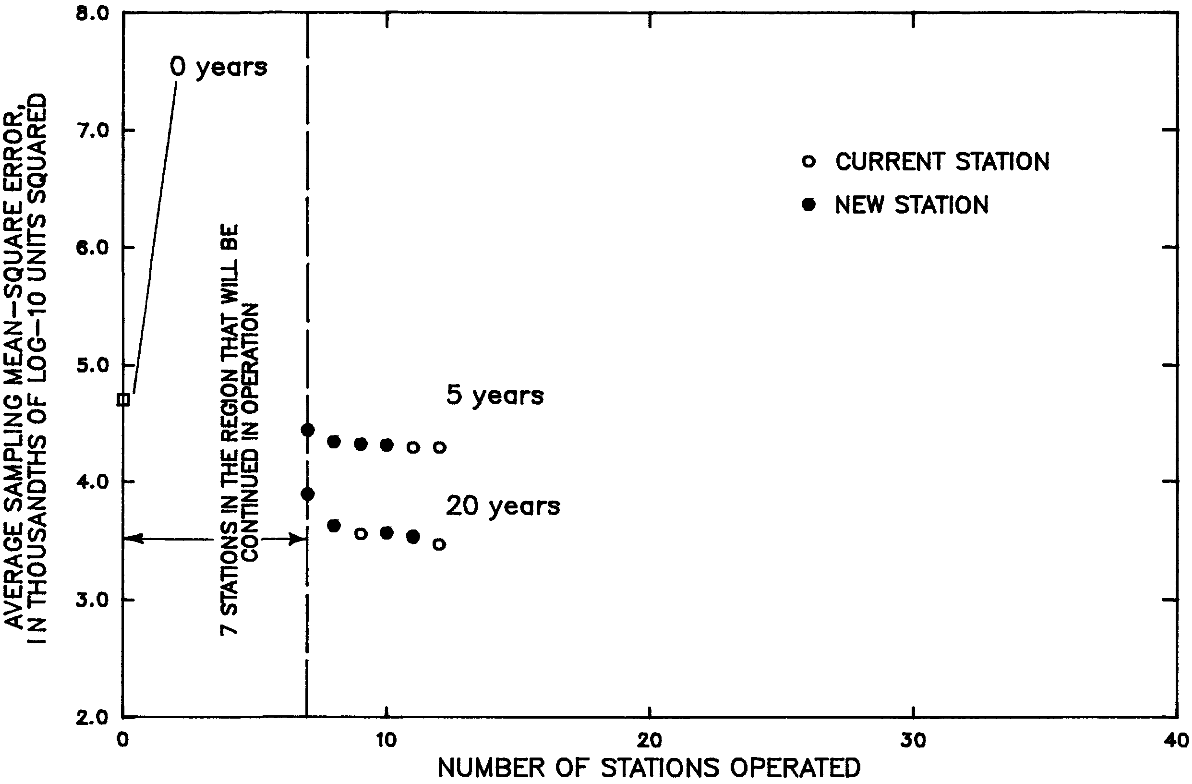


Figure 13.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the Northwest Region.

for each streamflow characteristic using the 20-year planning horizon. The composite ranking provides a means of ranking stations in order of priority and assumes that all flow characteristics are of equal importance. In some instances, some stations may have a substantial effect on one flow characteristic but not on the others. In the Upper Yellowstone-Central Mountain Region (table 7), for example, the results of analysis indicate that, using the composite station ranking, station NEW-02 would have a negligible effect on decreasing the average sampling mean-square error. However, using the 20-year planning horizon for a 50-year recurrence interval, NEW-02 is the sixth best station for decreasing the average sampling mean-square error.

The final decision on whether to restructure the network needs to be based on answers to the following questions: (1) Will the network continue to be operated, and (2) if network operation is continued, how long will it be operated, what will be its size, should effective stations be added to decrease the average sampling mean-square error, and which current stations could be deleted? If the decision is to continue the operation of the network for several years, then the resulting decrease in the average sampling mean-square error needs to be compared to existing conditions and to conditions resulting from operation of the network during other periods. The decision also needs to be based on the net effect of adding or discontinuing stations in the network. If adding new or retaining current stations results in a negligible decrease in the average sampling mean-square error, then little additional regional information would be provided to the network. Such stations are not effective and would probably not be part of the most effective network. Conversely, if an effective station were added to the network and effective current stations were retained, the network would be more effective.

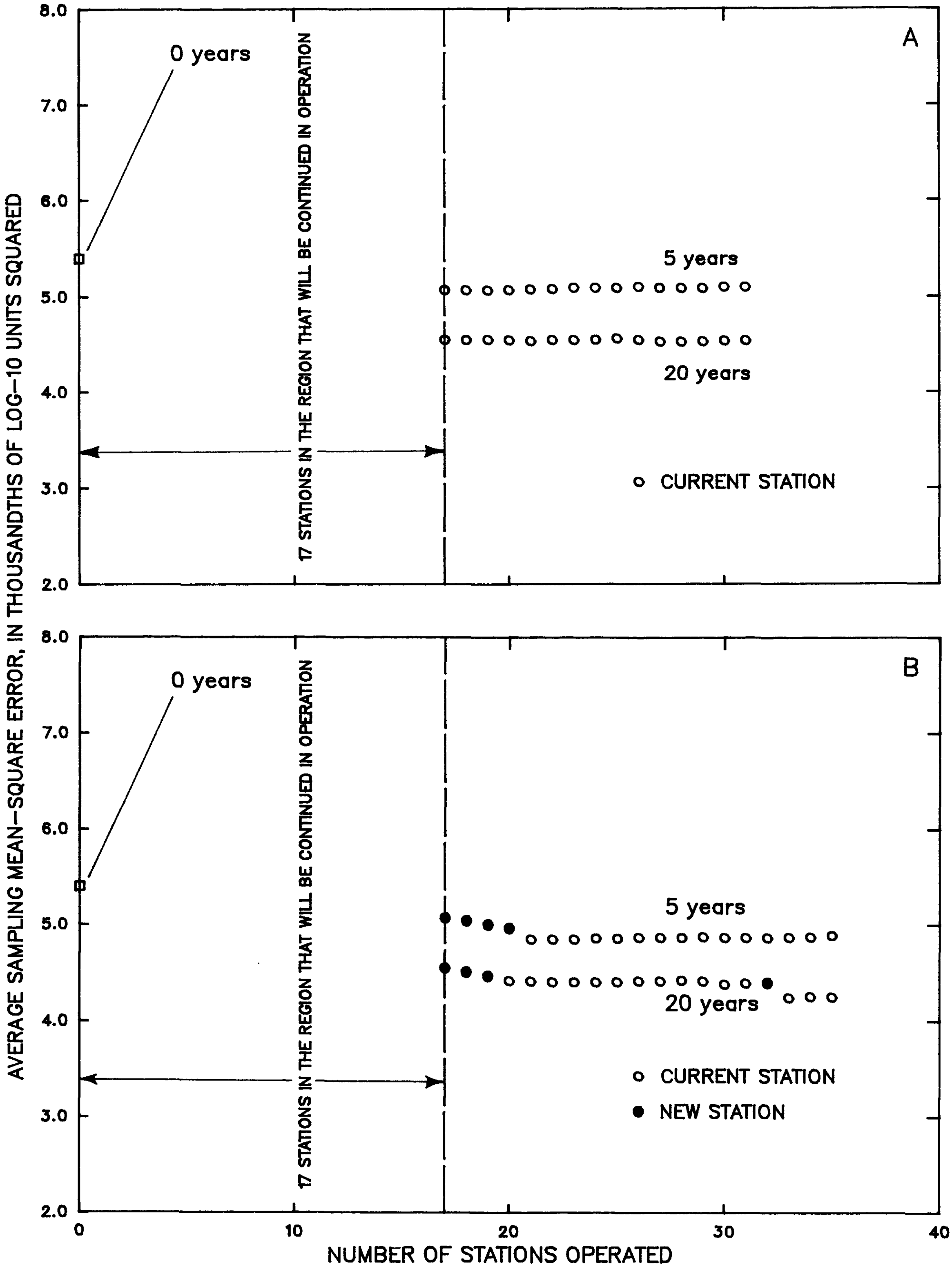


Figure 14.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the Southwest Region. A, Continued operation of all current stations. B, Addition of four stations.

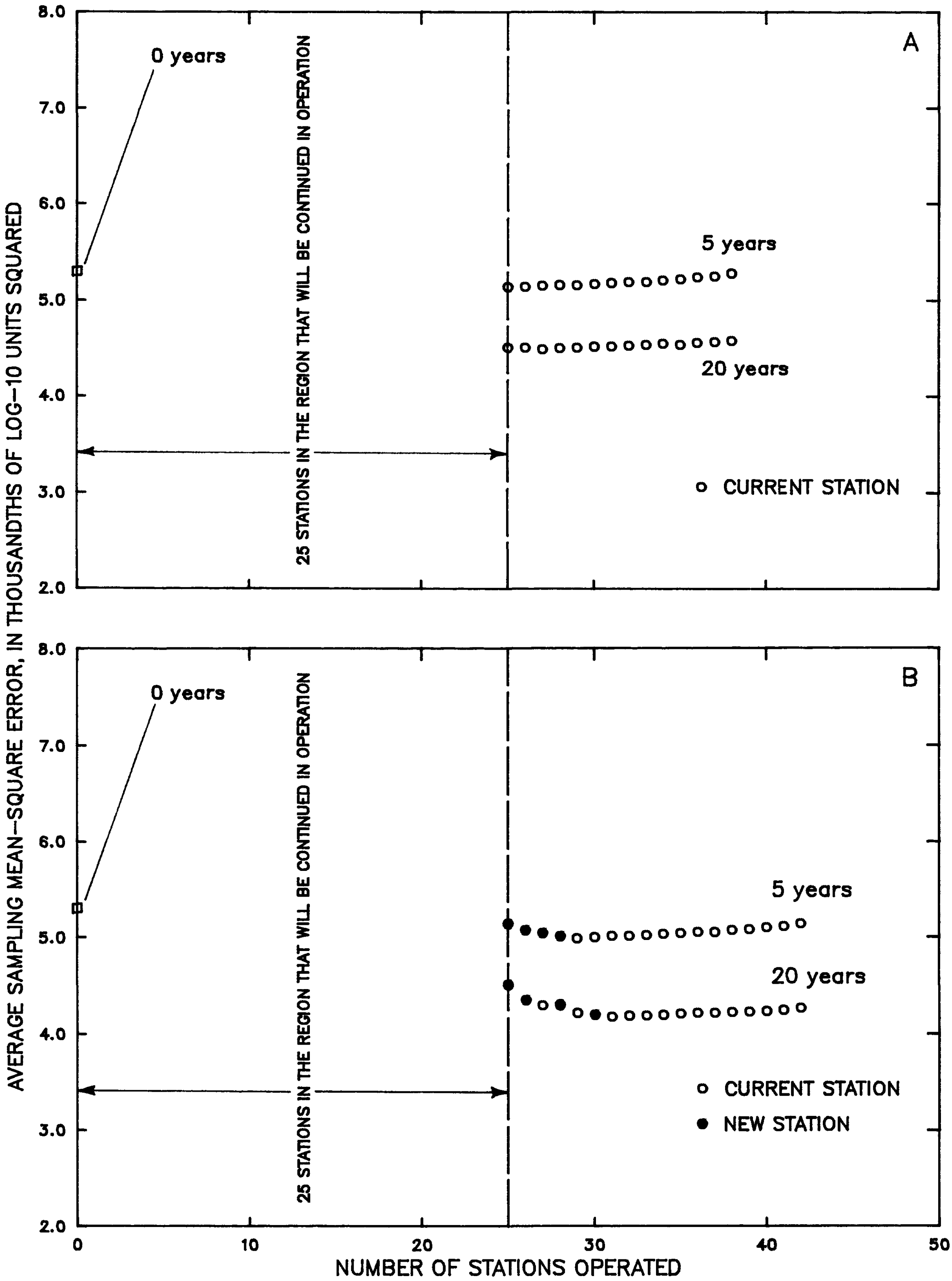


Figure 15.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the Upper Yellowstone-Central Mountain Region. A, Continued operation of all current stations. B, Addition of four stations.

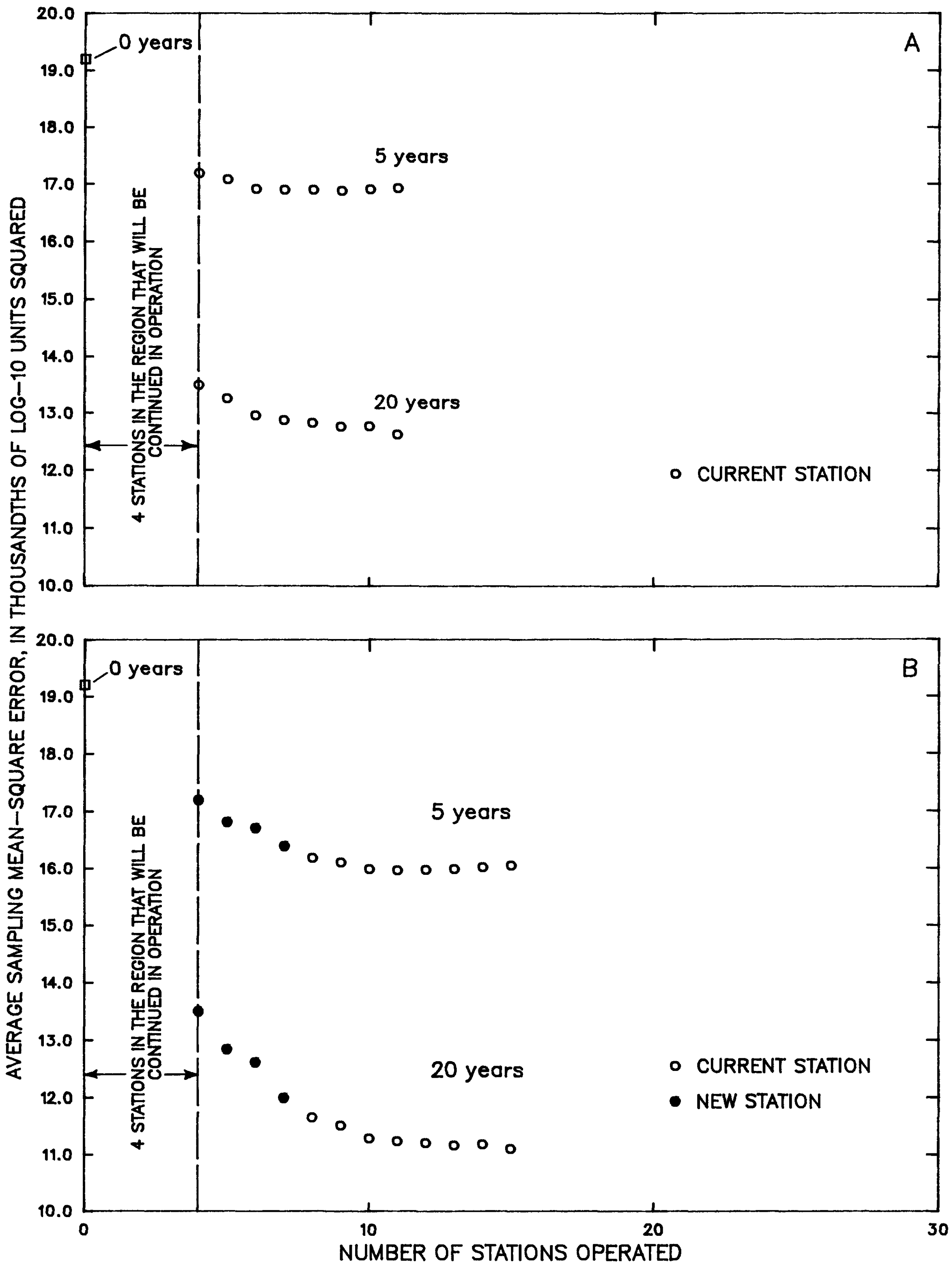


Figure 16.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the Northwest Foothills Region. A, Continued operation of all current stations. B, Addition of four stations.

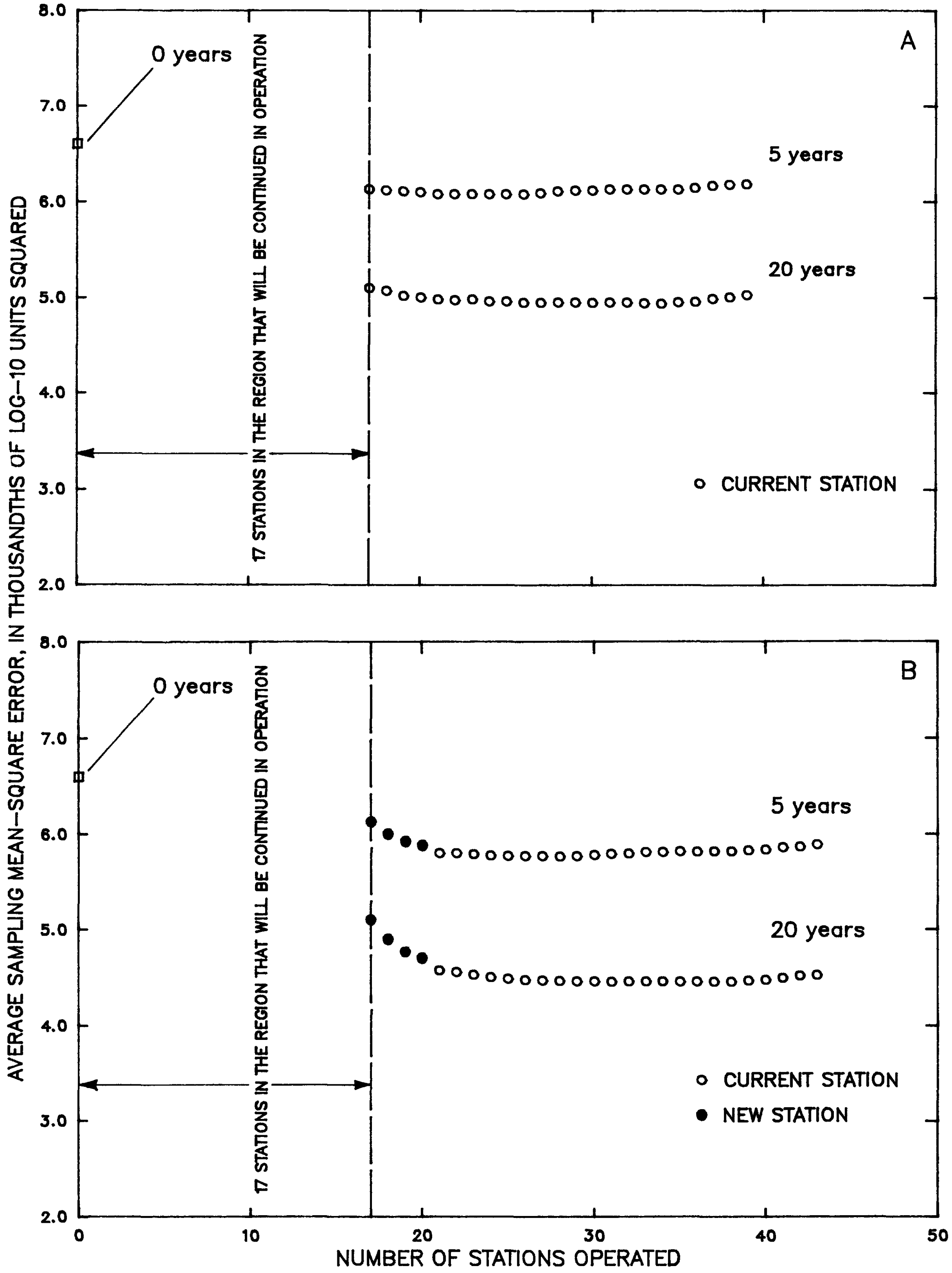


Figure 17.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the Northeast Plains Region. A, Continued operation of all current stations. B, Addition of four stations.

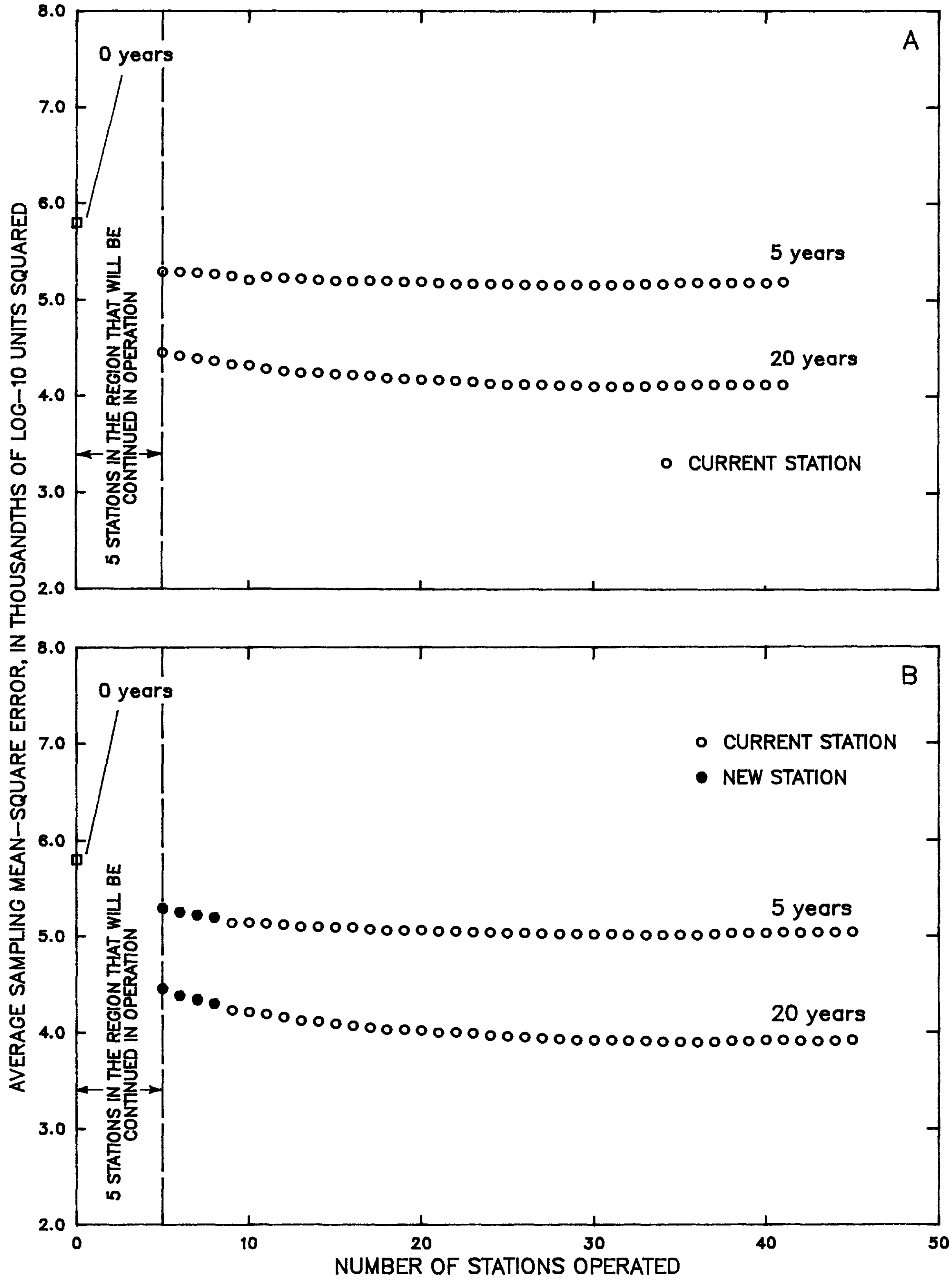


Figure 18.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the East-Central Plains Region. A, Continued operation of all current stations. B, Addition of four stations.

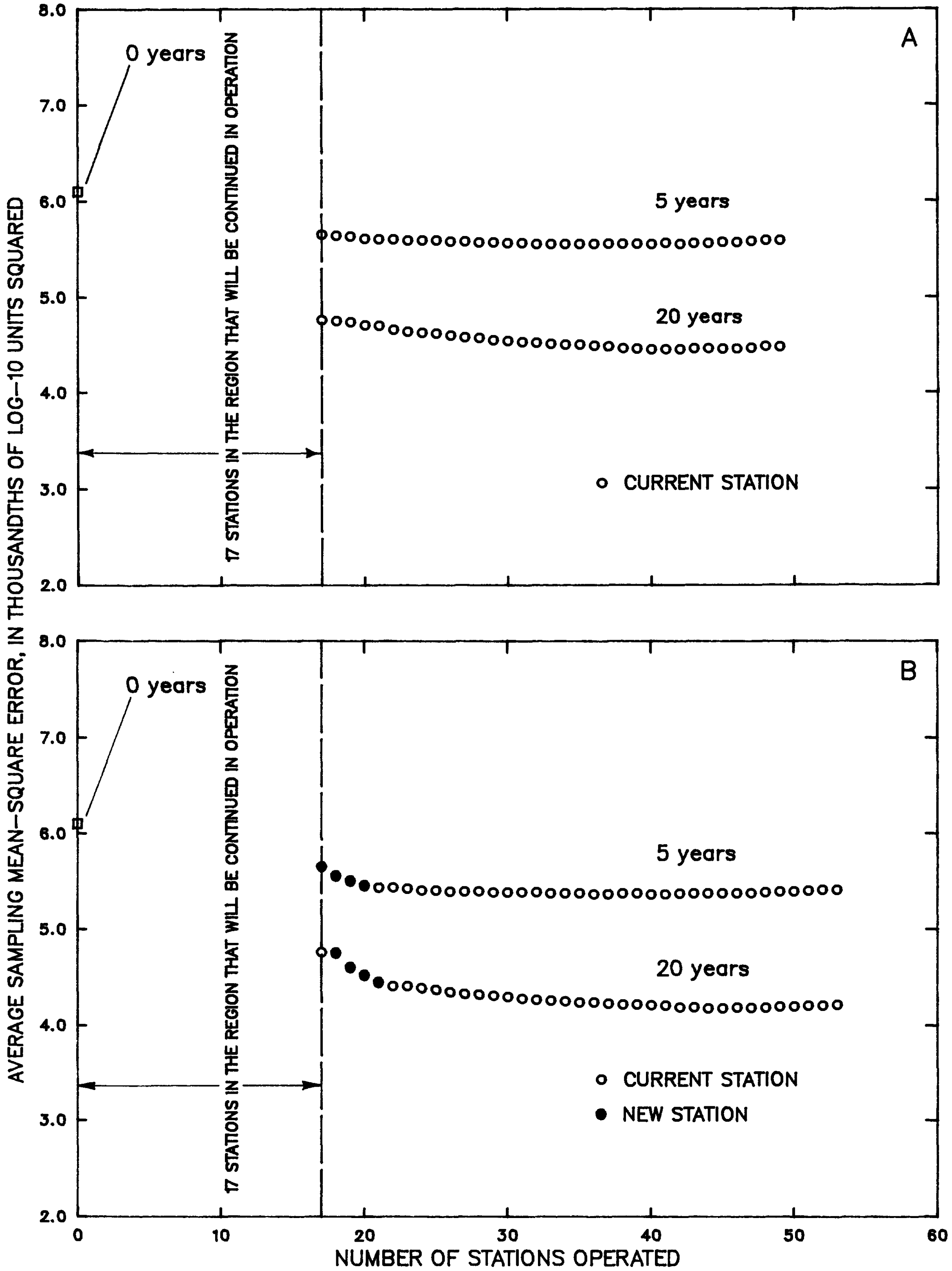


Figure 19.--Relation of average sampling mean-square error for peak flow having a 50-year recurrence interval to number of stations operated in the peak-flow gaging network for 0, 5, and 20 years for the Southeast Plains Region. A, Continued operation of all current stations. B, Addition of four stations.

As a result of network analysis, three viable options regarding the network are possible. The first option is to continue the number of current stations and the level of funding. If this option were chosen, the network would remain the same and the average sampling mean-square error would be reduced from the 0-year horizon to that shown for the current station farthest to the right in figures 12A, 13, and 14A-19A.

The second option is to discontinue all stations in each region that cause minimal change in the average sampling mean-square error by continued operation and to retain only effective stations. If this option were chosen, the level of funding would be decreased, and the average sampling mean-square error would also be decreased to about the same level as that for option one. The goal of providing maximum regional information would not be met, however.

The third option is to discontinue all non-effective stations in each region and to add stations that would contribute more effectively to decreasing the average sampling mean-square error. As shown in figures 12B, 13, and 14B-19B, this option would result in the smallest average sampling mean-square error and, hence, the peak-flow gaging network with maximum regional information. On the basis of a somewhat subjective analysis of the information provided by figures 12B, 13, and 14B-19B, the following adjustments would result in maximum regional information and the most cost-effective network in Montana:

1. West Region--Add 3 stations, retain 2 current stations, and discontinue 14 stations.

2. Northwest Region--Add 2 stations and discontinue 2 stations.

3. Southwest Region--Add 3 stations, retain 2 current stations, and discontinue 13 stations.

4. Upper Yellowstone-Central Mountain Region--Add 4 stations, retain 3 current stations, and discontinue 11 stations.

5. Northwest Foothills Region--Add 4 stations, retain 3 current stations, and discontinue 5 stations.

6. Northeast Plains Region--Add 4 stations, retain 6 current stations, and discontinue 17 stations.

7. East-Central Plains Region--Add 4 stations, retain 26 current stations, and discontinue 11 stations.

8. Southeast Plains Region--Add 4 stations, retain 22 current stations, and discontinue 11 stations.

This network design was determined by using figures 12-19 and tables 4-11. The composite station ranking from the tables was used to determine the importance of continuing or adding stations. This network design would result in an average decrease in the average sampling mean-square error from the 0-year to 20-year horizon of about 4 percent, thereby increasing the quantity of available regional information by a similar percentage. The proposed network would lessen the operation and maintenance costs of the program by about 30 percent.

SUMMARY AND CONCLUSIONS

Flood-frequency relations were updated for 522 crest-stage and streamflow-gaging stations on unregulated streams in Montana, adjoining States, and Canada having at least 10 years of peak-flow data and having drainage areas that range from 0.04 to 2,554 mi^2 using a log-Pearson type III frequency distribution and guidelines outlined by the Interagency Advisory Committee on Water Data. Log-Pearson type III estimates of flood magnitudes having recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years are reported for each station. These flood magnitudes were related to basin characteristics using ordinary least-squares multiple regression techniques to identify the basin characteristics that were most significant in each region. Drainage area, mean annual precipitation, mean basin elevation, and percentage of basin above 6,000 ft elevation were identified as significant basin characteristics. The maximum number of basin characteristics found to be significant in any region was three and the minimum number of basin characteristics was two. Drainage area was the most significant basin characteristic in all regions.

Final regression equations were developed using generalized least-squares regression for each of the eight regions. This procedure provided an error of prediction that incorporated the effects of both sampling error and model error. The standard error of estimate for equations that estimate floods having a 100-year recurrence interval ranged from 32 to 63 percent. The standard error of estimate associated with all of the regression models ranged from 22 to 128 percent. The standard error of prediction for equations that estimate floods having a 100-year recurrence interval ranged from 38 to 67 percent. Standard errors of estimate for equations used to estimate floods for most of the recurrence intervals were an improvement compared to those of a previous regression analysis.

The flood magnitude at ungaged sites upstream or downstream from a gaged station can be estimated using a drainage-area ratio adjustment. Curves that relate peak flow to drainage area can be used to determine desired flood magnitudes for seven major streams in Montana on which streamflow-gaging stations are located.

The generalized least-squares regression model was also used to analyze the peak-flow gaging network of crest-stage stations. The reason for the analysis was to assess the effect of adding or deleting stations and thereby improve the cost effectiveness of supplying regional flood information.

The network analyses were performed using peak flows having recurrence intervals of 2, 10, and 50 years to ensure that the information supplied by each of eight sub-networks was representative of a wide range of flood magnitudes. Three planning horizons were considered in this analysis: a 0-year planning horizon, which depicts the reliability of current network operation using data collected through water year 1988; one at 5 years, which represents a short-term continuation of the network; and another at 20 years, which represents a long-term continuation of the network. In the analyses, new stations were added to the network for each region on the basis of the effect that each station would have on the regression results using drainage-basin characteristics.

The network analysis determined which current crest-stage stations contributed most to decreasing the average sampling mean-square error for the indicated recurrence intervals and for the 5- and 20-year planning horizons. The analyses also used generalized least-squares regression to evaluate the decrease in the average sampling mean-square error that resulted from adding stations to the network using each planning horizon. A composite ranking was developed for the 20-year planning horizon.

Network analysis indicates that the most cost-effective peak-flow gaging network would result from discontinuing numerous crest-stage stations in most regions and adding at least two new stations in every region. The result would be a decrease in average sampling mean-square error of about 4 percent, an increase in the quantity of regional information of about 4 percent, and a savings in operation and maintenance costs of about 30 percent. The adjusted network would include 64 existing and 28 new crest-stage stations. The analysis indicated that 84 existing crest-stage stations could be discontinued.

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SUPPLEMENTAL INFORMATION

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*

[Station number: Stations are listed in downstream order by standard drainage basin number--Part 5 (Hudson Bay basin), Part 6 (Missouri River basin), Part 12 (upper Columbia River basin), and Part 13 (Snake River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number. All stations in Montana, except as indicated]

			Drainage-basin characteristic	
Station number	Station name	Length of record (years)	Drainage area (A) (square miles)	Mean annual precipitation (P) (inches)
	WEST REGION			
12300400	Cayuse Creek near Trego	13	5.29	28
12300500	Fortine Creek near Trego	23	110	28
12300800	Deep Creek near Fortine	30	18.9	50
12301300	Tobacco River near Eureka	30	440	32
12301700	Kootenai River tributary near Rexford	12	.86	30
12301800	Gold Creek near Rexford	11	6.12	31
12301810	Big Creek near Rexford	10	139	37
12301993	Wolf Creek tributary near Libby	11	2.76	25
12301997	Richards Creek near Libby	16	9.50	29
12301999	Wolf Creek near Libby	11	216	27
12302055	Fisher River near Libby	38	838	32
12302400	Shaughnessy Creek near Libby	30	1.16	60
12302500	Granite Creek near Libby	19	23.6	67
12303100	Flower Creek near Libby	29	11.1	67
12303400	Ross Creek near Troy	17	23.8	79
12303440	Camp Creek near Troy	17	11.3	63
12303500	Lake Creek at Troy	19	210	67
12304060	Blacktail Creek near Yaak	14	8.66	35
12304120	Zulu Creek near Yaak	13	5.27	34
12304250	Whitetail Creek near Yaak	15	2.48	35
12304300	Cyclone Creek near Yaak	29	5.73	67
12304400	Fourth of July Creek near Yaak	15	7.84	64
12304500	Yaak River near Troy	33	766	43
12330000	Boulder Creek at Maxville	49	71.3	31
12332000	Middle Fork Rock Creek near Philipsburg	51	123	35
12334510	Rock Creek near Clinton	17	885	27
12338500	Blackfoot River near Ovando	23	1,274	29
12338600	Monture Creek at Forest Service boundary, near Ovando	16	105	41
12338690	Monture Creek near Ovando	10	140	35
12339300	Deer Creek near Seeley Lake	15	19.8	39
12339450	Clearwater River near Clearwater	14	345	37
12339900	West Twin Creek near Bonner	30	7.33	25
12340000	Blackfoot River near Bonner	54	2,290	29
12340200	Marshall Creek near Missoula	15	5.63	23
12341000	Rattlesnake Creek at Missoula	10	79.7	34
12342950	Trapper Creek near Conner	15	28.5	66
12343400	East Fork Bitterroot River near Conner	36	381	32
12344000	Bitterroot River near Darby	51	1,049	22
12345800	Camas Creek near Hamilton	16	5.05	62
12345850	Sleeping Child Creek near Hamilton	17	65.2	31
12346500	Skalkaho Creek near Hamilton	29	87.8	36
12347500	Blodgett Creek near Corvallis	23	26.4	64
12348500	Willow Creek near Corvallis	19	21.9	29
12350000	Bear Creek near Victor	19	26.8	63
12350200	Gash Creek near Victor	16	3.37	60
12350500	Kootenai Creek near Stevensville	22	28.9	64
12351000	Burnt Fork Bitterroot River near Stevensville	40	73.2	32
12351200	Bitterroot River near Florence	12	2,354	36
12351400	Eightmile Creek near Florence	16	19.5	21
12352000	Lolo Creek above Sleeman Creek, near Lolo	10	250	52

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
51	90	119	160	192	226	311	187
775	1,100	1,330	1,610	1,830	2,040	2,560	1,810
130	175	203	237	261	285	339	310
1,480	2,010	2,330	2,710	2,970	3,220	3,760	2,810
6	11	13	17	20	23	30	14
65	112	148	200	244	291	416	230
1,330	2,360	3,090	4,040	4,750	5,440	7,040	2,680
14	21	26	32	38	43	56	33
22	50	75	113	145	180	274	100
521	1,340	2,090	3,240	4,230	5,310	8,120	1,660
3,240	4,590	5,460	6,520	7,280	8,020	9,670	8,720
10	26	43	74	107	149	295	200
603	878	1,080	1,370	1,610	1,870	2,560	2,000
240	343	413	503	572	642	810	709
894	1,500	1,970	2,650	3,210	3,830	5,490	3,820
244	363	449	564	655	750	991	980
2,290	3,030	3,550	4,210	4,730	5,260	6,570	7,000
74	128	168	223	266	311	424	280
43	73	97	132	162	196	290	190
29	45	58	75	90	105	143	100
128	174	206	247	279	312	395	350
174	245	288	338	372	404	472	400
6,970	9,010	10,300	12,000	13,200	14,400	17,200	13,400
388	603	763	983	1,160	1,350	1,830	1,460
926	1,240	1,420	1,620	1,750	1,860	2,090	1,680
3,340	5,060	6,140	7,420	8,300	9,120	10,900	6,500
5,330	7,920	9,910	12,800	15,100	17,700	24,800	17,600
1,270	1,690	1,960	2,290	2,530	2,760	3,300	2,400
1,540	1,920	2,140	2,400	2,570	2,730	3,080	2,120
248	321	367	423	463	503	593	425
1,560	1,990	2,260	2,610	2,860	3,120	3,710	2,900
91	158	210	285	348	416	599	370
9,240	12,900	15,200	17,800	19,700	21,400	25,100	19,200
18	29	38	50	60	71	99	60
1,300	1,720	1,980	2,290	2,510	2,720	3,190	2,400
402	567	771	1,190	1,680	2,390	5,520	1,800
1,930	2,820	3,380	4,050	4,530	5,000	6,020	5,100
6,230	8,550	9,900	11,400	12,400	13,300	15,200	11,500
149	209	246	290	320	348	410	265
491	776	964	1,190	1,360	1,520	1,870	1,500
667	857	962	1,080	1,150	1,220	1,350	1,210
636	773	854	948	1,010	1,070	1,210	1,170
106	137	154	172	184	194	215	170
695	893	1,020	1,160	1,270	1,370	1,590	1,340
110	159	189	225	251	274	326	200
819	1,060	1,190	1,340	1,440	1,530	1,710	1,300
341	507	617	754	854	952	1,170	1,100
15,700	19,400	21,700	24,500	26,400	28,300	32,400	28,400
50	74	89	108	122	135	166	104
1,510	1,830	2,040	2,290	2,470	2,650	3,050	2,660

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean annual precipitation (P) (inches)
	WEST REGION--Continued			
12352200	Hayes Creek near Missoula	15	4.16	33
12353250	Ninemile Creek near Alberton	10	50.2	42
12353280	Ninemile Creek near Huson	10	170	38
12353400	Negro Gulch near Alberton	20	8.02	33
12353800	Thompson Creek near Superior	20	12.2	43
12353850	East Fork Timber Creek near Haugan	16	2.72	58
12354000	St. Regis River near St. Regis	25	303	52
12354100	North Fork Little Joe Creek near St. Regis	15	14.7	56
12355350	Big Creek at Big Creek Ranger Station, near Columbia Falls	17	82.1	48
12363900	Rock Creek near Olney	15	3.61	35
12363920	Stillwater River at Olney	10	146	40
12364000	Logan Creek at Tally Lake, near Whitefish	10	183	28
12365000	Stillwater River near Whitefish	37	524	31
12366000	Whitefish River near Kalispell	38	170	37
12369200	Swan River near Condon	16	73.3	54
12369250	Holland Creek near Condon	15	22.3	44
12370000	Swan River near Bigfork	67	671	23
12370500	Dayton Creek near Proctor	29	20.9	20
12370900	Teepee Creek near Polson	20	2.55	51
12371100	Hell Roaring Creek near Polson	26	6.22	48
12374300	Mill Creek near Niarada	15	28.2	27
12375700	Garden Creek near Hot Springs	15	3.29	19
12378000	Mission Creek near St. Ignatius	11	74.8	48
12389150	McGregor Creek tributary near Marion	11	2.55	30
12389500	Thompson River near Thompson Falls	33	642	41
12390700	Prospect Creek at Thompson Falls	32	182	54
12391100	White Pine Creek near Trout Creek	11	8.75	58
12391200	Canyon Creek near Trout Creek	16	8.64	62
12391430	Skeleton Creek near Noxon	12	2.10	59
12391525	Snake Creek near Noxon	13	3.11	57
12391550	Bull River near Noxon	10	139	65
12411000	Coeur D'Alene River above Shoshone Creek, near Prichard, Idaho	38	335	52
12413100	Boulder Creek at Mullan, Idaho	19	3.13	55
12413200	Montgomery Creek near Kellogg, Idaho	10	4.53	40
13336850	Weir Creek near Powell Ranger Station, Idaho	10	12.2	48
	NORTHWEST REGION			
05010000	Belly River at international boundary	17	74.8	79
05011000	Belly River near Mountain View, Alberta	68	121	65
05012500	Boundary Creek at international boundary	17	21	75
05013000	Waterton River near Waterton Park, Alberta	55	238	68
05014000	Grinnell Creek near Many Glacier	29	3.47	95
05014500	Swiftcurrent Creek at Many Glacier	71	31.4	95
05015000	Canyon Creek near Many Glacier	13	7.09	105
06073000	Dearborn River near Clemons	28	123	37
06078500	North Fork Sun River near Augusta	25	258	42
06079600	Beaver Creek at Gibson Dam, near Augusta	15	20.3	29
06080000	Sun River near Augusta	27	609	42
06084500	Elk Creek at Augusta	20	157	21
06092000	Two Medicine River near Browning	43	317	36
06092500	Badger Creek near Browning	23	133	39
06097100	Blacktail Creek near Heart Butte	14	16.4	25

Discharge, in cubic feet per second, for indicated recurrence interval, in years

2	5	10	25	50	100	500	Maximum of record
11	26	40	60	78	96	146	56
530	783	958	1,190	1,360	1,540	1,970	1,280
1,120	1,450	1,640	1,850	1,990	2,120	2,390	1,700
28	61	89	130	166	205	308	170
68	118	154	200	234	269	348	230
40	60	73	89	101	112	136	112
4,180	6,590	8,460	11,100	13,300	15,700	22,200	29,000
184	239	268	299	319	335	367	295
1,000	1,450	1,780	2,200	2,450	2,700	3,300	2,130
15	25	31	40	47	54	71	40
661	991	1,220	1,530	1,770	2,020	2,620	1,740
468	879	1,190	1,620	1,960	2,310	3,170	1,380
1,510	2,350	2,900	3,570	4,050	4,510	5,520	4,330
803	1,050	1,200	1,390	1,530	1,660	1,960	1,580
862	1,080	1,220	1,390	1,510	1,620	1,890	1,540
263	323	357	395	420	443	489	385
5,180	6,380	7,100	7,960	8,560	9,130	10,400	8,890
36	64	84	114	137	162	225	131
11	21	31	48	64	84	145	66
30	62	88	127	159	194	286	160
93	167	219	287	338	388	503	250
26	49	67	91	110	130	180	100
408	665	929	1,420	1,930	2,610	5,180	1,700
16	30	41	58	73	89	134	80
2,450	3,650	4,460	5,490	6,260	7,020	8,800	6,190
1,640	2,310	2,770	3,380	3,840	4,310	5,470	5,490
219	344	434	554	648	745	986	781
140	195	229	268	294	319	373	250
24	34	40	47	52	57	67	46
45	83	112	150	181	212	287	126
2,130	2,910	3,410	4,020	4,460	4,890	5,870	3,890
5,870	8,660	10,700	13,600	15,900	18,400	24,800	22,000
100	143	173	215	247	281	350	220
72	121	160	218	268	324	449	155
264	415	526	677	795	922	1,230	500
1,550	1,900	2,210	3,050	5,600	12,000	28,000	12,000
1,950	2,680	3,210	4,800	9,200	16,700	33,000	16,400
540	680	790	1,000	1,500	2,600	5,100	5,930
4,600	5,850	7,000	9,000	15,000	25,700	48,000	25,700
177	256	320	419	506	605	898	540
1,010	1,310	1,510	1,900	3,300	6,700	14,000	6,700
195	310	400	620	1,000	1,800	3,500	720
1,140	2,000	2,750	4,300	6,200	10,500	21,000	17,400
3,100	4,000	4,650	6,200	10,500	17,500	33,000	51,100
119	276	450	800	1,350	2,500	5,300	4,360
6,400	9,600	12,000	17,100	24,500	38,000	66,500	59,700
868	2,080	3,240	5,180	6,980	9,100	15,500	12,000
3,600	5,200	6,700	9,900	15,500	29,000	60,000	100,000
1,600	2,400	3,000	4,300	7,100	13,000	26,500	49,700
131	383	709	1,420	2,280	3,540	6,500	1,390

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean annual precipitation (P) (inches)
	NORTHWEST REGION--Continued			
06098000	Dupuyer Creek near Valier	23	137	25
06132200	South Fork Milk River near Babb	28	68.6	36
12335000	Blackfoot River near Helmville	16	481	15
12355000	Flathead River at Flathead, British Columbia	60	450	55
12355500	North Fork Flathead River near Columbia Falls	67	1,548	26
12356000	Skyland Creek near Essex	25	8.37	47
12356500	Bear Creek near Essex	22	20.7	47
12357000	Middle Fork Flathead River at Essex	24	510	52
12357300	Moccasin Creek near West Glacier	17	2.38	57
12358500	Middle Fork Flathead River near West Glacier	49	1,128	59
12359000	South Fork Flathead River at Spotted Bear Ranger Station, near Hungry Horse	18	958	52
12359500	Spotted Bear River near Hungry Horse	10	184	56
12359800	South Fork Flathead River above Twin Creek, near Hungry Horse	24	1,160	52
12360000	Twin Creek near Hungry Horse	13	47.0	53
12361000	Sullivan Creek near Hungry Horse	26	71.3	35
12361500	Graves Creek near Hungry Horse	13	27.0	67

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
490	1,340	2,450	5,100	8,700	14,000	26,000	21,600
380	790	1,200	2,100	3,400	6,200	12,500	12,000
2,100	3,670	4,900	6,640	8,070	9,620	13,700	9,500
7,330	9,870	11,500	13,400	14,900	16,200	19,400	16,300
20,600	26,300	30,000	35,200	39,500	44,500	51,800	69,100
160	225	275	380	620	1,100	3,800	3,820
410	620	800	1,040	1,560	2,350	4,500	8,380
9,800	14,000	17,000	22,000	27,000	34,500	52,000	75,300
130	235	335	515	820	1,400	2,600	490
19,400	28,400	36,000	47,900	58,600	71,200	109,000	140,000
15,600	20,600	24,200	29,200	33,300	37,700	49,300	36,700
3,700	4,450	4,900	5,500	6,000	6,900	9,000	20,200
19,200	26,700	32,100	39,400	45,300	51,500	67,400	50,900
1,400	1,950	2,310	2,890	3,050	4,100	6,500	5,830
1,860	2,430	2,800	3,210	3,600	4,100	5,000	5,020
1,230	1,840	2,340	3,120	3,800	4,590	6,910	3,780

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Basin above 6,000 feet elevation (HE) (percent)
	SOUTHWEST REGION			
06011000	Red Rock River at Kennedy Ranch, near Lakeview	28	323	100
06011400	Long Creek near Lakeview	10	33.9	100
06013200	Traux Creek near Lima	15	4.06	100
06013400	Muddy Creek near Lima	15	62.7	99
06013500	Big Sheep Creek below Muddy Creek, near Dell	37	280	99
06015430	Clark Canyon near Dillon	16	18.0	90
06015500	Grasshopper Creek near Dillon	39	348	94
06017500	Blacktail Deer Creek near Dillon	20	312	96
06019400	Sweetwater Creek near Alder	15	81.5	100
06019500	Ruby River above reservoir, near Alder	50	538	91
06019800	Idaho Creek near Alder	26	11.0	83
06024500	Trail Creek near Wisdom	12	71.4	100
06024590	Wise River near Wise River	13	214	100
06025100	Quartz Hill Gulch near Wise River	15	14.3	95
06025300	Moose Creek near Divide	15	41.4	97
06025500	Big Hole River near Melrose	64	2,476	91
06027700	Fish Creek near Silver Star	30	39.5	80
06029000	Whitetail Creek near Whitehall	18	30.8	97
06030300	Jefferson River tributary No. 2 near Whitehall	31	4.50	31
06030500	Boulder River above Rock Creek, near Basin	11	23.9	100
06031950	Cataract Creek near Basin	16	30.6	94
06033000	Boulder River near Boulder	48	381	80
06034700	Sand Creek at Sappington	15	9.41	0
06035000	Willow Creek near Harrison	51	83.8	71
06036600	Jefferson River tributary No. 4 near Three Forks	16	.53	0
06037500	Madison River near West Yellowstone	62	420	99
06038550	Cabin Creek near West Yellowstone	15	30.3	100
06040300	Jack Creek near Ennis	13	51.5	94
06055500	Crow Creek near Radersburg	19	78.0	86
06056200	Castle Creek tributary near Bozeman	16	2.59	80
06056300	Cabin Creek near Townsend	29	12.6	44
06056600	Deep Creek below North Fork Deep Creek, near Townsend	16	87.7	61
06058700	Mitchell Gulch near East Helena	30	8.09	12
06061500	Prickly Pear Creek near Clancy	49	192	34
06061700	Jackson Creek near East Helena	15	3.44	59
06061800	Crystal Creek near East Helena	15	3.77	39
06061900	McClellan Creek near East Helena	16	33.2	47
06062500	Tenmile Creek near Rimini	74	32.7	86
06062700	Little Porcupine Creek tributary near Helena	15	.48	77
06063000	Tenmile Creek near Helena	46	102	40
06068500	Little Prickly Pear Creek near Marysville	20	44.4	55
06071200	Lyons Creek near Wolf Creek	16	29.4	13
06071400	Dog Creek near Craig	16	15.9	0
06071600	Wegner Creek at Craig	29	35.0	3
12323300	Smith Gulch near Silver Bow	30	4.85	55
12323500	German Gulch Creek near Ramsay	15	40.6	88
12324100	Racetrack Creek below Granite Creek, near Anaconda	17	39.5	93
12324200	Clark Fork at Deer Lodge	10	1,005	62
12324250	Cottonwood Creek at Deer Lodge	14	45.4	69
12324590	Little Blackfoot River near Garrison	16	398	50
12324700	Clark Fork tributary near Drummond	31	4.61	6
12331600	Clark Fork at Drummond	12	2,378	51
12331700	Edwards Gulch at Drummond	18	4.69	13
12335500	Nevada Creek above reservoir, near Finn	49	116	36
13038900	Targhee Creek near Macks Inn, Idaho	18	20.8	100

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
723	934	1,050	1,180	1,260	1,330	1,480	1,030
132	256	379	597	816	1,100	2,000	1,850
5	24	52	108	166	238	460	40
62	109	142	184	214	244	309	197
346	528	647	794	901	1,000	1,240	1,400
57	115	162	230	286	346	498	415
399	682	878	1,130	1,310	1,490	1,890	1,870
175	310	430	570	690	820	1,100	910
69	169	260	400	521	654	1,010	330
980	1,100	1,400	1,800	2,500	3,200	5,100	3,810
25	44	58	77	91	106	142	90
867	1,030	1,110	1,210	1,270	1,330	1,440	1,350
1,690	2,180	2,450	2,740	2,940	3,110	3,460	2,730
6	17	32	111	111	180	521	102
103	143	168	195	214	232	269	180
7,300	10,400	12,200	14,200	15,500	16,800	19,300	23,000
128	179	211	249	276	302	360	250
68	99	119	144	163	181	223	142
7	31	65	141	232	359	861	169
180	337	468	666	838	1,030	1,570	1,020
272	490	670	939	1,170	1,430	2,160	3,150
1,090	1,810	2,380	3,230	3,940	4,740	6,960	7,000
20	137	356	959	1,790	3,090	9,080	2,130
226	347	434	550	642	737	975	813
2	8	17	36	60	97	259	320
1,350	1,650	1,820	2,010	2,140	2,260	2,500	2,340
418	606	729	881	992	1,100	1,350	1,500
331	436	501	577	631	683	797	555
537	848	1,110	1,500	1,850	2,260	3,440	3,640
20	31	40	52	63	74	106	47
12	30	49	86	124	173	345	70
222	347	445	588	708	841	1,210	740
34	76	118	190	240	310	550	195
266	480	715	1,070	1,400	1,800	3,200	2,300
13	25	36	55	74	96	172	111
11	27	45	77	112	158	325	80
154	319	486	786	1,090	1,480	2,850	1,730
210	420	610	1,000	1,360	1,860	3,650	3,290
2	6	9	15	22	30	61	20
255	520	835	1,360	1,820	2,440	4,000	3,770
141	255	354	510	650	813	1,300	454
93	229	381	677	1,000	1,440	3,090	580
58	205	428	989	1,750	2,990	9,420	1,160
97	254	445	846	1,310	1,990	4,820	1,020
19	44	68	106	140	179	289	123
186	285	357	454	531	612	815	692
367	485	554	632	685	733	835	580
3,800	5,320	6,340	7,600	8,470	9,410	11,600	2,500
244	606	936	1,440	1,880	2,360	3,620	1,820
1,190	2,290	3,170	4,430	5,470	6,580	9,470	8,650
42	107	166	253	326	404	598	280
3,830	7,550	10,500	14,600	17,900	21,300	29,900	15,800
13	47	91	181	282	418	919	318
506	962	1,330	1,850	2,280	2,740	3,930	1,800
2,270	341	379	423	452	479	594	458

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Basin above 6,000 feet elevation (HE) (percent)
	SOUTHWEST REGION--Continued			
13108500	Camas Creek at Eightmile Shearing Corral, Idaho	22	210	100
13113000	Beaver Creek at Spencer, Idaho	30	120	100
13117200	Main Fork near Goldburg, Idaho	10	15.6	100
13117300	Sawmill Creek near Goldburg, Idaho	13	74.3	100
13305700	Dahlonega Creek at Gibbonville, Idaho	10	32.0	100
13305800	Hughes Creek near North Fork, Idaho	19	15.7	100

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
870	1,330	1,640	2,020	2,310	2,590	4,880	2,590
323	525	689	933	1,140	1,380	2,060	1,190
134	197	238	288	324	358	478	273
364	538	650	788	888	985	1,170	651
98	164	211	272	319	366	692	235
138	208	256	320	368	417	535	250

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)	Drainage-basin characteristic: Basin above 6,000 feet elevation (HE) (percent)
	UPPER YELLOWSTONE-CENTRAL MOUNTAIN REGION				
06043000	Taylor Creek near Grayling	11	98.0	8,320	99
06043200	Squaw Creek near Gallatin Gateway	17	40.4	7,440	98
06043300	Logger Creek near Gallatin Gateway	29	2.48	7,120	87
06043500	Gallatin River near Gallatin Gateway	60	825	7,960	95
06046500	Rocky Creek near Bozeman	32	49.0	6,110	55
06046700	Pitcher Creek near Bozeman	16	2.33	5,680	15
06047000	Bear Canyon near Bozeman	18	17.0	6,690	92
06048000	East Gallatin River at Bozeman	22	148	6,210	51
06048500	Bridger Creek near Bozeman	27	62.5	6,540	62
06050000	Hyalite Creek at Hyalite Ranger Station, near Bozeman	57	48.2	7,710	97
06052500	Gallatin River at Logan	69	1,795	6,820	64
06053050	Lost Creek near Ringling	15	9.59	5,750	19
06074500	Smith River near White Sulphur Springs	12	30.7	6,770	81
06075600	Fivemile Creek near White Sulphur Springs	15	6.00	5,980	45
06076000	Newland Creek near White Sulphur Springs	22	6.74	6,380	81
06076700	Sheep Creek near Neihart	29	5.22	7,210	99
06076800	Nugget Creek near Neihart	15	1.48	7,190	99
06077000	Sheep Creek near White Sulphur Springs	33	54.4	6,910	94
06115500	North Fork Musselshell River near Delpine	39	31.4	6,120	77
06117000	Checkerboard Creek at Delpine	10	23.9	6,340	77
06117800	Big Coulee near Martinsdale	16	2.86	5,230	0
06118500	South Fork Musselshell River above Martinsdale	38	287	6,110	60
06120500	Musselshell River at Harlowton	80	1,125	5,650	39
06120700	Antelope Creek tributary near mouth, near Harlowton	18	1.9	5,200	0
06120800	Alkali Creek near Harlowton	33	21.2	4,570	0
06120900	Antelope Creek at Harlowton	23	88.7	4,930	8
06122000	American Fork below Lebo Creek, near Harlowton	21	166	5,480	25
06123200	Sadie Creek near Harlowton	17	2.07	5,090	0
06187500	Tower Creek at Tower Falls, Yellowstone National Park, Wyo.	21	50.4	8,340	99
06188000	Lamar River near Tower Falls Ranger Station, Yellowstone National Park, Wyo.	49	660	7,400	91
06191000	Gardner River near Mammoth, Yellowstone National Park	39	202	7,940	98
06193000	Shields River near Wilsall	22	87.8	7,040	97
06193500	Shields River at Clyde Park	41	543	6,090	44
06194000	Brackett Creek near Clyde Park	27	57.9	6,140	60
06197000	Big Timber Creek near Big Timber	12	74.9	6,680	59
06197500	Boulder River near Contact	34	226	8,510	91
06200000	Boulder River at Big Timber	41	523	7,570	75
06200500	Sweet Grass Creek above Melville	44	63.8	7,630	75
06201000	Sweet Grass Creek below Melville	30	143	6,110	33
06201550	Yellowstone River tributary near Greycliff	15	2.72	4,290	0
06201600	Bridger Creek near Greycliff	16	61.5	5,320	12
06201650	Work Creek near Reed Point	15	32.5	4,630	0
06201700	Hump Creek near Reed Point	29	7.61	4,420	0
06201750	Berry Creek near Columbus	16	23.5	4,270	0
06204050	West Rosebud Creek near Roscoe	23	52.1	9,560	100
06204500	Rosebud Creek near Absarokee	35	394	7,890	66
06205000	Stillwater River near Absarokee	58	975	7,220	53
06205100	Allen Creek near Park City	28	7.17	3,960	0
06206500	Sunlight Creek near Painter, Wyo.	29	135	8,500	100
06207500	Clarks Fork Yellowstone River near Belfry	67	1,154	7,430	80

Discharge, in cubic feet per second, for indicated recurrence interval, in years

2	5	10	25	50	100	500	Maximum of record
784	928	1,010	1,090	1,150	1,200	1,300	1,020
265	396	492	621	723	830	1,100	690
16	27	36	50	62	74	109	92
5,020	6,610	7,620	8,870	9,780	10,700	12,700	9,690
398	609	769	995	1,180	1,380	1,910	1,230
16	34	52	86	119	162	310	142
153	250	324	428	513	604	843	489
553	876	1,130	1,500	1,800	2,140	3,080	2,460
300	497	656	892	1,090	1,320	1,950	1,140
395	555	670	823	945	1,070	1,390	956
4,870	6,590	7,700	9,080	10,100	11,100	13,400	9,840
60	135	210	330	420	540	800	297
115	260	416	712	1,030	1,450	3,050	770
13	24	35	52	69	89	155	52
12	26	39	64	88	120	229	56
56	87	111	144	172	203	284	138
8	15	22	32	41	53	89	37
208	305	378	482	568	661	913	460
85	158	221	319	406	506	798	423
47	102	157	256	355	480	906	167
76	205	360	640	860	1,200	2,000	260
746	1,340	1,900	2,830	3,720	4,830	8,450	5,240
1,010	2,040	2,930	4,270	5,440	6,740	10,300	7,270
36	128	240	462	696	1,000	2,040	307
94	454	1,050	2,630	4,790	8,260	25,400	5,390
135	750	1,950	5,200	8,800	16,000	35,000	24,400
342	682	974	1,420	1,810	2,260	3,500	2,050
5	28	73	208	415	776	2,830	204
320	470	565	680	761	839	1,010	642
8,490	10,500	11,700	12,900	13,800	14,600	16,200	13,600
1,230	1,570	1,770	2,000	2,160	2,320	2,640	2,080
545	847	1,090	1,440	1,730	2,060	2,980	1,770
1,060	1,750	2,320	3,190	3,950	4,810	7,320	4,500
205	386	556	840	1,110	1,440	2,520	1,400
670	1,210	1,700	2,510	3,260	4,180	7,090	5,870
3,720	4,560	5,110	5,820	6,360	6,900	8,230	6,800
5,740	7,080	7,960	9,070	9,890	10,700	12,700	9,840
929	1,340	1,660	2,120	2,500	2,910	4,040	3,510
937	1,540	2,030	2,770	3,410	4,150	6,250	3,000
8	25	46	89	138	207	479	55
138	560	1,210	2,830	4,960	8,330	24,500	2,680
85	377	815	1,850	3,120	5,000	12,900	3,200
22	104	234	560	986	1,640	4,630	307
18	100	270	700	1,350	2,400	5,500	2,000
684	1,130	1,470	1,930	2,300	2,690	3,690	1,630
2,300	3,240	3,910	4,810	5,520	6,260	8,140	5,790
6,510	8,330	9,500	11,000	12,000	13,100	15,600	12,000
65	239	473	980	1,570	2,410	5,710	1,580
1,180	1,480	1,680	1,920	2,100	2,280	2,700	4,000
7,620	9,330	10,400	11,600	12,400	13,300	15,100	14,800

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)	Drainage-basin characteristic: Basin above 6,000 feet elevation (HE) (percent)
	UPPER YELLOWSTONE-CENTRAL MOUNTAIN REGION--Continued				
06207600	Jack Creek tributary near Belfry	14	.85	4,380	0
06207800	Bluewater Creek near Bridger	11	28.1	4,860	0
06208500	Clarks Fork Yellowstone River at Edgar	66	2,032	6,130	45
06209500	Rock Creek near Red Lodge	52	124	9,540	99
06210000	West Fork Rock Creek below Basin Creek, near Red Lodge	19	63.1	9,050	100
06211000	Red Lodge Creek above Cooney Reservoir, near Boyd	52	143	5,710	24
06211500	Willow Creek near Boyd	51	53.3	4,730	8
06214150	Mills Creek at Rapelje	15	3.32	4,120	0
06215000	Pryor Creek above Pryor	12	39.6	6,000	48
06216000	Pryor Creek at Pryor	24	117	5,280	41
06216200	West Wets Creek near Billings	34	8.80	3,980	0
06216300	West Buckeye Creek near Billings	20	2.64	3,780	0
06216500	Pryor Creek near Billings	48	440	4,550	12
06287500	Soap Creek near St. Xavier	20	98.3	4,240	5
06288000	Rotten Grass Creek near St. Xavier	10	147	4,390	11
06288200	Beauvais Creek near St. Xavier	11	100	4,210	0
06289000	Little Bighorn River at State line, near Wyola	50	193	7,830	93
06290000	Pass Creek near Wyola	27	111	5,570	15
06290200	Little Bighorn River tributary near Wyola	15	4.43	4,060	0
06290500	Little Bighorn River below Pass Creek, near Wyola	48	428	6,140	47
06291000	Owl Creek near Lodge Grass	15	161	4,280	0
06291500	Lodge Grass Creek above Willow Creek Diversion, near Wyola	42	80.7	6,360	52
06293300	Long Otter Creek near Lodgegrass	16	11.7	3,490	0
06294000	Little Bighorn River near Hardin	36	1,294	4,770	20
06294400	Andresen Coulee near Custer	26	2.35	2,850	0
06298000	Tongue River near Dayton, Wyo.	59	204	8,330	92
06298500	Little Tongue River near Dayton, Wyo.	23	25.1	7,560	82
06299500	Wolf Creek at Wolf, Wyo.	45	37.8	7,700	90
06300500	East Fork Big Goose Creek near Big Horn, Wyo.	34	20.1	9,560	100

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
18	43	67	106	141	182	302	90
98	259	454	860	1,330	2,000	4,810	2,650
7,450	9,080	10,100	11,200	12,100	12,900	14,700	10,900
1,220	1,690	2,000	2,390	2,680	2,970	3,640	3,110
510	671	775	904	999	1,090	1,310	933
587	1,190	1,730	2,580	3,350	4,230	6,800	2,260
263	579	899	1,470	2,050	2,780	5,300	1,720
7	20	36	68	105	156	364	77
131	275	415	658	895	1,190	2,160	575
174	371	576	953	1,350	1,860	3,730	2,280
88	203	314	504	684	902	1,580	565
79	196	324	567	824	1,160	2,390	924
653	1,280	1,870	2,880	3,850	5,040	8,920	14,900
404	921	1,480	2,560	3,710	5,250	11,100	7,810
410	757	1,060	1,560	2,000	2,530	4,140	9,740
566	1,160	1,710	2,630	3,500	4,550	7,850	7,350
1,050	1,490	1,800	2,210	2,530	2,860	3,690	2,730
295	602	905	1,430	1,960	2,630	4,890	5,560
29	84	155	270	390	560	1,000	226
1,250	2,010	2,640	3,610	4,470	5,450	8,350	8,010
249	481	682	995	1,270	1,590	2,510	1,020
432	643	792	991	1,150	1,310	1,700	1,130
26	94	182	365	571	852	1,900	298
1,850	3,290	4,500	6,340	7,960	9,790	15,100	22,600
6	14	22	35	46	59	95	40
1,660	2,260	2,630	3,070	3,390	3,690	4,350	3,400
123	228	316	448	564	693	1,060	850
294	467	604	807	980	1,170	1,720	1,130
519	705	839	1,020	1,160	1,320	1,710	1,230

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)
	NORTHWEST FOOTHILLS REGION			
06073600	Black Rock Creek near Augusta	15	5.54	4,380
06087900	Muddy Creek tributary near Power	17	3.15	3,840
06088500	Muddy Creek at Vaughn	53	391	3,840
06089300	Sun River tributary near Great Falls	20	21.1	3,510
06090810	Ninemile Coulee near Fort Benton	16	16.9	3,460
06098700	Powell Coulee near Browning	15	12.7	4,380
06099000	Cut Bank Creek at Cut Bank	47	1,065	4,460
06099700	Middle Fork Dry Fork Marias River near Dupuyer	15	20.2	4,590
06100200	Heines Coulee tributary near Valier	17	.60	3,910
06100300	Lone Man Coulee near Valier	29	14.1	3,890
06101520	Favot Coulee tributary near Ledger	15	.86	3,570
06101600	Marias River tributary No. 3 near Chester	16	.26	2,990
06101700	Fey Coulee tributary near Chester	26	2.47	3,260
06101800	Sixmile Coulee near Chester	17	24.6	3,110
06101900	Dead Indian Coulee near Fort Benton	16	2.85	3,340
06102100	Dry Fork Coulee tributary near Loma	15	.84	2,770
06102200	Marias River tributary at Loma	17	1.62	2,830
06102300	Marias River tributary No. 2 at Loma	17	.25	2,750
06105800	Bruce Coulee tributary near Choteau	26	1.70	4,170
06108000	Teton River near Dutton	33	1,307	4,470
06108200	Kinley Coulee near Dutton	16	9.67	3,700
06108300	Kinley Coulee tributary near Dutton	15	2.65	3,760
06132400	Dry Fork Milk River near Babb	27	17.4	5,130
06133000	Milk River at western crossing of international boundary, Alberta	57	397	4,870
06133500	North Fork Milk River above St. Mary Canal, near Browning	49	61.8	4,850
06134800	Van Cleeve Coulee tributary near Sunburst	26	10.8	3,600
	NORTHEAST PLAINS REGION			
06077300	Trout Creek near Eden	11	13.2	5,410
06077500	Smith River near Eden	20	1,594	5,840
06077700	Smith River tributary near Eden	15	1.44	3,840
06077800	Goodman Coulee near Eden	24	21.8	4,020
06090500	Belt Creek near Monarch	31	368	6,190
06090550	Little Otter Creek near Raynesford	15	39.5	5,210
06109530	Little Sandy Creek tributary near Big Sandy	16	.80	3,530
06109560	Alkali Coulee tributary near Big Sandy	15	.96	2,940
06109800	South Fork Judith River near Utica	21	58.7	6,640
06109900	Judith River tributary near Utica	15	7.15	5,420
06110000	Judith River near Utica	55	328	6,540
06111000	Ross Fork Creek near Hobson	15	337	4,640
06111700	Mill Creek near Lewistown	29	3.14	4,630
06112100	Cottonwood Creek near Moore	18	47.9	5,840
06112800	Bull Creek tributary near Hilger	15	.99	4,150
06114500	Wolf Creek near Stanford	11	112	6,190
06114550	Wolf Creek tributary near Coffee Creek	15	1.73	4,020
06114900	Taffy Creek tributary near Winifred	15	2.95	3,290
06115300	Duval Creek near Landusky	26	3.31	3,110
06124600	East Fork Roberts Creek tributary near Judith Gap	15	.74	4,850
06128400	South Fork Bear Creek near Roy	15	39.6	3,570
06128500	South Fork Bear Creek tributary near Roy	27	5.40	3,430
06129100	North Fork McDonald Creek tributary near Heath	16	2.24	4,750
06129200	Alkali Creek near Heath	15	3.76	4,570
06129400	South Fork McDonald Creek tributary near Grassrange	15	.51	3,850

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
190	355	490	690	840	1,010	1,320	550
126	305	484	792	1,090	1,450	2,580	620
645	1,250	1,900	3,130	4,470	6,280	13,300	7,600
74	274	542	1,120	1,780	2,710	6,300	690
91	383	836	1,960	3,450	5,780	16,800	2,110
22	123	293	713	1,240	2,020	5,230	370
1,630	3,320	5,060	8,250	11,600	15,900	31,800	16,600
72	261	552	1,300	2,340	4,050	13,200	4,240
7	29	64	163	310	568	2,090	249
69	399	956	2,350	4,140	6,790	18,000	5,440
14	56	109	210	312	438	829	92
8	19	28	43	57	73	119	38
27	135	289	614	969	1,430	2,990	675
18	100	235	564	972	1,570	3,950	1,000
9	75	216	619	1,180	2,060	5,920	403
19	64	118	225	338	483	978	244
17	55	102	199	306	451	998	300
4	11	21	39	59	86	183	42
56	144	240	424	617	872	1,790	390
946	2,860	5,440	11,300	18,700	29,900	81,800	71,300
66	170	340	700	1,500	3,000	8,000	2,070
50	96	170	350	580	1,050	2,700	465
175	670	1,380	3,000	4,300	6,600	14,000	2,640
957	2,270	3,570	5,840	8,040	10,700	19,300	7,930
256	706	1,240	2,310	3,490	5,120	11,400	3,090
28	79	133	229	321	433	779	239
41	115	214	442	732	1,180	3,340	430
1,900	3,520	5,110	7,900	10,700	14,300	26,900	12,300
3	11	25	64	124	233	910	80
86	219	379	714	1,110	1,670	4,060	1,340
1,610	3,020	4,370	6,710	9,000	11,900	21,600	11,000
25	80	151	305	487	749	1,840	245
4	8	13	26	43	71	225	47
8	25	44	81	121	173	361	112
268	634	1,030	1,790	2,600	3,680	7,680	1,950
14	56	111	227	358	535	1,190	125
482	805	1,020	1,300	1,500	1,690	2,120	1,750
393	1,130	1,810	2,820	3,650	4,510	6,580	2,640
12	32	53	89	124	167	298	87
370	868	1,340	2,100	2,800	3,610	5,980	1,740
12	32	51	83	111	144	236	78
17	56	113	251	437	736	2,270	990
14	48	118	371	872	2,030	14,000	780
43	103	158	245	321	407	641	180
58	177	307	540	767	1,040	1,910	640
22	50	77	122	163	211	353	82
252	672	1,110	1,900	2,670	3,630	6,690	2,200
53	112	157	220	268	317	432	190
12	27	40	60	76	94	140	60
26	103	208	433	690	1,040	2,360	757
14	36	57	92	123	160	264	141

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)
	NORTHEAST PLAINS REGION--Continued			
06129500	McDonald Creek at Winnett	36	421	4,140
06135500	Sage Creek at Q Ranch, near Wild Horse, Alberta	43	175	3,200
06137570	Boxelder Creek near Rocky Boy	13	48.2	4,070
06137600	Sage Creek tributary No. 2 near Joplin	15	2.21	3,220
06137900	England Coulee at Hingham	15	.93	3,090
06138700	South Fork Spring Coulee near Havre	29	6.47	3,100
06138800	Spring Coulee near Havre	15	17.8	3,090
06139500	Big Sandy Creek near Havre	27	1,805	3,200
06140400	Bullhook Creek near Havre	16	39.6	3,220
06141900	Milk River tributary near Lohman	15	.11	2,500
06144350	Middle Creek near Saskatchewan Boundary, Alberta	25	116	3,970
06145000	McRae Creek at international boundary, Saskatchewan	22	59.0	2,900
06148000	Battle Creek above Cypress Lake west inflow canal, near West Plains, Saskatchewan	28	270	4,070
06150000	Woodpile Coulee near international boundary	45	60.2	2,950
06150500	East Fork Battle Creek near international boundary	44	89.5	3,000
06151000	Lyons Creek at international boundary, Saskatchewan	54	66.7	3,000
06153400	Fifteenmile Creek tributary near Zurich	15	1.40	3,670
06154350	Peoples Creek tributary near Lloyd	14	2.51	4,620
06154400	Peoples Creek near Hays	22	220	3,570
06154410	Little Peoples Creek near Hays	16	13.0	4,640
06154500	Peoples Creek near Dodson	28	670	3,500
06155100	Black Coulee near Malta	12	7.03	2,550
06155200	Alkali Creek near Malta	17	162	2,470
06155300	Disjardin Coulee near Malta	33	4.84	2,470
06155400	South Fork Taylor Coulee near Malta	19	3.89	2,530
06155600	Murphy Coulee tributary near Hogeland	15	2.62	3,330
06156000	Whitewater Creek near international boundary	52	458	2,820
06156100	Lush Coulee near Whitewater	16	8.58	2,670
06164600	Beaver Creek tributary near Zortman	15	3.89	3,260
06164800	Beaver Creek above Dix Creek, near Malta	12	929	2,730
06165200	Guston Coulee near Malta	15	2.06	2,500
06168500	Rock Creek at international boundary	35	241	2,910
06169000	Horse Creek at international boundary	46	73.5	2,810
06169500	Rock Creek below Horse Creek, near international boundary	41	328	2,870
06170000	McEachern Creek at international boundary	53	182	2,830
06170200	Willow Creek near Hinsdale	10	283	2,710
06174600	Snow Coulee at Opheim	16	3.11	3,250
06178000	Poplar River at international boundary	56	362	2,950
06178500	East Poplar River at international boundary, Saskatchewan	55	534	2,800
06179100	Butte Creek tributary near Four Buttes	16	1.60	2,610
06179500	West Fork Poplar River at international boundary, Saskatchewan	20	139	3,000
06180000	West Fork Poplar River near Richland	15	428	2,900
06181995	Beaver Creek at international boundary, Saskatchewan	11	180	2,450
06182500	Big Muddy Creek at Daleview	25	279	2,510
06182700	Middle Fork Big Muddy Creek near Flaxville	11	3.12	2,730
06183100	Box Elder Creek near Plentywood	19	9.40	2,380
06183300	Marron Creek tributary near Plentywood	34	7.05	2,440
06183400	Spring Creek at Highway 16, near Plentywood	19	16.9	2,330
06183450	Big Muddy Creek near Antelope	10	967	2,380
06184200	Lost Creek tributary near Homestead	16	1.90	2,060
06329700	Painted Woods Creek tributary near Williston, N. Dak.	19	.37	2,150
06329800	Painted Woods Creek near Williston, N. Dak.	19	17.0	2,300
06329900	Painted Woods Creek tributary No. 2 near Williston, N. Dak.	19	8.30	2,300
06330100	Sand Creek near Williston, N. Dak.	19	38.0	2,150
06331900	White Earth River tributary near Tioga, N. Dak.	14	9.60	2,400

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
343	726	1,040	1,470	1,820	2,190	3,080	1,590
517	1,170	1,690	2,420	2,980	3,540	4,840	2,950
83	227	385	675	967	1,340	2,570	898
5	24	53	111	172	248	486	67
12	53	104	199	290	398	705	299
16	59	109	201	292	400	724	190
30	178	394	838	1,300	1,870	3,600	345
412	1,820	3,470	6,330	8,890	11,700	26,000	6,000
113	320	516	820	1,080	1,360	2,070	700
1	8	20	49	84	133	311	72
230	854	1,490	2,460	3,250	4,060	5,890	4,980
274	646	933	1,310	1,580	1,840	2,390	1,160
557	1,110	1,550	2,160	2,650	3,170	4,440	3,020
369	1,210	2,060	3,410	4,560	5,790	8,870	7,280
334	904	1,430	2,240	2,910	3,640	5,480	2,780
177	539	873	1,360	1,750	2,140	3,040	1,400
18	76	165	400	580	930	1,900	1,250
7	18	27	39	49	60	84	34
220	1,020	2,170	4,670	7,520	11,400	25,500	8,460
43	131	232	417	604	838	1,600	576
805	2,190	3,510	5,600	7,410	9,420	14,800	7,590
75	179	291	499	716	999	2,010	2,350
156	756	1,660	3,730	6,190	9,680	23,200	22,900
25	68	123	246	398	630	1,700	360
10	59	132	279	430	613	1,140	220
38	142	273	538	825	1,200	2,530	403
177	948	2,030	4,210	6,460	9,240	17,600	3,500
31	87	148	256	362	491	897	335
70	185	297	478	638	820	1,320	280
1,400	4,000	7,100	14,000	18,000	25,000	43,000	26,500
2	10	22	48	81	129	330	43
569	1,330	1,980	2,890	3,630	4,390	6,240	3,310
299	731	1,090	1,610	2,020	2,440	3,420	1,800
950	2,240	3,270	4,640	5,670	6,680	8,880	5,110
695	1,970	3,050	4,520	5,620	6,680	8,920	7,080
1,840	4,150	6,280	9,670	12,700	16,200	26,300	14,600
30	98	169	285	388	503	807	245
734	2,110	3,640	6,520	9,480	13,300	26,100	12,700
428	1,590	2,840	4,880	6,650	8,570	13,400	4,020
19	90	195	426	694	1,060	2,430	609
218	959	1,950	3,950	6,070	8,790	17,700	5,450
589	1,490	2,320	3,610	4,710	5,930	9,150	3,600
540	1,040	1,400	1,890	2,250	2,620	3,460	1,680
1,030	2,500	3,780	5,650	7,190	8,820	12,900	6,360
36	111	186	308	416	537	856	200
93	191	266	369	447	527	714	328
29	81	136	234	329	445	810	524
83	365	740	1,500	2,300	3,320	6,690	690
665	1,650	2,550	3,950	5,170	6,520	10,100	2,890
26	143	317	696	1,120	1,670	3,550	1,260
8	30	56	104	151	209	383	110
94	253	405	648	863	1,100	1,750	1,200
29	103	185	335	480	654	1,170	276
134	455	814	1,450	2,070	2,800	4,970	1,250
71	192	309	497	662	848	1,350	1,120

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)
	EAST-CENTRAL PLAINS REGION			
06115100	Missouri River tributary near Landusky	17	3.39	2,690
06125680	Big Coulee Creek tributary near Cushman	15	2.41	3,790
06125700	Big Coulee Creek near Lavina	15	232	4,230
06126300	Currant Creek near Roundup	15	220	4,250
06126470	Halfbreed Creek near Klein	11	53.2	3,870
06127100	South Willow Creek tributary near Roundup	15	1.38	3,590
06127200	Musselshell River tributary near Musselshell	15	10.8	3,300
06127520	Home Creek near Sumatra	16	1.98	3,190
06127570	Butts Coulee near Melstone	26	6.71	3,000
06127585	Little Wall Creek tributary near Grassrange	15	3.95	3,890
06128900	Box Elder Creek tributary near Winnett	19	16.2	2,900
06129000	Box Elder Creek near Winnett	20	684	3,470
06129700	Gorman Coulee near Cat Creek	18	2.32	2,910
06129800	Gorman Coulee tributary near Cat Creek	34	.81	2,900
06130600	Cat Creek near Cat Creek	18	36.5	2,870
06130610	Bair Coulee near Mosby	15	1.79	3,130
06130620	Blood Creek tributary near Valentine	15	1.97	3,100
06130700	Sand Creek near Jordan	10	317	3,050
06130800	Second Creek tributary near Jordan	16	.52	2,830
06130850	Second Creek tributary No. 2 near Jordan	31	2.08	2,830
06130900	Second Creek tributary No. 3 near Jordan	15	.72	2,780
06130915	Russian Coulee near Jordan	15	3.45	2,660
06130925	Thompson Creek tributary near Cohagen	15	1.23	2,830
06130940	Spring Creek tributary near Van Norman	15	1.39	2,570
06130950	Little Dry Creek near Van Norman	19	1,224	2,860
06131000	Big Dry Creek near Van Norman	47	2,554	2,870
06131100	Terry Coulee near Van Norman	15	.48	2,540
06131200	Nelson Creek near Van Norman	10	100	2,620
06131300	McGuire Creek tributary near Van Norman	15	.79	2,460
06172200	Buggy Creek near Tampico	11	105	2,770
06172300	Unger Coulee near Vandalia	31	11.1	2,560
06172350	Mooney Coulee near Tampico	15	14.3	2,410
06173300	Willow Creek tributary near Fort Peck	16	.86	2,360
06174000	Willow Creek near Glasgow	34	538	2,400
06174300	Milk River tributary No. 3 near Glasgow	15	1.82	2,320
06175000	Porcupine Creek at Nashua	19	725	2,800
06175540	Prairie Elk Creek near Oswego	10	352	2,460
06175550	East Fork Sand Creek near Vida	15	8.51	2,440
06175700	East Fork Wolf Creek near Lustre	33	9.61	2,850
06175900	Wolf Creek tributary No. 2 near Wolf Point	30	6.54	2,470
06176500	Wolf Creek near Wolf Point	32	251	2,570
06176950	Missouri River tributary No. 6 near Wolf Point	16	.53	2,140
06177020	Tule Creek tributary near Wolf Point	15	1.91	2,450
06177050	East Fork Duck Creek near Brockway	34	12.4	2,910
06177100	Duck Creek near Brockway	17	54.0	2,910
06177150	Redwater River at Brockway	17	216	2,810
06177200	Tusler Creek near Brockway	16	90.2	2,980
06177250	Tusler Creek tributary near Brockway	17	3.17	2,700
06177300	Redwater River tributary near Brockway	17	.29	2,620
06177350	South Fork Dry Ash Creek near Circle	17	5.74	2,840
06177400	McCune Creek near Circle	22	29.9	2,810
06177500	Redwater River at Circle	56	547	2,810
06177700	Cow Creek tributary near Vida	26	1.71	2,490
06177720	West Fork Sullivan Creek near Richey	16	14.8	2,740
06177800	Gady Coulee near Vida	27	.91	2,450

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
56	276	633	1,520	2,670	4,410	12,100	1,950
6	36	91	246	468	835	2,700	460
109	382	743	1,520	2,430	3,700	8,790	2,400
136	436	796	1,510	2,270	3,280	6,880	1,620
26	109	234	538	929	1,520	4,220	630
70	185	307	522	733	992	1,820	510
48	137	228	379	518	677	1,130	380
29	90	151	251	339	437	697	140
80	183	275	417	540	677	1,050	488
7	19	32	51	69	89	145	35
127	281	417	625	805	1,010	1,550	1,030
1,310	2,900	4,330	6,570	8,540	10,800	17,100	9,910
89	275	467	790	1,080	1,420	2,360	810
26	95	185	367	565	828	1,760	380
42	185	430	1,000	1,620	2,600	5,300	748
25	116	242	502	785	1,150	2,380	420
7	41	97	242	430	718	1,980	533
679	1,780	2,910	4,890	6,820	9,170	16,600	6,600
19	55	97	179	268	388	831	334
25	90	170	326	490	701	1,400	760
11	41	86	185	270	410	800	458
24	92	166	295	412	545	902	200
33	110	200	371	547	770	1,500	510
18	56	98	174	248	339	620	238
2,030	3,600	4,730	6,200	7,320	8,440	11,000	5,200
2,530	7,680	12,600	20,200	26,600	33,400	40,500	24,600
28	75	121	195	261	336	545	158
588	1,150	1,550	2,080	2,460	2,840	3,680	1,750
82	176	249	346	419	492	654	250
525	2,270	4,270	7,610	10,500	13,700	21,500	7,660
58	343	806	1,900	3,200	5,020	11,800	4,460
38	173	337	629	896	1,200	1,980	450
55	200	367	669	961	1,310	2,340	940
1,690	4,970	8,040	12,600	16,400	20,400	29,900	12,400
26	132	269	520	757	1,030	1,750	251
759	1,800	2,780	4,350	5,770	7,390	12,000	6,600
1,280	2,180	2,810	3,630	4,240	4,850	6,240	3,080
185	460	727	1,170	1,580	2,060	3,460	1,220
48	230	463	896	1,310	1,800	3,150	2,230
77	380	787	1,590	2,420	3,430	6,500	3,900
366	1,840	4,000	8,760	14,200	21,500	47,600	9,780
13	33	51	76	96	116	161	74
40	71	95	127	153	180	212	118
100	266	410	618	784	953	1,350	650
164	596	1,060	1,830	2,520	3,270	5,200	1,000
554	1,450	2,220	3,320	4,200	5,090	7,160	3,550
139	340	505	731	905	1,080	1,470	430
7	77	226	638	1,180	1,960	5,000	1,610
9	33	64	128	198	293	638	234
31	78	118	178	226	277	402	350
68	331	736	1,680	2,840	4,510	11,200	4,870
791	2,570	4,360	7,180	9,580	12,200	18,600	6,960
91	279	479	827	1,150	1,540	2,680	950
22	76	146	288	445	657	1,430	313
86	330	617	1,140	1,630	2,220	3,920	1,250

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence interval for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)
	EAST-CENTRAL PLAINS REGION--Continued			
06177820	Horse Creek tributary near Richey	15	.63	2,640
06177825	Redwater River near Vida	10	1,974	2,560
06181200	Missouri River tributary No. 2 near Brockton	15	1.60	2,170
06185100	Big Muddy Creek tributary near Culbertson	15	7.38	2,110
06185200	Missouri River tributary No. 3 near Culbertson	15	1.23	2,090
06185300	Missouri River tributary No. 4 near Bainville	15	11.6	2,170
06185400	Missouri River tributary No. 5 at Culbertson	26	3.67	2,210
06217300	Twelvemile Creek near Shepherd	16	9.05	3,490
06217700	North Fork Crooked Creek near Shepherd	27	6.85	3,660
06294900	Middle Fork Froze to Death Creek tributary near Ingomar	15	1.36	3,220
06294960	Anderson Creek at Vananda	12	5.71	2,870
06295020	Short Creek near Forsyth	27	3.23	2,820
06295050	Little Porcupine Creek near Forsyth	19	614	2,910
06296115	Reservation Creek near Miles City	16	6.29	2,620
06309020	Rock Springs Creek tributary at Rock Springs	17	.96	3,000
06309040	Dry House Creek near Angela	16	35.6	2,940
06309060	North Sunday Creek tributary No. 2 near Angela	27	.22	2,710
06309075	Sunday Creek near Miles City	10	714	2,890
06309078	Tree Coulee near Kinsey	16	4.13	2,560
06326550	Cherry Creek tributary near Terry	16	2.52	2,520
06326900	Yellowstone River tributary No. 4 near Fallon	15	.67	2,410
06326950	Yellowstone River tributary No. 5 near Marsh	27	.82	2,440
06326960	Timber Fork Upper Sevenmile Creek tributary near Lindsay	15	1.13	2,810
06328400	Thirteenmile Creek tributary near Bloomfield	16	.67	2,640
06328700	Linden Creek at Intake	16	4.20	2,320
06328800	Indian Creek at Intake	16	.46	2,130
06328900	War Dance Creek near Intake	16	3.69	2,320
06329200	Burns Creek near Savage	21	233	2,600
06329510	Fox Creek tributary near Lambert	16	5.01	2,580
06329570	First Hay Creek near Sidney	26	30.0	2,360
	SOUTHEAST PLAINS REGION			
06294600	East Cabin Creek tributary near Hardin	16	8.63	3,450
06294800	Unknown Creek near Bighorn	15	14.6	3,060
06294850	Buckingham Coulee near Myers	15	2.63	3,120
06294930	Sarpy Creek tributary near Colstrip	17	4.44	3,340
06294940	Sarpy Creek near Hysham	11	453	3,420
06294985	East Fork Armells Creek tributary near Colstrip	15	1.87	3,110
06294995	Armells Creek near Forsyth	11	370	3,280
06295100	Rosebud Creek near Kirby	22	34.2	4,650
06295200	Whitedirt Creek near Lame Deer	15	1.58	3,560
06295250	Rosebud Creek near Colstrip	14	799	3,920
06296000	Rosebud Creek near Forsyth	30	1,279	3,610
06296100	Snell Creek near Hathaway	23	10.5	2,840
06306100	Squirrel Creek near Decker	10	33.6	4,460
06306900	Spring Creek near Decker	29	34.7	4,010
06306950	South Fork Leaf Rock Creek near Kirby	29	4.53	4,240
06307520	Canyon Creek near Birney	17	50.2	4,010
06307600	Hanging Woman Creek near Birney	14	470	3,880
06307640	Spring Creek near Ashland	15	1.56	3,160
06307660	Walking Horse Creek near Ashland	16	3.33	3,170
06307700	Cow Creek near Fort Howes Ranger Station, near Otter	17	8.37	3,860

Discharge, in cubic feet per second, for indicated recurrence interval, in years

2	5	10	25	50	100	500	Maximum of record
24	60	103	175	235	310	550	105
859	4,080	8,400	16,900	25,700	36,600	70,200	8,230
53	117	173	260	335	418	645	313
46	171	328	637	964	1,380	2,800	676
13	80	203	535	989	1,710	5,030	2,570
324	633	874	1,210	1,470	1,740	2,410	1,670
32	153	325	683	1,070	1,570	3,250	1,320
26	95	179	339	503	707	1,360	250
86	385	860	2,000	3,000	4,900	9,500	5,120
73	143	206	304	392	493	790	463
53	132	205	321	423	537	852	420
141	412	706	1,230	1,750	2,390	4,400	1,000
1,740	3,600	5,290	7,970	10,400	13,200	21,600	13,000
231	625	991	1,550	2,030	2,540	3,860	1,340
11	29	46	75	101	130	215	87
150	524	966	1,800	2,640	3,680	7,010	1,560
41	94	140	206	261	319	465	320
1,630	3,750	5,540	8,090	10,200	12,300	17,600	6,760
480	960	1,400	2,100	2,550	3,200	4,800	1,630
62	145	216	321	408	502	741	466
82	159	223	315	393	478	703	338
13	68	142	290	440	624	1,180	267
5	18	33	63	96	138	286	101
38	67	88	113	132	149	187	110
9	24	39	66	92	125	220	160
14	46	84	156	231	327	645	150
11	40	74	140	207	290	553	240
315	1,040	1,810	3,110	4,300	5,670	9,450	2,100
6	32	73	173	299	487	1,280	390
31	176	403	922	1,530	2,350	5,340	950
27	74	135	230	330	455	800	171
146	515	954	1,780	2,620	3,670	7,020	1,400
28	88	156	283	413	576	1,110	398
13	47	95	206	345	552	1,470	590
81	265	473	853	1,230	1,690	3,110	428
11	44	87	178	280	419	930	160
103	478	1,010	2,160	3,470	5,220	11,500	960
79	185	284	446	594	767	1,270	540
8	25	42	73	103	139	252	45
126	265	400	631	857	1,140	2,050	605
355	735	1,080	1,620	2,120	2,690	4,370	3,000
95	200	290	427	544	673	1,020	410
50	126	210	369	535	754	1,540	584
72	267	529	1,100	1,770	2,710	6,460	1,400
17	84	182	400	650	992	2,250	222
28	203	559	1,610	3,160	5,760	18,900	2,490
146	648	1,360	2,900	4,650	7,050	15,900	2,060
128	276	417	654	879	1,150	2,000	2,080
4	28	69	163	272	417	903	58
15	48	88	167	252	364	761	200

Table 1.--*Drainage-basin characteristics and flood-frequency data for selected recurrence intervals for crest-stage and streamflow-gaging stations*--Continued

Station number	Station name	Length of record (years)	Drainage-basin characteristic: Drainage area (A) (square miles)	Drainage-basin characteristic: Mean basin elevation (E) (feet above sea level)
	SOUTHEAST PLAINS REGION--Continued			
06307720	Brian Creek near Ashland	15	8.03	3,520
06307740	Otter Creek at Ashland	14	707	3,730
06307780	Stebbins Creek at mouth, near Ashland	26	20.8	3,480
06307930	Jack Creek near Volborg	16	5.47	2,840
06308100	Sixmile Creek tributary near Epsie	17	.80	3,600
06308200	Basin Creek tributary near Volborg	33	.14	2,980
06308300	Basin Creek near Volborg	19	11.1	3,060
06308330	Deer Creek tributary near Volborg	16	1.65	2,950
06308340	La Grange Creek near Volborg	16	3.66	2,820
06308400	Pumpkin Creek near Miles City	12	697	3,290
06309080	Deep Creek near Kinsey	27	11.5	2,610
06309090	Ash Creek near Locate	15	6.23	3,150
06324700	Sand Creek near Broadus	30	10.2	3,330
06324995	Badger Creek at Biddle	17	6.06	3,590
06325400	East Fork Little Powder River tributary near Hammond	11	3.45	3,400
06325500	Little Powder River near Broadus	24	1,974	3,930
06325700	Deep Creek near Powderville	16	3.00	3,000
06325950	Cut Coulee near Mizpah	16	2.23	2,800
06326300	Mizpah Creek near Mizpah	12	797	3,210
06326400	Meyers Creek near Locate	15	9.42	2,860
06326510	Locate Creek tributary near Locate	16	.91	2,810
06326580	Lame Jones Creek tributary near Willard	15	.51	3,160
06326600	O'Fallon Creek near Ismay	27	669	3,080
06326650	O'Fallon Creek tributary near Ismay	15	.16	2,780
06326700	Deep Creek near Baker	16	3.79	3,180
06326800	Pennel Creek tributary near Baker	27	.86	3,170
06326940	Spring Creek tributary near Fallon	17	3.10	2,540
06327550	South Fork Horse Creek tributary near Wibaux	16	1.34	2,940
06327700	Griffith Creek near Glendive	12	15.5	2,490
06327720	Griffith Creek tributary near Glendive	16	3.48	2,430
06327790	Krug Creek tributary No. 2 near Wibaux	15	.44	2,870
06328100	Yellowstone River tributary No. 6 near Glendive	15	2.93	2,330
06329350	Alkali Creek near Sidney	15	.49	2,350
06334000	Little Missouri River near Alzada	53	904	3,910
06334100	Wolf Creek near Hammond	34	10.1	3,710
06334200	Willow Creek near Alzada	16	122	3,690
06334330	Little Missouri River tributary near Albion	17	1.49	3,360
06334610	Hawksnest Creek tributary near Albion	16	.92	3,530
06334625	Coal Creek tributary near Mill Iron	15	.64	3,450
06334630	Boxelder Creek near Webster	14	1,092	3,440
06334640	North Fork Coal Bank Creek near Mill Iron	15	15.6	3,170
06334720	Soda Creek tributary near Webster	27	2.22	3,200
06335000	Little Beaver Creek near Marmarth, N. Dak.	41	587	3,280
06335700	Deep Creek near Bowman, N. Dak.	19	.20	3,000
06336100	Sheep Creek tributary near Medora, N. Dak.	15	.29	2,440
06336200	Sheep Creek tributary No. 2 near Medora, N. Dak.	16	.42	2,520
06336300	Little Missouri River tributary near Watford City, N. Dak.	19	.32	2,490
06336400	Jules Creek near Medora, N. Dak.	19	3.80	2,430
06336450	Spring Creek near Wibaux	17	4.00	2,900
06336500	Beaver Creek at Wibaux	32	351	3,020
06336980	Little Missouri River tributary near Watford City, N. Dak.	14	2.10	2,100
06337100	Spring Creek near Watford City, N. Dak.	14	22.7	2,350
06356000	South Fork Grand River at Buffalo, S. Dak.	34	148	3,000
06358600	South Fork Moreau River tributary near Redig, S. Dak.	22	2.33	3,100
06358620	Sand Creek tributary near Redig, S. Dak.	22	.04	3,100

Discharge, in cubic feet per second, for indicated recurrence interval, in years							
2	5	10	25	50	100	500	Maximum of record
7	28	59	120	190	295	600	93
54	137	234	432	658	977	2,280	425
85	258	433	721	980	1,270	2,070	570
194	323	408	508	578	644	781	448
52	135	230	380	520	700	1,150	290
8	31	60	122	191	285	632	390
170	524	913	1,610	2,290	3,130	5,700	990
39	147	285	565	869	1,270	2,670	1,170
50	132	212	344	463	600	987	378
450	1,310	2,200	3,720	5,140	6,800	11,600	2,890
396	961	1,470	2,240	2,890	3,600	5,470	2,430
19	80	172	387	655	1,050	2,740	1,400
18	78	159	328	512	755	1,590	715
22	121	302	807	1,540	2,760	9,170	2,530
34	93	148	231	301	376	564	155
1,160	1,840	2,310	2,910	3,360	3,800	4,840	3,160
31	87	148	258	369	507	958	480
116	223	304	415	502	590	804	420
713	1,460	2,050	2,870	3,530	4,220	5,910	2,270
265	565	844	1,300	1,710	2,200	3,680	2,230
12	44	81	148	214	294	535	130
2	5	10	22	37	59	161	28
1,020	2,360	3,440	4,920	6,060	7,210	9,850	4,700
31	52	66	84	97	110	140	61
116	169	205	250	284	318	397	260
37	75	110	166	216	275	450	350
14	71	147	295	443	620	1,140	303
11	50	101	198	297	418	787	169
117	368	682	1,330	2,070	3,100	7,090	14,600
29	156	359	845	1,440	2,310	570	1,070
17	29	38	52	63	75	107	16
33	139	269	502	724	982	1,700	210
15	35	55	88	118	155	267	305
1,890	3,270	4,240	5,470	6,390	7,290	9,330	6,000
192	469	711	1,070	1,360	1,680	2,460	1,170
640	1,170	1,570	2,120	2,560	3,010	4,110	1,800
3	13	27	58	95	149	370	90
44	70	87	108	123	137	167	80
3	13	25	48	71	98	182	35
1,910	4,490	6,900	10,800	14,300	18,300	30,000	23,000
155	381	569	831	1,030	1,240	1,700	750
8	32	66	138	220	331	737	250
3,310	5,860	7,630	9,870	11,500	13,100	16,700	12,700
12	27	41	62	80	100	158	58
25	47	64	99	124	154	169	147
41	101	156	239	310	387	596	210
3	17	39	86	141	215	481	200
175	401	596	885	914	1,380	2,040	629
67	156	235	354	454	563	849	438
771	2,700	4,740	8,110	12,500	30,000	45,000	30,000
250	672	1,070	1,710	2,270	2,900	4,610	1,050
253	674	1,080	1,710	2,270	2,900	4,590	1,100
635	1,280	1,790	2,470	3,000	3,540	4,810	2,780
52	123	192	306	414	541	925	450
21	36	46	61	73	85	116	64

Table 2.--*Regional flood-frequency equations based on drainage-basin characteristics*

[Regression equation: Q_t, flood magnitude in cubic feet per second, with subscript t designating the given recurrence interval, in years; A, drainage area, in square miles; P, mean annual precipitation, in inches; HE, percentage of basin above 6,000 feet elevation; E, mean basin elevation, in feet]

Regression equation	Standard error of estimate (percent)	Average standard error of prediction (percent)	Equivalent years of record
WEST REGION			
$Q_2 = 0.042\ A^{0.94}\ P^{1.49}$	51	52	1
$Q_5 = 0.140\ A^{0.90}\ P^{1.31}$	45	47	2
$Q_{10} = 0.235\ A^{0.89}\ P^{1.25}$	44	45	2
$Q_{25} = 0.379\ A^{0.87}\ P^{1.19}$	44	45	3
$Q_{50} = 0.496\ A^{0.86}\ P^{1.17}$	45	46	3
$Q_{100} = 0.615\ A^{0.85}\ P^{1.15}$	46	48	4
$Q_{500} = 0.874\ A^{0.83}\ P^{1.14}$	53	55	4
NORTHWEST REGION			
$Q_2 = 0.266\ A^{0.94}\ P^{1.12}$	41	44	2
$Q_5 = 2.34\ A^{0.87}\ P^{0.75}$	30	34	8
$Q_{10} = 7.84\ A^{0.84}\ P^{0.54}$	27	31	13
$Q_{25} = 23.1\ A^{0.81}\ P^{0.40}$	23	27	26
$Q_{50} = 25.4\ A^{0.79}\ P^{0.46}$	22	26	39
$Q_{100} = 38.9\ A^{0.74}\ P^{0.50}$	32	38	24
$Q_{500} = 87.1\ A^{0.67}\ P^{0.49}$	52	59	18
SOUTHWEST REGION			
$Q_2 = 2.48\ A^{0.87}\ (HE+10)^{0.19}$	84	88	1
$Q_5 = 24.8\ A^{0.82}\ (HE+10)^{-0.16}$	67	69	2
$Q_{10} = 81.5\ A^{0.78}\ (HE+10)^{-0.32}$	60	63	3
$Q_{25} = 297\ A^{0.72}\ (HE+10)^{-0.49}$	57	60	4
$Q_{50} = 695\ A^{0.70}\ (HE+10)^{-0.62}$	60	63	5
$Q_{100} = 1{,}520\ A^{0.68}\ (HE+10)^{-0.74}$	62	66	5
$Q_{500} = 7{,}460\ A^{0.64}\ (HE+10)^{-0.99}$	75	80	5

Table 2.--*Regional flood-frequency equations based on drainage-basin characteristics*--Continued

Regression equation	Standard error of estimate (percent)	Average standard error of prediction (percent)	Equivalent years of record
UPPER YELLOWSTONE-CENTRAL MOUNTAIN REGION			
$Q_2 = 0.117\ A^{0.85}\ (E/1000)^{3.57}\ (HE+10)^{-0.57}$	69	72	2
$Q_5 = 0.960\ A^{0.79}\ (E/1000)^{3.44}\ (HE+10)^{-0.82}$	50	53	7
$Q_{10} = 2.71\ A^{0.77}\ (E/1000)^{3.36}\ (HE+10)^{-0.94}$	43	46	12
$Q_{25} = 8.54\ A^{0.74}\ (E/1000)^{3.16}\ (HE+10)^{-1.03}$	40	44	14
$Q_{50} = 19.0\ A^{0.72}\ (E/1000)^{2.95}\ (HE+10)^{-1.05}$	42	46	14
$Q_{100} = 41.6\ A^{0.70}\ (E/1000)^{2.72}\ (HE+10)^{-1.07}$	46	50	14
$Q_{500} = 205\ A^{0.65}\ (E/1000)^{2.17}\ (HE+10)^{-1.07}$	58	63	15
NORTHWEST FOOTHILLS REGION			
$Q_2 = 0.653\ A^{0.49}\ (E/1000)^{2.60}$	78	88	4
$Q_5 = 3.70\ A^{0.48}\ (E/1000)^{2.22}$	43	52	13
$Q_{10} = 8.30\ A^{0.47}\ (E/1000)^{2.10}$	37	48	19
$Q_{25} = 20.3\ A^{0.46}\ (E/1000)^{1.95}$	38	50	25
[1] $Q_{50} = 47.7\ A^{0.47}\ (E/1000)^{1.62}$	41	54	28
[1] $Q_{100} = 79.8\ A^{0.48}\ (E/1000)^{1.40}$	47	62	28
[1] $Q_{500} = 344\ A^{0.50}\ (E/1000)^{0.98}$	71	75	31
NORTHEAST PLAINS REGION			
$Q_2 = 15.4\ A^{0.69}\ (E/1000)^{-0.39}$	81	85	3
$Q_5 = 77.0\ A^{0.65}\ (E/1000)^{-0.71}$	60	63	6
$Q_{10} = 161\ A^{0.63}\ (E/1000)^{-0.84}$	52	56	10
$Q_{25} = 343\ A^{0.61}\ (E/1000)^{-1.00}$	51	53	14
$Q_{50} = 543\ A^{0.60}\ (E/1000)^{-1.09}$	49	53	17
$Q_{100} = 818\ A^{0.59}\ (E/1000)^{-1.19}$	51	56	18
$Q_{500} = 1{,}720\ A^{0.57}\ (E/1000)^{-1.37}$	63	68	18

Table 2.--*Regional flood-frequency equations based on drainage-basin characteristics*--Continued

Regression equation	Standard error of estimate (percent)	Average standard error of prediction (percent)	Equivalent years of record
EAST-CENTRAL PLAINS REGION			
$Q_2 = 141\ A^{0.55}\ (E/1000)^{-1.88}$	96	99	3
$Q_5 = 509\ A^{0.53}\ (E/1000)^{-1.92}$	72	75	5
$Q_{10} = 911\ A^{0.52}\ (E/1000)^{-1.88}$	63	66	8
$Q_{25} = 1{,}545\ A^{0.50}\ (E/1000)^{-1.79}$	59	62	11
$Q_{50} = 2{,}100\ A^{0.49}\ (E/1000)^{-1.72}$	59	62	14
$Q_{100} = 2{,}620\ A^{0.49}\ (E/1000)^{-1.62}$	61	65	15
$Q_{500} = 3{,}930\ A^{0.47}\ (E/1000)^{-1.44}$	71	75	16
SOUTHEAST PLAINS REGION			
$Q_2 = 537\ A^{0.55}\ (E/1000)^{-2.91}$	128	134	1
$Q_5 = 1{,}350\ A^{0.53}\ (E/1000)^{-2.75}$	85	88	3
$Q_{10} = 2{,}050\ A^{0.52}\ (E/1000)^{-2.64}$	70	73	5
$Q_{25} = 3{,}240\ A^{0.51}\ (E/1000)^{-2.55}$	59	63	9
$Q_{50} = 4{,}160\ A^{0.50}\ (E/1000)^{-2.47}$	56	59	12
$Q_{100} = 5{,}850\ A^{0.50}\ (E/1000)^{-2.51}$	58	62	13
$Q_{500} = 8{,}250\ A^{0.49}\ (E/1000)^{-2.33}$	62	67	15

[1]Equation not valid if the ungaged stream originates in the Northwest Region.

Table 3.--*Range of drainage-basin characteristics for each region used in the regression analysis*

Region	Drainage area (A) (square miles)	Mean annual precip-itation (P) (inches)	Mean basin elevation (E) (feet above sea level)	Basin above 6,000 feet elevation (HE) (percent)
West	0.86-2,354	19-79	--	--
Northwest	2.38-1,548	15-105	--	--
Southwest	0.48-2,476	--	--	0-100
Upper Yellowstone-Central Mountain	0.85-2,032	--	2,850-9,560	0-100
Northwest Foothills	0.25-1,307	--	2,750-5,130	--
Northeast Plains	0.11-1,805	--	2,060-6,640	--
East-Central Plains	0.22-2,554	--	2,090-4,250	--
Southeast Plains	0.04-1,974	--	2,100-4,650	--

Table 4.--*Station ranking in order of importance in providing regional peak-flow information for the West Region*

[Station number: Stations are identified by standard drainage basin number, Part 12 (upper Columbia River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	Station ranking for indicated planning horizon and recurrence interval						
	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
12300800	5	4	8	1	1	1	1
NEW-03[1]	2	2	2	3	3	3	2
12301997	6	5	5	5	4	5	3
NEW-01[1]	4	3	1	6	11	2	4
NEW-04[1]	1	1	4	2	2	20	5
12345850	7	12	12	7	10	8	6
12369250	8	11	7	8	12	6	7
12339300	11	7	6	12	8	7	8
NEW-02[1]	3	6	3	4	20	4	9
12353400	10	9	16	10	7	13	10
12391200	9	14	10	9	13	9	11
12370500	12	8	17	11	5	18	12
12338600	14	15	11	14	16	10	13
12339900	15	10	20	15	6	19	14
12302400	17	13	18	17	9	15	15
12342950	13	18	9	13	18	11	16
12303440	16	16	13	16	15	12	17
12304300	20	19	19	19	14	16	18
12355350	19	17	14	20	17	14	19
12303400	18	20	15	18	19	17	20

[1]Indicates new station that could be added to network.

Table 5.--*Station ranking in order of importance in providing regional peak-flow information for the Northwest Region*

Station number: Stations are identified by standard drainage basin number--Part 5 (Hudson Bay basin), Part 6 (Missouri River basin), and Part 12 (upper Columbia River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	Station ranking for indicated planning horizon and recurrence interval						
	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
NEW-04[1]	1	2	2	2	2	2	1
NEW-03[1]	5	1	3	5	1	4	2
NEW-01[1]	6	4	1	6	4	1	3
12356500	3	5	5	3	5	3	4
NEW-02[1]	4	3	4	4	3	5	5
06097100	2	6	6	1	6	6	6

[1] Indicates new station that could be added to network.

Table 6.--*Station ranking in order of importance in providing regional peak-flow information for the Southwest Region*

[Station number: Stations are identified by standard drainage basin number--Part 6 (Missouri River basin) and Part 12 (upper Columbia River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	Station ranking for indicated planning horizon and recurrence interval						
	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
NEW-02[1]	2	2	1	2	4	1	1
06025100	5	3	5	5	2	5	2
NEW-01[1]	1	1	4	1	1	16	3
06015430	6	5	9	6	6	8	4
NEW-03[1]	3	12	2	3	17	2	5
06038550	7	7	7	7	11	6	6
NEW-04[1]	4	19	3	4	19	3	7
12324250	9	14	6	10	14	4	8
06031950	10	8	10	9	12	9	9
06019400	8	16	8	8	16	7	10
12331700	11	4	16	11	3	18	11
06030300	12	6	18	12	5	17	12
12323300	13	10	17	13	8	15	13
06056300	15	13	15	14	10	14	14
06027700	16	17	11	15	15	10	15
12324700	17	11	13	18	9	13	16
06058700	14	9	19	16	7	19	17
06071600	18	15	12	19	13	12	18
06013500	19	18	14	17	18	11	19

[1] Indicates new station that could be added to network.

Table 7.--*Station ranking in order of importance in providing regional peak-flow information for the Upper Yellowstone-Central Mountain Region*

[Station number: Stations are identified by standard drainage basin number--Part 6 (Missouri River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
NEW-04[1]	8	1	3	13	1	4	1
NEW-01[1]	17	2	1	16	2	1	2
06043300	1	12	5	2	14	3	3
06293300	4	8	13	4	6	13	4
06201700	7	11	10	6	9	10	5
06205100	6	10	12	5	8	12	6
06053050	12	9	6	11	10	5	7
06207600	3	7	17	3	7	16	8
NEW-03[1]	13	3	2	14	11	2	9
06216200	10	13	11	7	12	11	10
06076700	9	17	7	8	17	7	11
06046500	11	18	8	9	16	8	12
06294400	2	15	16	1	15	17	13
NEW-02[1]	5	16	4	10	18	6	14
06120800	14	14	9	12	13	9	15
06117800	15	6	14	15	5	14	16
06123200	16	5	15	17	4	15	17
06214150	18	4	18	18	3	18	18

[1] Indicates new station that could be added to network.

Table 8.--*Station ranking in order of importance in providing regional peak-flow information for the Northwest Foothills Region*

[Station number: Stations are identified by standard drainage basin number--Part 6 (Missouri River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
NEW-02[1]	1	1	1	1	2	1	1
06073600	6	5	5	3	1	5	2
NEW-04[1]	3	4	3	6	3	3	3
NEW-01[1]	2	2	4	5	4	4	4
NEW-03[1]	4	3	2	7	5	2	5
06101520	5	6	6	2	6	6	6
06101700	7	8	8	4	9	8	7
06098700	8	7	7	10	7	7	8
06134800	9	10	9	8	10	9	9
06100300	10	12	10	9	12	10	10
06105800	11	9	11	11	8	12	11
06132400	12	11	12	12	11	11	12

[1] Indicates new station that could be added to network.

Table 9.--*Station ranking in order of importance in providing regional peak-flow information for the Northeast Plains Region*

[Station number: Stations are identified by standard drainage basin number--Part 6 (Missouri River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	Station ranking for indicated planning horizon and recurrence interval						
	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
NEW-03[1]	3	2	1	3	2	1	1
NEW-02[1]	1	1	4	1	1	4	2
NEW-01[1]	2	3	3	2	3	3	3
NEW-04[1]	4	4	2	4	4	2	4
06137600	5	5	5	6	6	5	5
06154350	6	8	8	5	8	6	6
06165200	7	6	6	10	7	7	7
06153400	8	9	9	8	10	9	8
06179100	9	7	7	11	9	8	9
06124600	14	10	15	15	5	14	10
06174600	10	16	12	7	18	10	11
06184200	11	11	10	9	17	11	12
06114900	12	13	11	13	16	12	13
06112800	13	15	16	12	13	16	14
06090550	18	12	14	19	11	13	15
06155600	16	14	13	16	14	15	16
06164600	15	19	17	14	20	17	17
06156100	17	21	18	17	21	18	18
06109530	20	17	19	24	12	20	19
06109560	19	20	20	21	19	19	20
06114550	21	18	21	25	15	21	21
06128500	22	24	23	18	24	22	22
06115300	23	22	22	22	23	23	23
06111700	25	23	24	23	22	24	24
06138700	24	25	25	20	25	25	25
06183300	26	26	26	26	27	26	26
06155300	27	27	27	27	26	27	27

[1] Indicates new station that could be added to network.

Table 10.--*Station ranking in order of importance in providing regional peak-flow information for the East-Central Plains Region*

[Station number: Stations are identified by standard drainage basin number--Part 6 (Missouri River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

	Station ranking for indicated planning horizon and recurrence interval						
	5-year planning horizon			20-year planning horizon			
Station number	2-year	10-year	50-year	2-year	10-year	50-year	Composite
06125680	5	5	5	1	1	5	1
NEW-04[1]	2	4	1	3	5	1	2
NEW-02[1]	3	2	2	4	3	2	3
NEW-03[1]	1	3	3	2	4	3	4
NEW-01[1]	4	1	4	5	2	4	5
06217300	6	6	7	7	6	7	6
06127585	7	7	8	6	7	8	7
06177020	11	10	10	11	10	10	8
06174300	8	8	6	13	13	6	9
06130620	9	11	16	8	8	16	10
06130940	10	9	11	10	9	15	11
06130610	13	13	13	9	14	13	12
06130915	12	12	9	14	15	9	13
06130925	14	15	17	12	12	18	14
06328400	17	16	14	17	16	12	15
06177720	16	17	15	16	17	14	16
06177820	15	14	18	15	11	23	17
06176950	18	18	12	23	20	11	18
06131100	20	19	20	19	18	20	19
06326550	21	21	19	21	22	17	20
06329510	19	20	22	18	19	25	21
06127520	24	25	24	20	26	21	22
06131300	25	24	21	26	24	19	23
06173300	23	23	23	24	23	22	24
06326960	22	22	26	22	21	26	25
06296115	27	27	25	28	27	24	26
06309078	26	26	27	27	25	27	27
06217700	29	31	32	25	28	32	28
06326950	28	28	28	29	29	28	29
06177800	30	29	29	31	30	29	30
06329570	31	30	30	30	32	30	31
06177700	32	32	31	32	31	31	32
06130850	33	33	34	34	33	35	33
06309060	38	38	37	38	37	37	34
06185400	35	34	33	35	35	33	35
06127570	34	35	36	33	34	36	36
06172300	36	36	35	37	38	34	37
06295020	37	37	38	36	36	39	38
06175700	39	39	39	39	40	38	39
06129800	41	40	41	40	39	41	40
06177050	40	41	40	41	41	40	41

[1] Indicates new station that could be added to network.

Table 11.--*Station ranking in order of importance in providing regional peak-flow information for the Southeast Plains Region*

[Station number: Stations are identified by standard drainage basin number--Part 6 (Missouri River basin). Each station number contains a 2-digit part number plus a 6-digit downstream order number]

Station number	Station ranking for indicated planning horizon and recurrence interval						
	5-year planning horizon			20-year planning horizon			
	2-year	10-year	50-year	2-year	10-year	50-year	Composite
06294600	3	4	5	1	1	1	1
NEW-04[1]	1	1	1	2	2	2	2
NEW-03[1]	2	2	2	3	3	3	3
NEW-01[1]	5	3	3	5	4	4	4
NEW-02[1]	4	5	4	4	14	5	5
06334625	6	9	7	7	11	9	6
06326580	14	6	6	17	6	7	7
06294985	17	12	10	22	9	8	8
06307720	10	13	8	12	18	12	9
06308100	16	14	16	18	12	14	10
06294930	34	7	13	35	5	6	11
06327550	7	16	14	9	22	18	12
06334330	26	10	9	33	8	10	13
06334610	11	18	19	11	19	21	14
06327790	25	8	12	32	7	13	15
06326510	13	17	18	13	21	19	16
06324995	35	11	11	36	10	11	17
06307700	24	19	20	29	15	17	18
06307520	19	21	15	25	23	15	19
06329350	33	15	17	34	13	16	20
06326940	8	26	24	6	32	27	21
06308330	22	22	23	24	20	22	22
06325950	15	24	26	14	26	26	23
06325700	28	20	21	30	17	20	24
06308340	18	25	27	16	29	24	25
06328100	9	27	25	8	33	31	26
06327720	21	23	22	23	27	23	27
06307930	12	30	28	10	34	32	28
06295100	32	29	29	28	25	25	29
06308200	36	28	33	31	16	33	30
06306950	23	33	32	20	31	31	31
06296100	30	34	30	27	28	28	32
06334720	29	31	31	26	30	29	33
06307780	20	35	34	15	35	35	34
06309080	27	36	36	21	36	36	35
06334100	31	37	37	19	37	37	36
06326800	37	32	35	37	24	34	37

[1] Indicates new station that could be added to network.

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