Flood hydrology of small drainage areas in Arizona—A progress report through June 1969

By

B. N. Aldridge and Alberto Condes de la Torre

Administrative report

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Flood hydrology of small drainage areas in Arizona—A progress report through June 1969

By

B. N. Aldridge and Alberto Condes de la Torre

Prepared in cooperation with the
Arizona Highway Department and
the U. S. Bureau of Public Roads

Administrative report
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Tucson, Arizona
May 1970

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FLOOD HYDROLOGY OF SMALL DRAINAGE AREAS IN ARIZONA—A PROGRESS REPORT THROUGH JUNE 1969

By

B. N. Aldridge and Alberto Condes de la Torre

INTRODUCTION

This is the second progress report on a study undertaken to relate the magnitude and frequency of floods from small drainage areas in Arizona to basin parameters. The first report (Click and Aldridge, 1967) included comprehensive descriptions of the objectives of the study and of the methods and equipment being used; therefore, these items are discussed only briefly in this report. The study includes the collection of peak-discharge data from selected streams throughout the State, measurement of basin parameters that may relate to the magnitude of floods, and derivation of formulas or diagrams that can be used to compute the frequency of flood peaks and runoff volumes from small drainage areas any place in the State. The study is being conducted by the Geological Survey in cooperation with the Arizona Highway Department and the U.S. Bureau of Public Roads and is under the general supervision of H. M. Babcock, district chief of the Water Resources Division in Arizona.

DATA-COLLECTION PROGRAM

When the investigation began in 1962, streamflow data were inadequate to define flood-frequency relations for small drainage areas in Arizona; therefore, the first phase of the program was to collect the required data. A network of crest-stage partial-record gaging stations—hereafter referred to as crest-stage stations—was established, and indirect measurements are made of unusual floods at ungaged sites.

Crest-Stage Gaging Station Network

In 1963-64, 100 crest-stage stations were established at selected sites in the State to provide peak-discharge data for drainage areas of less than 100 square miles. Stations were established on streams that were considered to be representative of other small streams in the area and that provided a good range in basin characteristics. The sites selected had channel characteristics that were suitable for reasonably accurate discharge computations. Since 1964, additional gaging stations have been installed, and stations that were not providing usable records have been discontinued. In 1966, the network of crest-stage stations was expanded to include stations on drainage areas of more than 100 square miles in places where no streamflow data had been collected. In June 1969, peak-discharge data were being

collected at 111 sites. In addition, data from 49 crest-stage stations established for other investigations in Pima and Maricopa Counties are being used to supplement data collected for this study. The crest-stage stations in operation for the three investigations are shown in figure 1.

The drainage areas gaged by crest-stage stations under the highway and related programs range in size from 0.1 to 787 square miles and are distributed as follows:

Drainage area (square miles)	Number of stations
Less than 1.0	37
1.01 to 5	49
5.01 to 10	20
10.1 to 20	19
20.1 to 50	11
50.1 to 100	5
101 to 500	11
More than 500	8

Each station is equipped with one or more crest-stage gages, which record the maximum stage and subsequent lower peak stages that occur between inspections of the gage. Flood-hydrograph

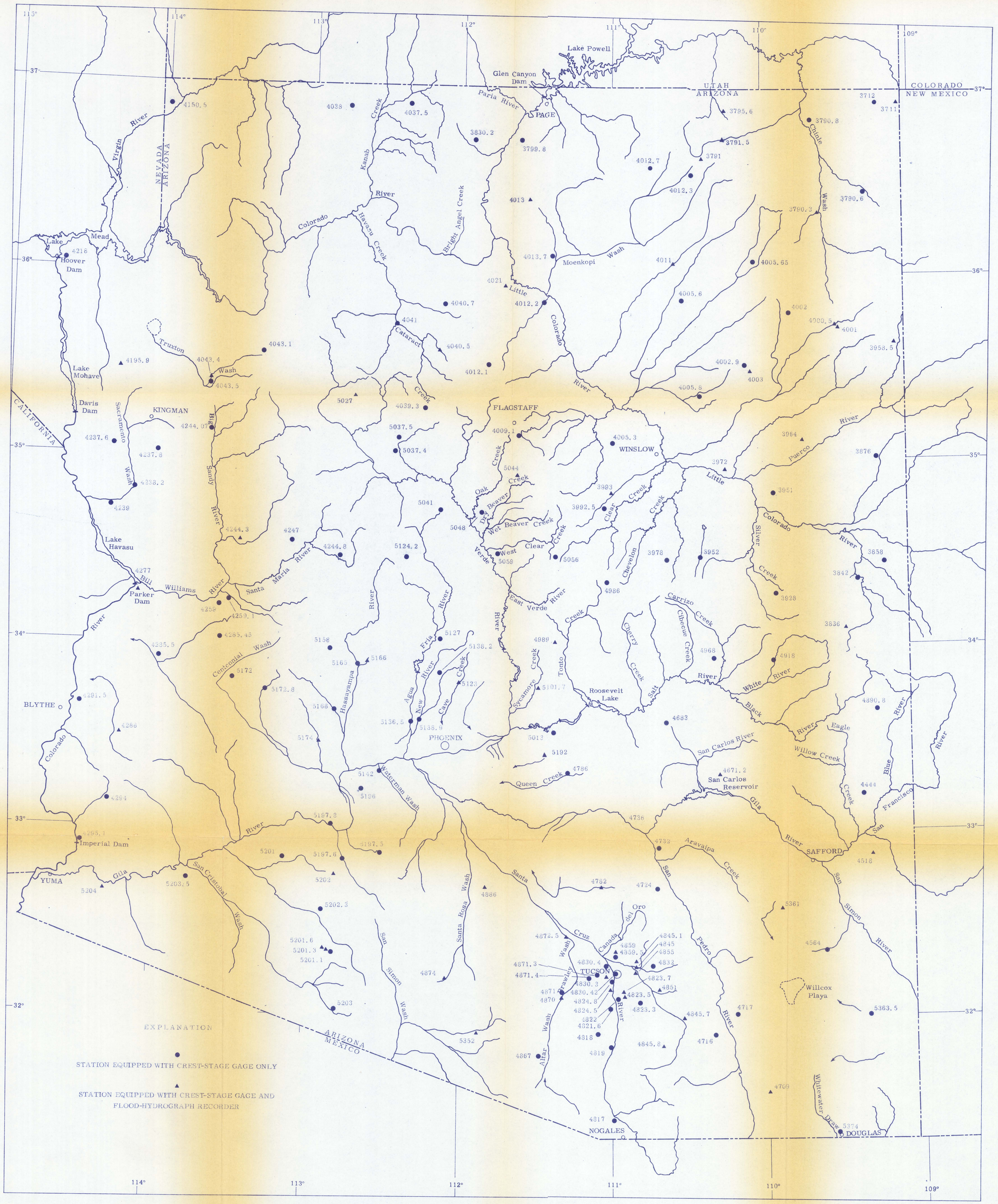


Figure 1.--Location of crest-stage stations.

recorders were installed at 51 of the stations; the recorders provide stage hydrographs above an established base elevation. The objective of the data-collection program is to obtain the annual maximum peak discharge at each of the gaged sites. Additional peak discharges may be computed to define stage-discharge relations, commonly called ratings. The types of gages and methods of computation being used in this investigation are discussed in more detail by Click and Aldridge (1967).

During the first 7 years of the study, the main emphasis was on the collection of peak-discharge data, definition of ratings, and measurement of drainage areas. Because the flow events on small drainage areas are generally of too short a duration to permit discharge measurements by current meter, most discharges are computed from surveys of channel properties and floodmarks by indirect methods (Benson and Dalrymple, 1967; Dalrymple and Benson, 1967; Bodhaine, 1968). Several computations used in the indirect methods have been programmed for use with a digital computer. The use of the computer has aided greatly in the computation of discharges and the development of ratings. The annual maximum instantaneous peak discharges for the stations used in this study are published each year in the "Surface Water Records of Arizona" (U. S. Geological Survey, issued annually),

and information on other peaks may be obtained from the U. S. Geological Survey, Water Resources Division, Tucson, Ariz. Runoff volumes have been computed for flow events for which the stage hydrograph was recorded, but the volumes have not been published. The size of drainage area has been measured for all stations, and other basin parameters have been determined for a few stations.

Peak-Discharge Measurements at Ungaged Sites

A peak-discharge measurement is made at any site where an unusually high runoff per unit area is known to have occurred, where lives have been lost, or where severe property damage has been caused by a flood. A special effort is made to obtain measurements at sites where highway structures have been damaged. The measurements are made primarily to provide information on specific floods or to indicate the maximum flow that may be expected in a given area; the measurements also may be useful in determining flood-frequency relations for small drainage areas. The data from these measurements were used in one of the analyses discussed in this report. The peak-discharge measurements made at ungaged sites are published each year in the "Surface Water Records of Arizona" (U. S. Geological Survey, issued annually).

PRELIMINARY ANALYSES

Sufficient data have been collected for preliminary analyses of flood-frequency and volume-peak discharge relations for small drainage areas in Arizona. The results of the preliminary analyses are encouraging and indicate that the peak discharges and volumes for floods from small drainage areas can be related to size of drainage area; however, final analysis can be made only after longer periods of record are available.

Flood-Frequency Relations

A preliminary analysis of flood frequencies was made in order to ascertain if data for small streams were suitable for use in developing flood-frequency relations using present methods and to determine if the data would provide a sound basis for expanding previous regional flood-frequency studies in Arizona and New Mexico (Patterson and Somers, 1966; Wiard, 1962) to include small drainage basins or places where flood-frequency relations have not been defined. Patterson and Somers (1966) defined flood-frequency relations for eight hydrologic areas that cover about 55 percent of Arizona. They extended five of their eight curves down to drainage areas of 30 to 50 square miles, although the definition for drainage areas of less than 100 square miles

is poor. Two of the eight curves were to be used for areas of more than 800 square miles. Wiard (1962) derived curves for areas as small as 0.1 square mile in New Mexico.

The index-flood method (Dalrymple, 1960) was used in the previous studies for regionalizing flood-frequency relations. In the index-flood method a flood of one recurrence interval is related to drainage area, and floods of other magnitudes are expressed in terms of ratios to the index flood. The index-flood method was used in this report in order that the adaptability of previous relations could be determined. The index-flood method has several weaknesses, which may be overcome using newer methods of analysis. The results from the index-flood method have been compared with those from pilot studies based on multiple-regression and multiplicative-probability methods. In the multiple-regression method, which now is recommended by the Geological Survey, floods of several recurrence intervals are related to drainage area and other basin parameters by means of a multiple-regression analysis. The results of a multiple-regression analysis of flood peaks from streams originating in Maricopa County (Hjalmarson, written commun., 1969) give some indication of the effects of different basin parameters on floods. Hjalmarson's (written commun., 1969) Maricopa County study can be used as a basis for

extending the method for a statewide analysis of flood data, but such an analysis cannot be made until longer periods of record are obtained from the crest-stage stations.

A short period of record may provide a reasonably accurate value for a flood having a small recurrence interval, but when the data are extended to floods having recurrence intervals of the size used in the design of highway structures, the results may be unreliable. Several methods for extending the length of record are being studied by different researchers; in addition, methods of combining data from several stations to give the equivalent of a long record are being studied. A method suggested by some researchers is based on the probability of a flood of a given size not being exceeded within a given period of time. This method—called the multiplicative-probability method—utilizes the maximum discharge measured at a site and eliminates the need for frequency curves for individual gaging stations. In this report the method was used in the analysis of data from one section of Arizona to see if it should be explored further.

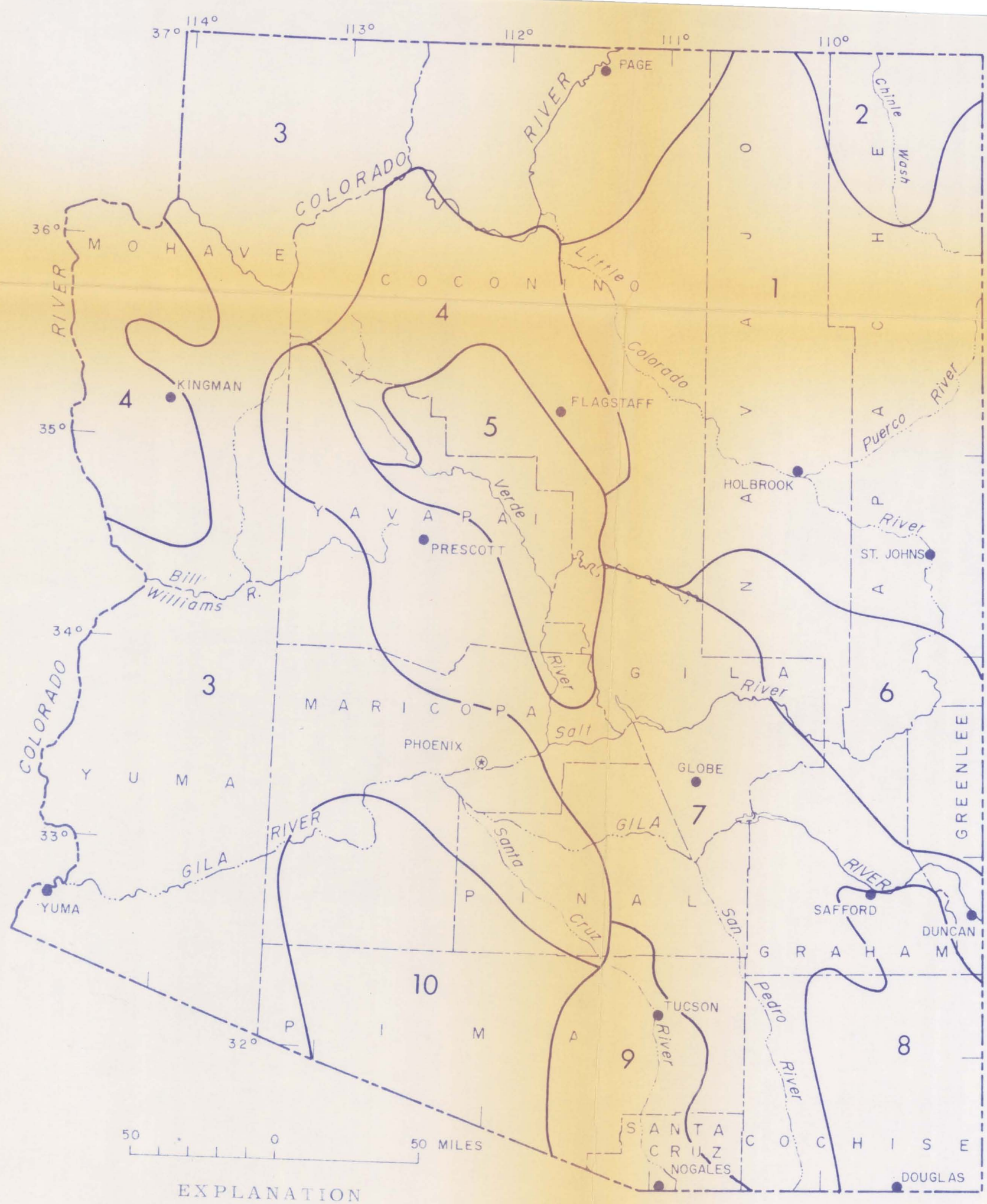
Index-flood method. --In the previous regional flood-frequency studies for Arizona and New Mexico, discharges having a recurrence interval of 2.33 years ($Q_{2.33}$)—defined as the mean annual flood—were related to the size of drainage area from which the floods originated.

Also, factors were derived by which floods of other magnitudes can be computed if $Q_{2.33}$ is known.

The present analysis is based on crest-stage data, numerous short-term continuous-gaging station records that either were not available for Patterson and Somers' (1966) study or were of too short a duration to be useful at that time, and the long-term records that were used by Patterson and Somers (1966). Data from stations near the boundaries of adjacent States also were used. Most of the records are at least 6 years in length, but a few records as short as 4 years were used to help define regional boundaries in those areas where longer records were not available. As in the previous studies, a flood-frequency graph was prepared for each gaging station, and the 2.33-year flood for each station was determined from the graph. Although Federal agencies are generally replacing graphical curves with computations based on the log-Pearson Type III distribution in order to obtain more uniform frequency data (Benson, 1968; Water Resources Council, 1967), the visually fitted curves were used in this study because they provide a better means of evaluating the effects of a large peak in a short period of record than does a statistical computation based on a theoretical distribution. It is envisioned that the log-Pearson distribution will be used in the final analysis of data for small streams.

The 2.33-year flood for each station, in cubic feet per second, was plotted against the contributing drainage area, in square miles. If the statewide data are plotted as a group on a correlation of $Q_{2.33}$ versus drainage area, the data points form an extremely scattered pattern, and there appears to be no reasonable relation between drainage area and $Q_{2.33}$. Only a slight improvement is obtained by grouping stations geographically according to the hydrologic areas defined by Patterson and Somers (1966, pl. 1). If, however, data are grouped by new areas, the alinement of data points is far better than would be expected for short periods of record, and curves relating the 2.33-year peak discharges to drainage area can be defined reasonably well for the entire State. The regionalized plotting of the data resulted in the State being divided into 10 hydrologic areas (fig. 2), which differ from those defined by Patterson and Somers (1966).

In general the curves developed by Patterson and Somers (1966) to relate $Q_{2.33}$ to drainage area were satisfactory for use with drainage areas of the size specified by Patterson and Somers; however, only three of the curves gave satisfactory results for small drainage areas. Therefore, several new relations were developed for this study (figs. 3-11). In general the new relations are intended to supplement rather than supersede those given by Patterson and



EXPLANATION

10

Hydrologic area

Hydrologic-area boundary

Figure 2. --Hydrologic areas as defined by the preliminary analysis.

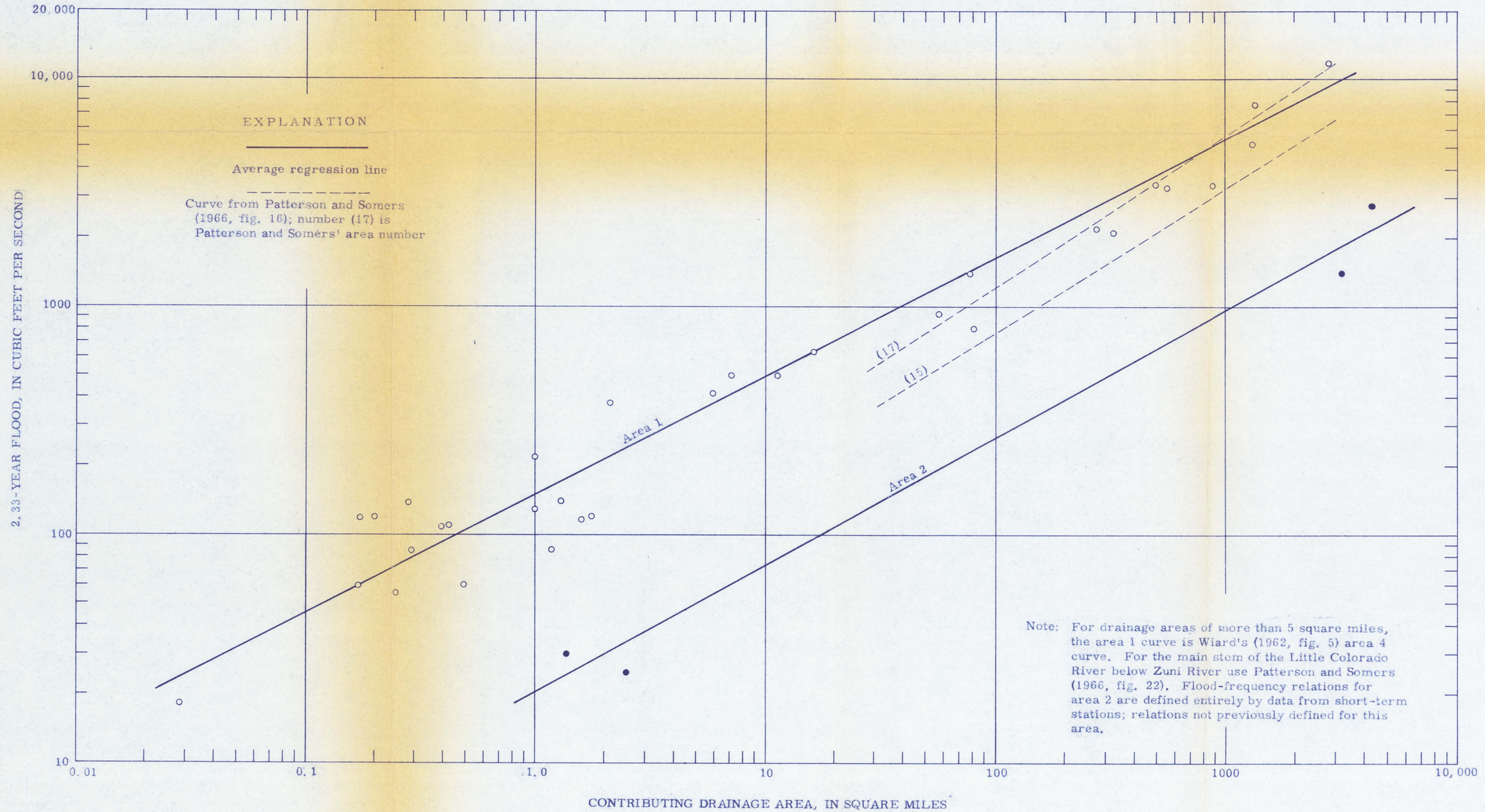


Figure 3.--Relation of the 2.33-year flood to contributing drainage area in hydrologic areas 1 and 2.

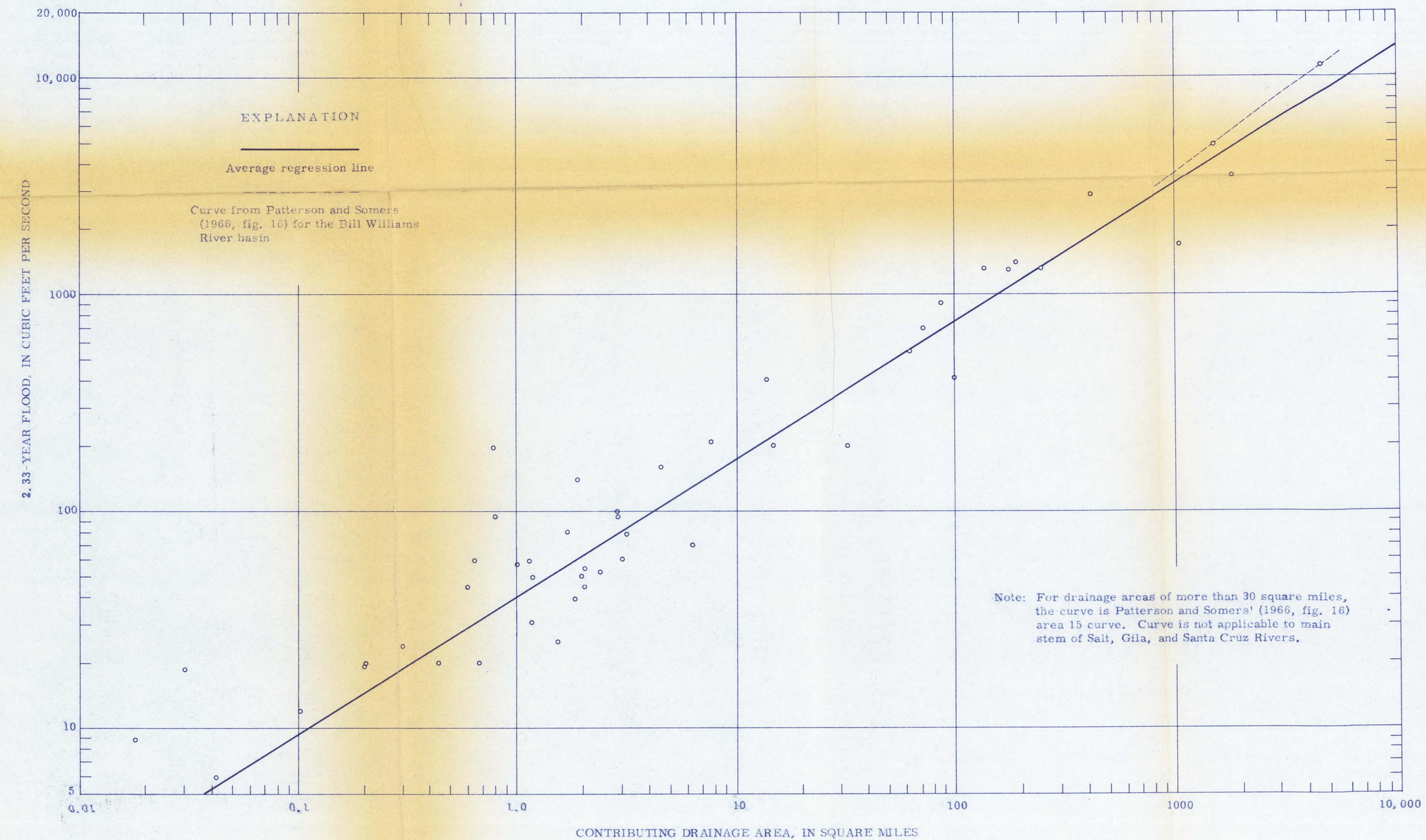


Figure 4.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 3.

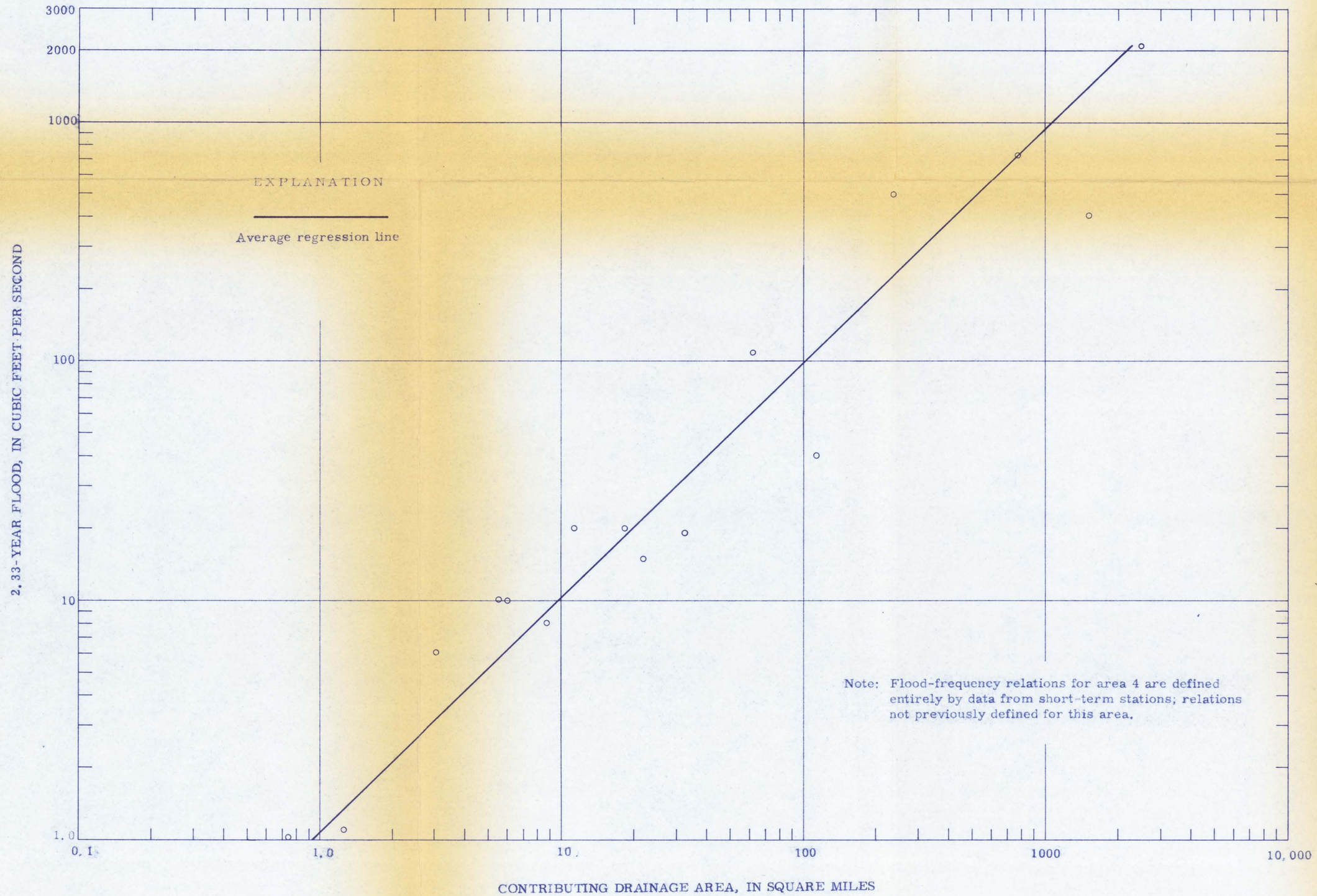


Figure 5.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 4.

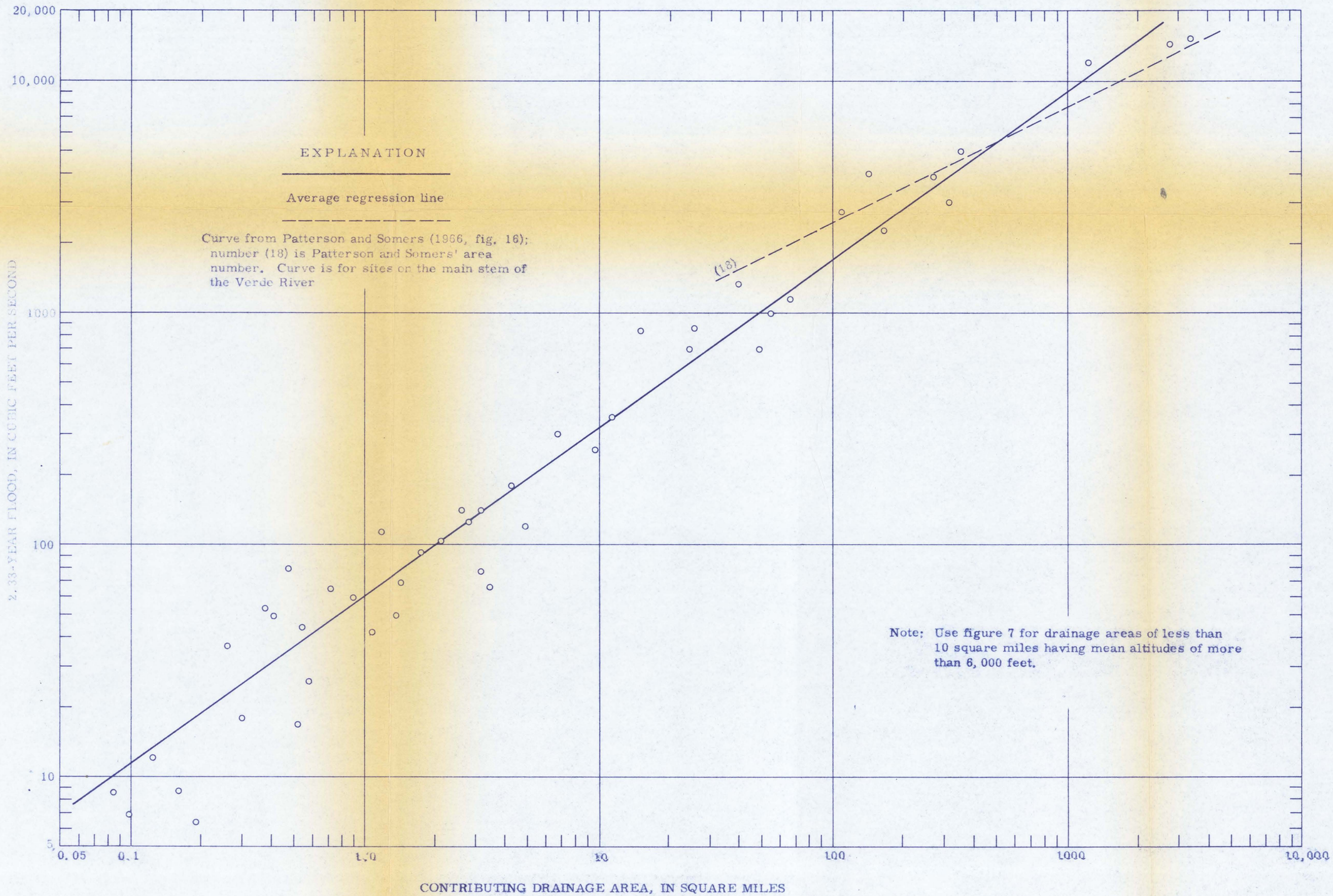


Figure 6.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 5.

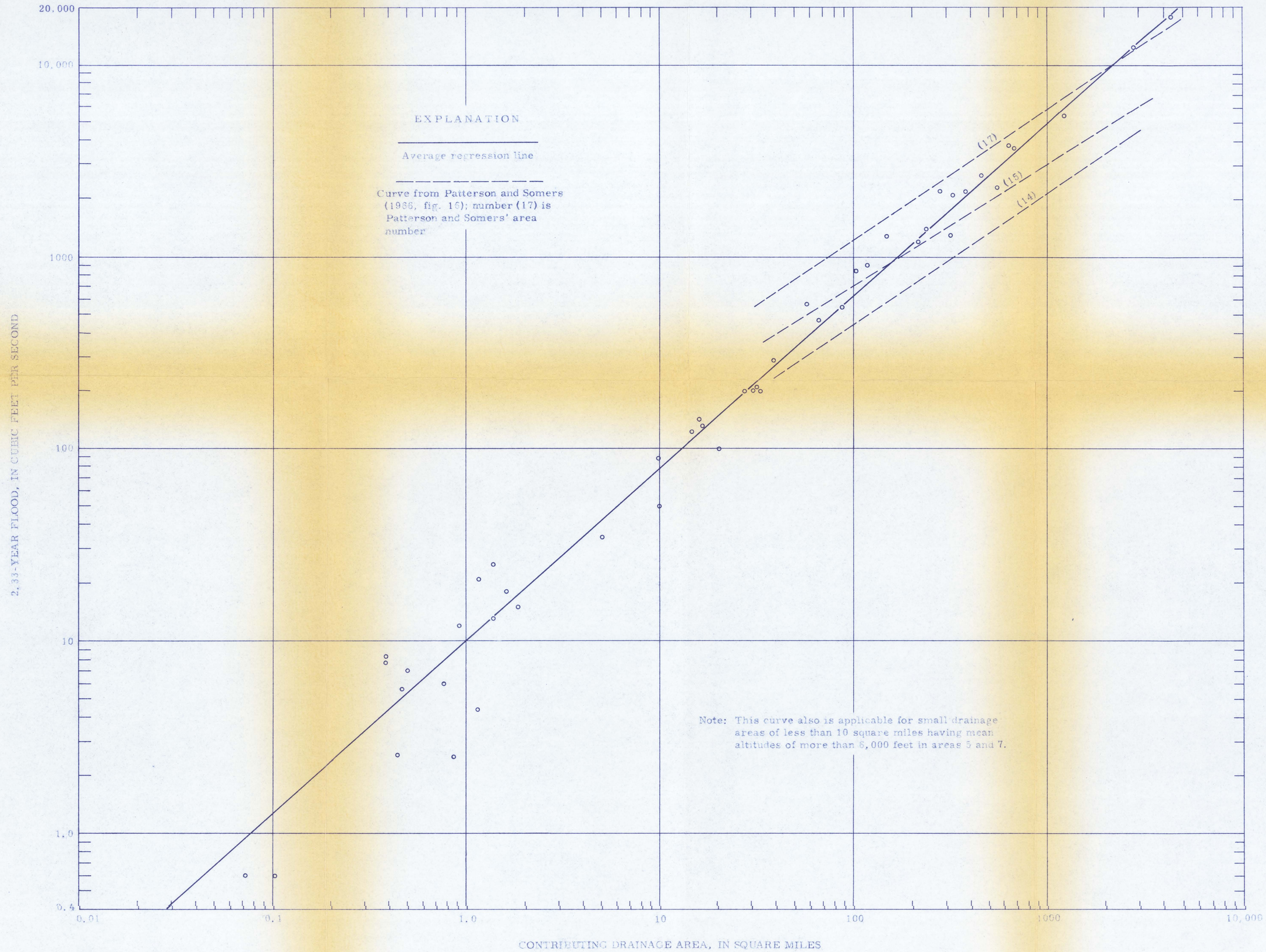


Figure 7.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 6.

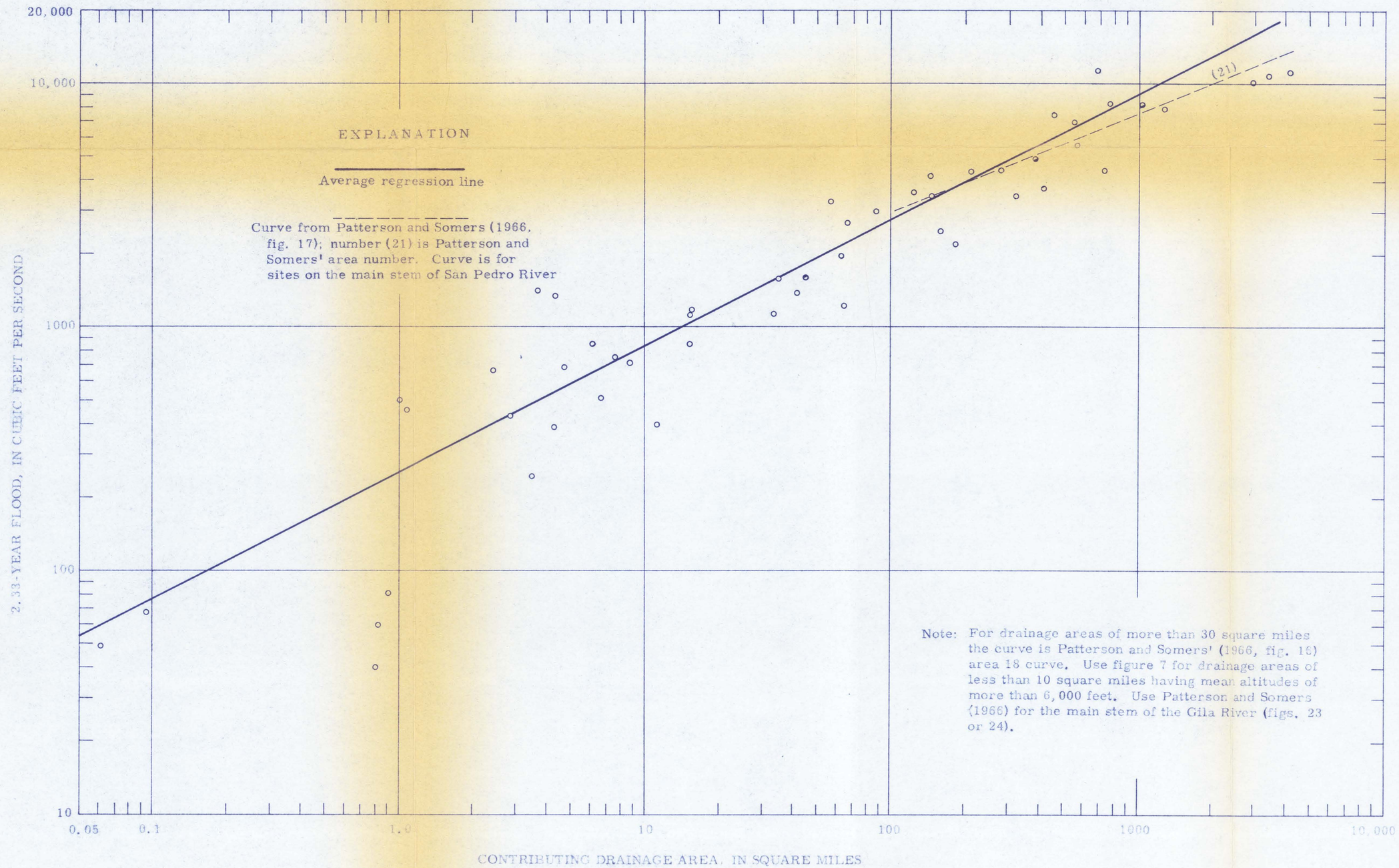


Figure 8.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 7.

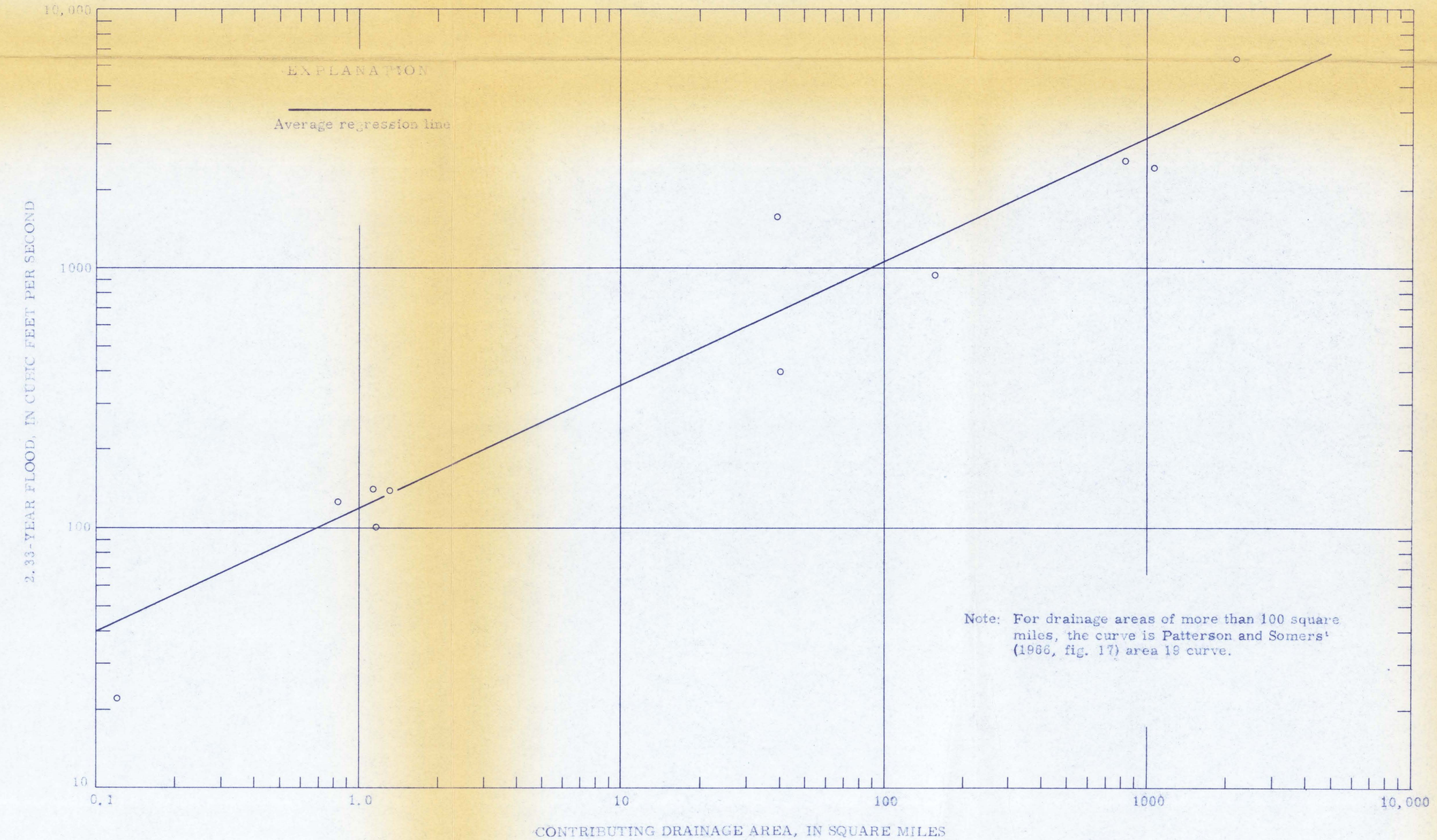


Figure 9.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 8.

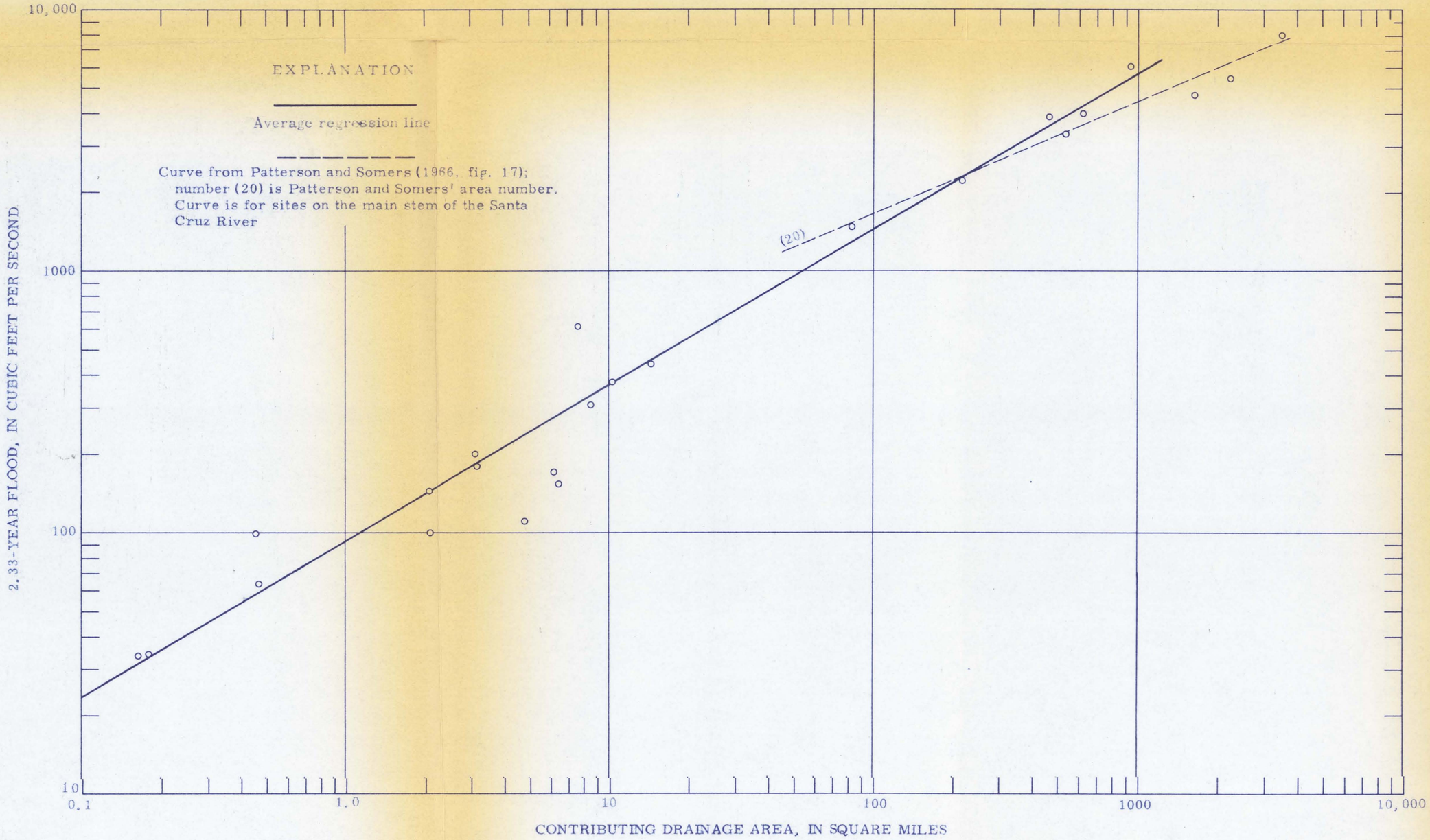


Figure 10.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 9.

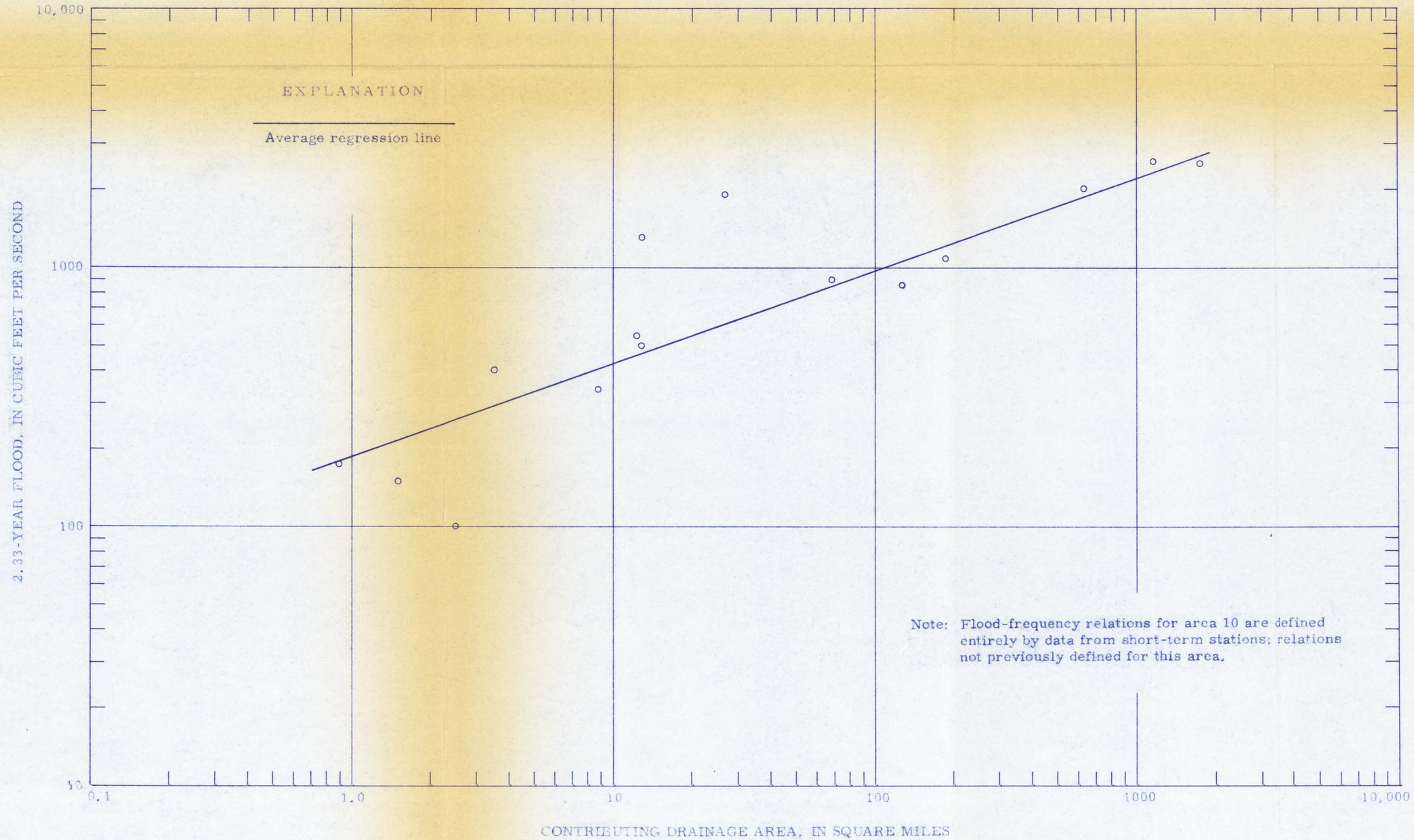


Figure 11.--Relation of the 2.33-year flood to contributing drainage area in hydrologic area 10.

Somers (1966). The new curves are considered to be preferable to those from Patterson and Somers (1966) for all drainage areas of less than 100 square miles and for all sizes of drainage area in hydrologic areas 1 and 6 (fig. 2). Patterson and Somers' (1966) curves should be used for sites on the main stems of the Colorado, Little Colorado, and Gila Rivers.

The curves reflect only average relations between the 2.33-year flood and contributing drainage area. Local conditions may cause peaks at individual sites to differ considerably from those obtained from the curves. Flood peaks from large impervious areas, isolated mountains, and southwestern exposures may be higher than the average; whereas, peaks from valley floors, rain shadows, northern exposures on high mountains, and areas of high permeability or dense vegetation may be lower than the average.

The relations derived from the preliminary analysis may change when more data are available, but they will be useful until more definite relations can be established. In the final analysis attempts will be made to improve these relations by using additional basin parameters; however, it is doubtful that significant improvements can be made because the present spread in data points is less than that which may occur by chance during a short period of record. In the preliminary analysis one attempt was made to determine the effects of parameters

other than drainage area on $Q_{2.33}$. The 2.33-year floods from 12 stations in Yuma and western Maricopa Counties were correlated with the slope and length of the channel, mean altitude of the basin, and a precipitation factor; however, no significant relation was found between $Q_{2.33}$ and any of the variables.

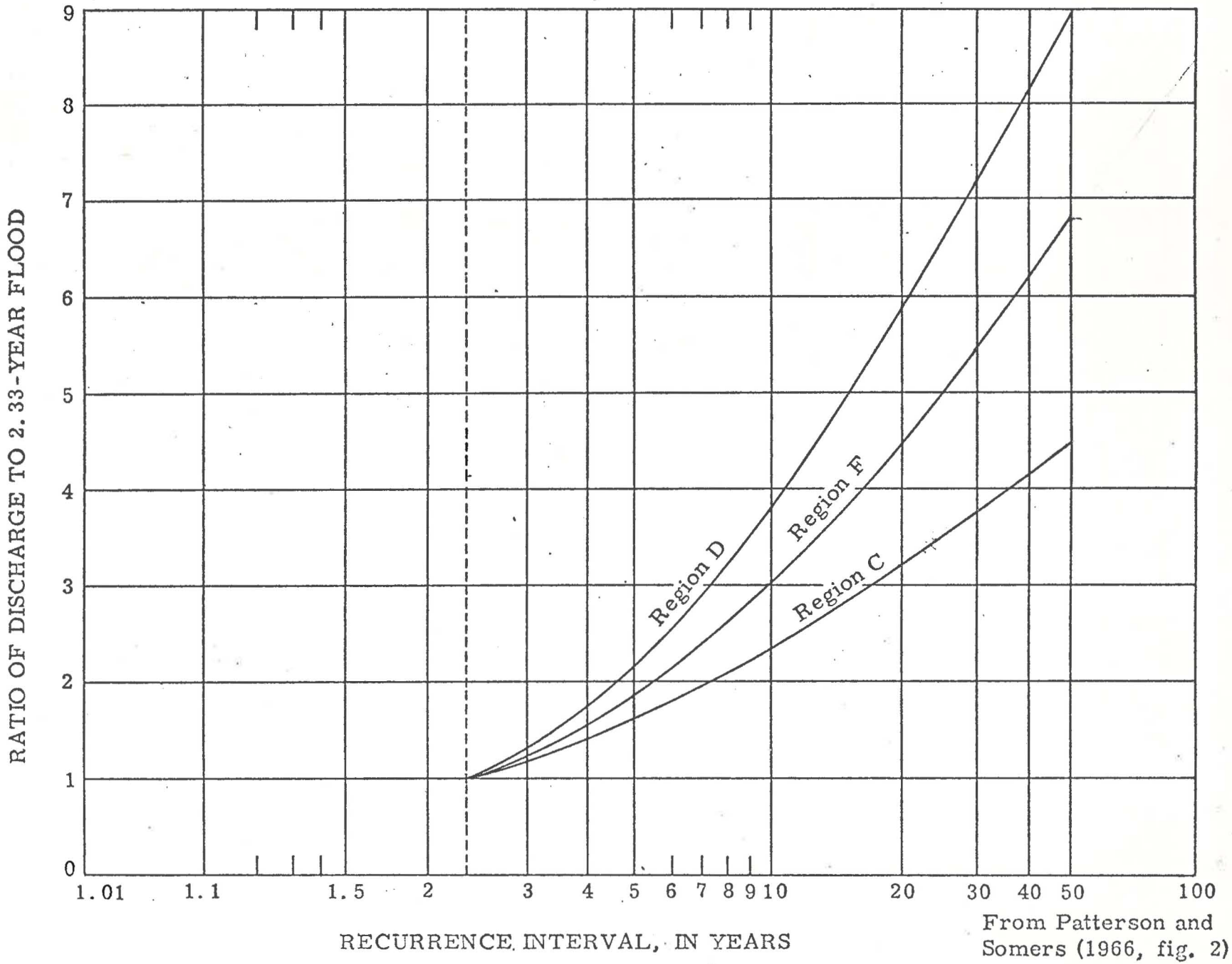
The slope of a frequency curve for an individual station having a short period of record is extremely dependent on whether or not a high peak has occurred during the period of record. The slopes of the frequency curves for many stations in Arizona are extremely steep, and the curves cannot be extended and give a reasonable relation. This is especially true for stations having mean annual floods that are small in proportion to the size of drainage area. Few of the frequency curves for the crest-stage stations in Arizona can be extended beyond a 10-year recurrence interval and retain much reliability; therefore, using the data available, it is impractical to attempt to relate small-drainage-area floods having recurrence intervals of more than 2.33 years to basin parameters or to attempt to develop new composite frequency curves.

A wide range occurs in the ratio of the 10-year flood to the 2.33-year flood at crest-stage stations, but, in general, the average value for a flood region is fairly close to the value obtained from the corresponding composite frequency curve of Patterson and Somers

(1966, fig. 2, p. 4). Until more data become available, the curves from Patterson and Somers (1966) can be used to compute small-drainage-area floods having recurrence intervals of more than 2.33 years. For the convenience of the user, these curves are shown in figure 12. Although the regional boundaries established by Patterson and Somers (1966, pl. 1) are generally satisfactory, there are a few small areas in Arizona where the data indicate that better results might be obtained by using a different curve than that specified by Patterson and Somers (1966). The three flood regions have been expanded to cover the entire State (fig. 13).

The crest-stage-gage data indicate that the composite frequency curve for the western part of the State may be steeper than any derived by Patterson and Somers. Several more years of record will be needed before an adequate composite frequency curve can be developed for that part of the State.

The approximate magnitude of a flood of any recurrence interval can be computed by multiplying the 2.33-year flood given in figures 3-11 by the ratio of discharge to the 2.33-year flood given in figure 12. The boundaries between hydrologic areas or flood regions are not distinct lines in the field, and the user must exercise judgment when computing flood-frequency relations for small drainage areas near a



From Patterson and Somers (1966, fig. 2)

Figure 12. Composite frequency curves for regions C, D, and F, shown in figure 13

Modified from Patterson and Somers (1966, pl. 1)

EXPLANATION

C

Flood-frequency region

Flood-frequency region boundary

1

Areas where short-term data indicate that the curve should be different than that used by Patterson and Somers are:

Area 1, use curve F
Area 2, use curve F
Area 3, use curve C

Note: Data indicate that the composite frequency curve for small streams in southwestern Arizona may be steeper than any of the curves shown in figure 12.

Figure 13.--Flood-frequency regions.

boundary. For some drainages it will be necessary to weight the values for two curves based on the percent of the drainage in each hydrologic area.

Multiple-regression method. --Using data from 33 gaging stations having 8 or more years of record for streams originating in Maricopa County, Hjalmarson (written commun., 1969) has correlated discharges for seven recurrence intervals with eight basin parameters. Using the electronic computer to make a step-backward regression of the data, Hjalmarson derived equations that relate a flood of a particular recurrence interval to the different basin parameters. A different equation was obtained for each recurrence interval. The parameters used in the correlations were size of drainage area, channel length, channel slope, altitude of the drainage area, mean annual precipitation, 10-year 6-hour precipitation, soil index, and density of vegetation. The mean annual precipitation was deleted from the correlation because it was highly correlative with the 10-year 6-hour precipitation, which was the more significant of the two parameters. In Maricopa County, drainage area was one of the least significant parameters for discharges having recurrence intervals of less than 2 years, but drainage area became the most significant parameter for discharges having recurrence intervals of 2 or more

years. Prior to Hjalmarson's analysis, the authors believed that altitude of the drainage area and length of channel would have significant effects on flood discharges; however, in the Maricopa County study, altitude proved to be insignificant in all the correlations, and channel length was significant only in the correlations for the 1.11- and 1.25-year peaks. For floods having recurrence intervals of 2 or more years, the correlations were improved by eliminating altitude and length of channel. The density of vegetation was a significant parameter at and below the 5-year recurrence interval but became insignificant at and above the 10-year recurrence interval. In order of significance other basin parameters that improved the correlations for the 10-year, 20-year, and 50-year floods are: soil index, 10-year 6-hour precipitation, and channel slope. Hjalmarson's correlations using drainage area only were improved slightly by adding one or more of the less significant parameters, as shown in the following tabulation:

Parameter	Standard error of estimate of the regression at the indicated recurrence interval, in log units		
	10-year flood	20-year flood	50-year flood
Drainage area	0.37	0.43	0.49
Drainage area and soil index	.37	.43	.48
Drainage area, soil index, and 10-year 6-hour precipitation	.36	.42	.47
Drainage area, soil index, 10-year 6-hour precipitation, and channel slope	.34	.40	.45

Hjalmarson (oral commun., 1969) has stated that only rough approximations can be made for the soil index and the density of vegetation. The soil index was determined from a generalized map, and the density of vegetation was based mainly on the altitude of the drainage area. More detailed maps and fieldwork will be necessary in order to refine the index values for soil and density of vegetation used in the correlations.

The Maricopa County study may be used as a guide to indicate some of the effects that the different basin parameters may have on flood frequencies elsewhere in Arizona, but additional studies will be

needed before the true significance of any parameter can be determined. In the Maricopa County study, frequency data for individual stations were computed directly from the log-Pearson Type III distribution (Water Resources Council, 1967). All the annual peaks were used, although some of the peaks in the short periods of record were the highest that have occurred in a much longer period of time. In future correlations, frequencies should be adjusted for the effects of the extreme peaks, and more tests should be made to insure that the data are homogeneous. In the initial correlation the Maricopa County data were grouped as a unit, but the county encompasses four of the hydrologic areas shown in figure 2. The slope of the regression curve obtained in the initial correlation may have been affected by manmade developments in both the smallest and largest drainage areas. The smallest drainage area in the county is a well-developed urban area that has a higher runoff rate than undeveloped areas of the same size. The largest drainage area is downstream from a reservoir that impounds all the water from the mountainous part of the basin. This basin has more low-altitude drainage and a longer wide sand channel than other natural basins of this size, and it may have lower runoff rates. In order to verify the relations established for streams in Maricopa County additional peak-discharge data are needed for streams that drain less than 0.5 square mile or more than 500 square miles.

Multiplicative-probability method. --Haynes (written commun., 1967) and Riggs and Golden (written commun., 1969) have used the multiplicative law of probability to compute flood frequencies from maximum floods during short periods of record. The probability that a flood having a recurrence interval of T years will not be exceeded in a period of n years is $p = (1 - \frac{1}{T})^n$. A regional flood-frequency analysis can be made using this concept if it is assumed that peaks are independent among stream sites, that the effects on floods of basin characteristics other than area are negligible, and that the floods occurring in an n-year period are representative of those that will occur in a long period of time.

Using the multiplicative-probability method, the maximum measured flood within a given period of years at each site is plotted against the drainage area for the site, and a line is drawn in such a manner that the computed theoretical number of nonexceedances falls below the line—50 percent of the maximum floods measured in a 10-year period will fall below a line representing the 15-year flood, and 82 percent will fall below a line representing the 50-year flood. Because the theory on which the method is based is independent of the statistical distribution of floods at a site, the method eliminates the need for frequency curves for individual sites. A good possibility

exists that this method will be applicable for computing frequencies for small drainage areas in Arizona where high flows occur from convective storms that cover small areas. Measurements of peak discharges at ungaged sites also can be used, if the discharge is known to be the maximum for the time period used in the study.

A statewide multiplicative-probability analysis has not been made for Arizona, but, as in any other type of analysis, it will be necessary to make this analysis on a regional basis. A pilot study was made for hydrologic area 7 (fig. 2) by applying the multiplicative-probability method to maximum discharges measured at gaging stations and ungaged sites. Curves have been developed for the 15- and 50-year floods (fig. 14).

Comparison of results from the three methods.--It is difficult to make a direct comparison of results from the three methods used in the preliminary analyses because of the many geographic divisions involved (fig. 15). Hydrologic area 7, in which the maximum floods were analyzed, is an elongated area that extends diagonally across most of the State but covers only one corner of Maricopa County. Area 7 encompasses parts of flood-frequency regions C, D, and F. Most of Maricopa County is in hydrologic areas that have smaller 2.33-year floods than those in area 7. It was impractical to limit the study of maximum discharge to either Maricopa County or one flood

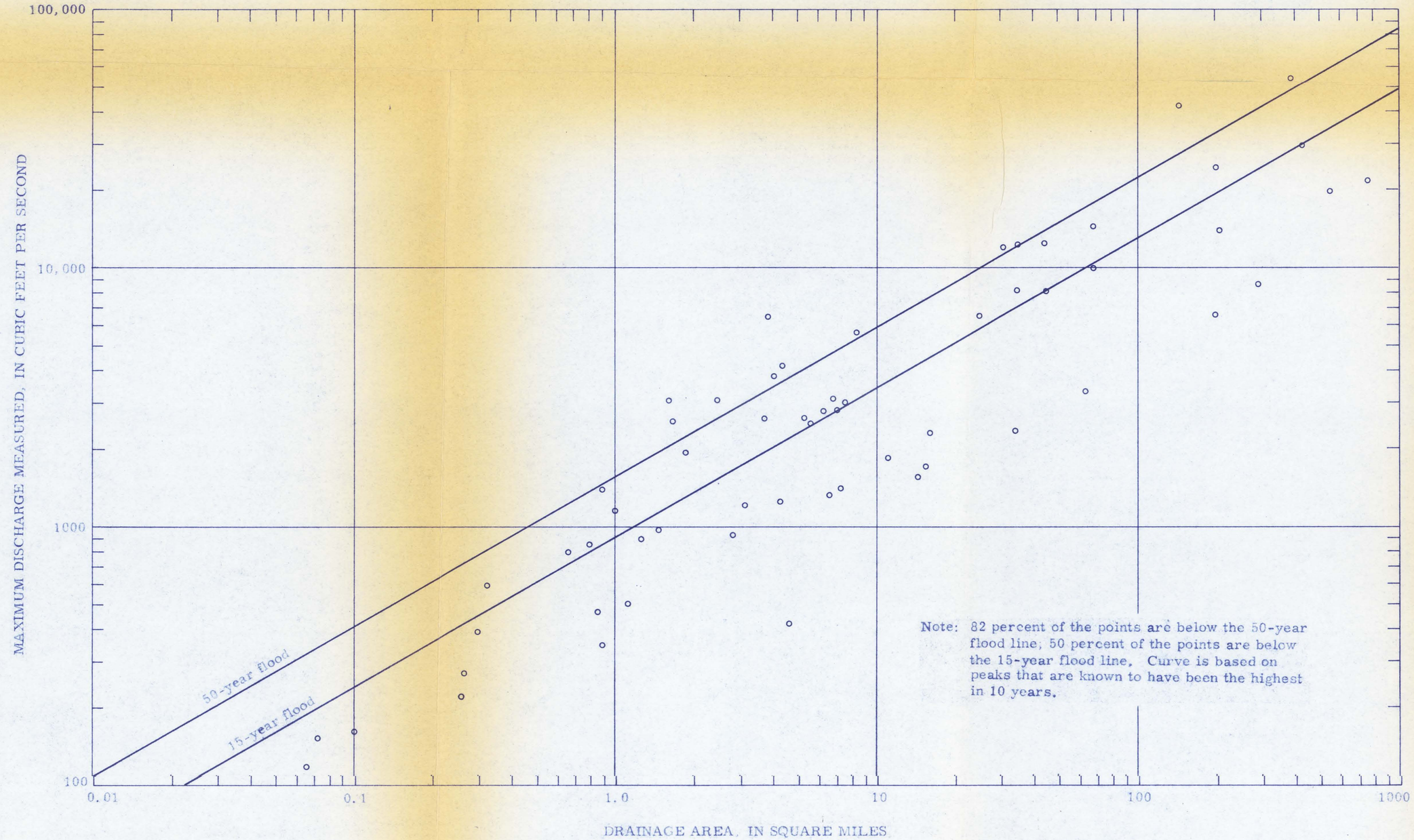


Figure 14.--Maximum discharge at gaging stations and ungaged sites versus drainage area in hydrologic area 7.

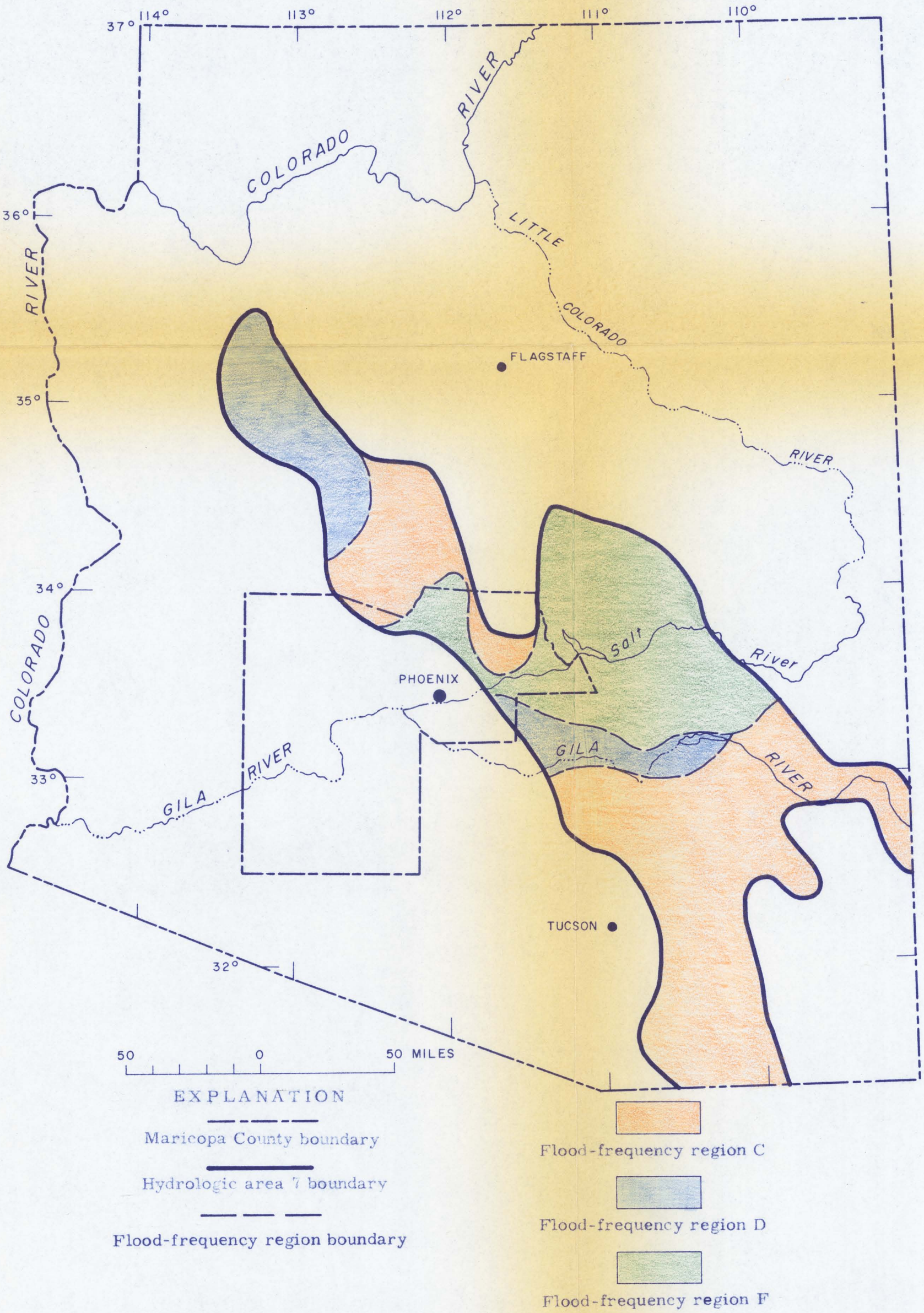


Figure 15. --Relation of Maricopa County to hydrologic area 7 and flood-frequency regions C, D, and F.

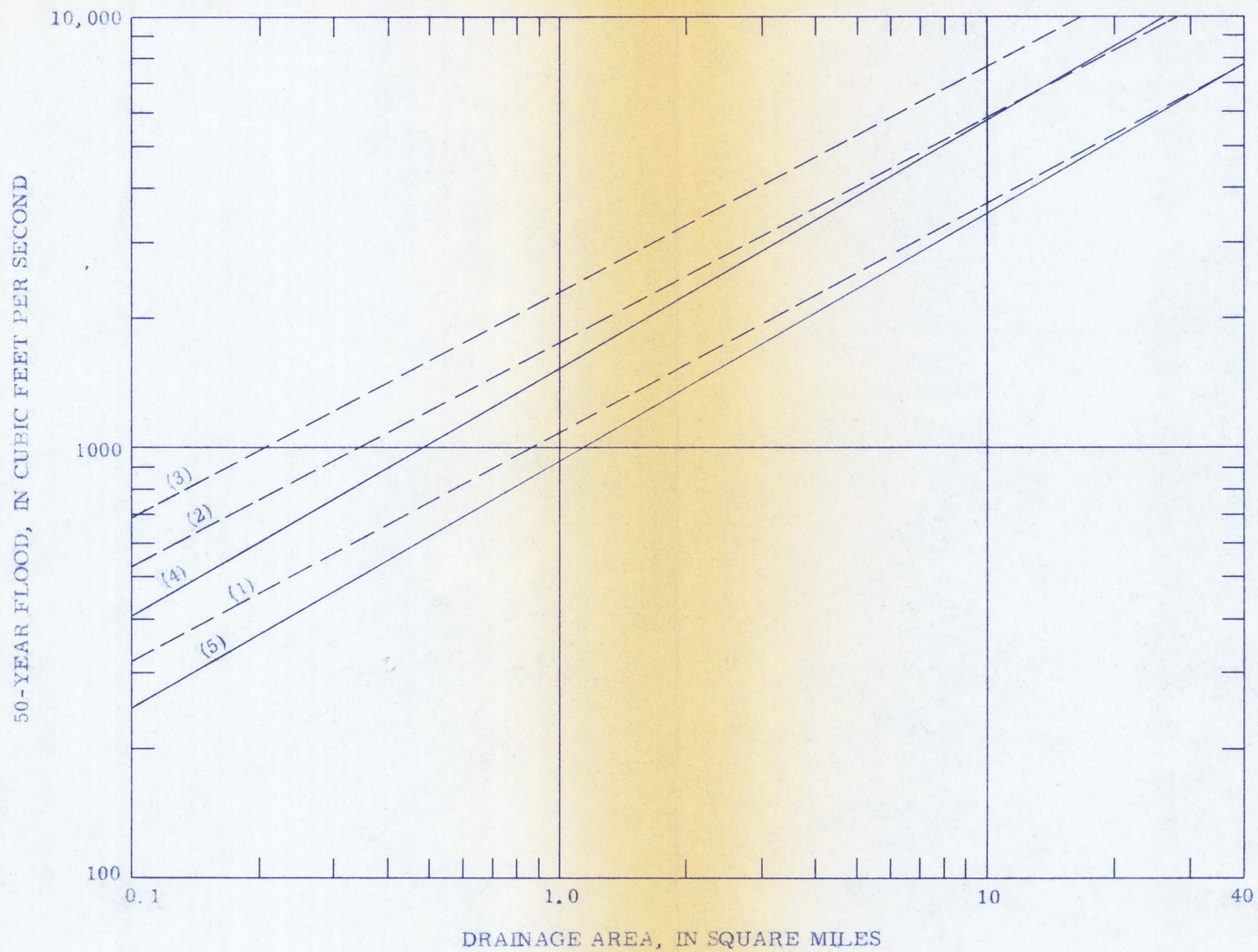
region because the number and range of data points would have been too small for a satisfactory analysis.

Figure 16 shows a comparison of 50-year floods computed by the three methods, which gave results that are in the same general range of magnitude regardless of the many geographic divisions involved. The variations owing to method are about equal to those that result from using different composite frequency curves in the index-flood method.

Volume-Peak Discharge Relations

A preliminary analysis was made of the relation between peak discharge and volume of flow during a runoff event. Flow volumes have been computed for peaks recorded by flood-hydrograph recorders, and the volumes seem to be related to the magnitudes of the peak discharge.

The flood volumes were plotted against the corresponding peak discharges in order to determine if there was a true relation (fig. 17). Data from 11 stations north of the Mogollon Rim were plotted in one group (fig. 17A), and data from 9 stations south of the rim were plotted in another group (fig. 17B). Although the data points are quite widely scattered, they do show a definite trend. An average curve



EXPLANATION

Flood-frequency relations using the index-flood method

Curve 1 is based on composite curve for region C (fig. 12); curve 2 is based on composite curve for region F (fig. 12); curve 3 is based on composite curve for region D (fig. 12)

Flood-frequency relations using other methods

Curve 4 is based on the multiplicative-probability method (fig. 14); curve 5 is based on the multiple-regression method for Maricopa County (Hjalmarson, written commun., 1969)

Figure 16.--Comparison of 50-year floods using three methods in hydrologic area 7 and Maricopa County.

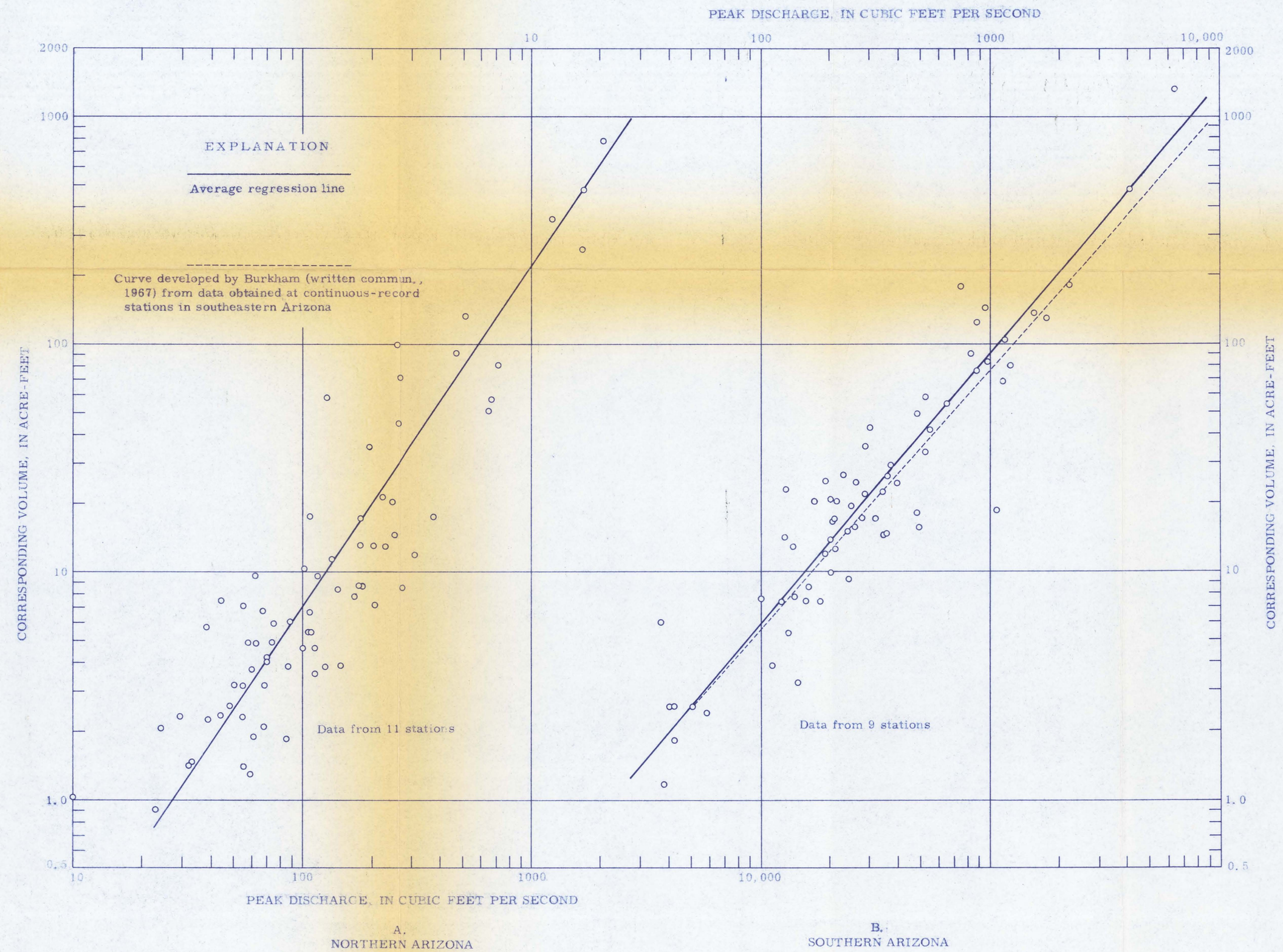


Figure 17.--Relation of runoff volume to maximum discharge during a flow event.

through the data points for southern Arizona closely corresponds to a curve developed by Burkham (written commun., 1967) from data obtained at continuous-record stations in southeastern Arizona. The relations obtained from the preliminary analysis can be expressed in the form:

$$V = CP^a,$$

in which

V = volume of runoff, in acre-feet,

C = coefficient obtained from figure 17,

P = corresponding peak discharge, in cubic feet per second, and

a = exponent obtained from figure 17.

should be 0.026

In northern Arizona the relation is $V = 0.008P^{1.5}$, and in southern Arizona it is $V = 0.26P^{1.18}$. No attempt was made to determine the frequency for the different volumes of flow, but usable relations probably can be developed by computing the frequency directly or by determining the frequency of peak discharges and relating them to volumes.

CONCLUSIONS AND FUTURE PLANS

Preliminary analyses have been made of the flood-frequency relations in Arizona using peak-discharge data from crest-stage stations in Arizona and adjacent States in conjunction with data from continuous-recording stations. Curves relating the 2.33-year flood to contributing drainage area were defined. These curves may be used in conjunction with previously developed regional composite frequency curves to obtain the approximate magnitude of floods having any recurrence interval from 2.33 to 50 years for any place in the State. In Maricopa County the multiple-regression method was used to correlate floods of seven recurrence intervals with eight basin parameters. The multiplicative-probability method was used to relate maximum discharge to drainage area in hydrologic area 7. The results obtained in this area using the three methods are of the same general magnitude. The results of the preliminary flood-frequency analyses are encouraging and indicate that floods from small drainage areas can be related to size of drainage area, and possibly to other basin parameters, when longer periods of record and better areal coverage are available. A preliminary analysis of runoff volumes indicated that volumes can be related to peak discharges.

The flood data should be reanalyzed after a few more years of record are available. It is envisioned that the multiple-regression method will be the primary method for regional flood-frequency analysis, although other methods discussed in this report may be used. Streamflow records are being studied to determine if mean, low, and high flows of different durations can be related to basin parameters, and the knowledge gained from this study will be a valuable aid in analyzing floods from small drainage areas.

The preliminary analyses have provided a means for evaluating individual gaging stations and the statewide gaging station network. In the preliminary analyses some data points deviate considerably from the average regression lines. The deviation may be the result of the extreme variability in runoff during the short period of record, variability of hydrologic conditions in the drainage area being studied from those of the surrounding area, or the quality of the records. The data from which each of the incongruous points was derived will be studied to determine the cause of the anomaly; if the cause of the anomaly is found to be in the station data and the data cannot be improved, the station will be discontinued. The preliminary analysis has shown that in some areas additional stations should be installed to provide better areal coverage and a larger range in size of drainage area.

A minimum of 10 years of record will be needed before a final analysis can be made of the flood-frequency relations in small drainage areas, and better results will be obtained if 15 or 20 years of record are available. Therefore, the data-collection program should be maintained at about its present level for at least 6 more years and preferably longer. After the final analysis, it may be desirable to maintain some stations on a semipermanent basis in order to provide a small monitoring network.

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