Magnitude and Frequency of Summer Floods in Western New Mexico and Eastern Arizona

by

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U. S. Geological Survey
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Introduction

Numerous small reservoirs and occasional water-spreading structures are being built on the ephemeral streams draining the public and Indian lands of the Southwest as part of the Soil and Moisture Conservation Program of the Bureau of Land Management and Bureau of Indian Affairs. Economic design of these structures requires some knowledge of flood rates and volumes. Information concerning flood frequencies on areas less than 100 square miles is deficient throughout the country, particularly on intermittent streams of the Southwest. Design engineers require a knowledge of the frequency and magnitude of flood volumes for the planning of adequate reservoir capacities and a knowledge of frequency and magnitude of flood peaks for spillway design. Hence, this study deals with both flood volumes and peaks, the same statistical methods being used to develop frequency curves for each.

It is proposed to summarize in this study the present knowledge of the magnitude and frequency of floods on ephemeral streams draining a portion of the arid Southwest. At the present time most of the soil and moisture conservation work on the public lands in this region is located in eastern Arizona and west of the Rio Grande in New Mexico. The bulk of these lands is semidesert where runoff in the "dry washes" occurs almost exclusively as a result of sporadic summer thunderstorms. All available records of stream flow in this region were examined with the intention of developing regional flood-frequency relationships which might serve as guides in hydraulic design problems of the Soil and Moisture Conservation Program. All available records

...streams in the semidesert lands were used in this analysis. Fifty-one such records were found. The lengths of the records are summarized in the following compilation:

Length in years:	3-4	5-9	10-14	15-19	20-29	30-39
Number of records:	7	17	14	6	4	3

All records for drainage areas larger than 75 square miles were obtained from U. S. Geological Survey water-supply papers. Of the runoff records for smaller drainage areas, 7 appear in U. S. Geological Survey publications and 18 were obtained from the files or published reports of the Soil Conservation Service. Of the 7 U. S. Geological Survey records, all except the record for Sabino Creek near Tucson, Ariz., and Tucson Arroyo at Tucson, Ariz., are considered poor because of unstable channel conditions. The Soil Conservation Service records are of uncertain quality, although all stations were equipped with water-stage recorders and artifical controls. Excessive sediment deposition near the controls is largely responsible for the uncertainty of the records. The controls for stations on the small drainage areas were weirs, a model of which had been calibrated at a hydraulic laboratory. Stations for large basins were rated by current meter.

The accompanying map (Plate I) shows the location of all gaging stations. A list of the stations shown on Plate I is given in table 1.

Method of analysis

After having selected the gaging station records to be studies, the next step was to compile an annual flood series for each station. An annual flood peak is considered as the highest instantaneous discharge rate observed during a water year. For the purposes of this report an annual flood volume is the greatest consecutive 3-day runoff, including the peak, observed during the water year. An annual flood series is a list of these single annual events.

Discussion of computation methods will be confined to flood volumes with the understanding that the same methods were followed with regard to flood-peak rates.

Reason for the choice of consecutive 3-day runoff as a flood volume unit is explained as follows: During the summer flood season on the desert range lands of the Southwest, runoff from areas of less than 100 square miles usually occurs as a flood flow of relatively brief duration, the stream channel being dry before and after the flood. Examination of the records of flow of such streams indicates that almost all summer floods endure for not more than 3 days. For all practical purposes it may be said that the same is true for larger watersheds. A low base flow may persist for varying lengths of time after a flood has passed from a basin of several hundred square miles, but usually the three consecutive days of highest runoff will be found to include 90 percent or more of the total flood runoff.

For each of the stations listed in table 1, the maximum flood volumes for all the years of record were arranged and numbered in order of magnitude. Having these data there is known the relative distribution of floods in a given period of years. The problem then is to determine what recurrence intervals these discharges represent. The formula used in this report is simple and gives results acceptably in conformance with some of the latest statistical theories. Recurrence intervals in years, T, are computed from the formula $\frac{N+1}{M}$ in which N equals number of years of record and M equals relative magnitude of the event, beginning with the highest as number one.

The annual-flood volumes for each station are then plotted on a special chart (see fig. 1 as an example). The vertical scale shows the volume of flood runoff, and the scale of recurrence intervals is graduated in accordance with the theory of largest values. Curves were fitted to the plotted data by inspection (see fig. 1). The charts for each station are not applicable directly to ungaged area. The records cover different periods of time, and experience has demonstrated that the average of the annual floods for one station may not be compared with the average for another station with a different period of record. Furthermore, many of the flood records are short and the sampling errors correspondingly large. It is therefore necessary to combine the flood data for the region to reduce the large sampling errors, to give the data regional significance, and so to make the flood frequency studies applicable to ungaged areas.

The procedure used in combining regional flood data was as follows: As long a period as possible was chosen during which a representative group of gaging stations was operated. In this case the 21-year period, 1930-50, was selected. The purpose was to determine the average annual-flood volume in the base period for each of the 15 stations shown in table 2. This average is not the simple arithmetic average but a graphical mean determined by the intersection of the visually best-fitting frequency line with the mean line (the line corresponding to the 2.33-year recurrence interval). This method of determining the mean in effect gives greater weight to the medium floods than to the extreme floods that have large sampling errors. The graphical mean then is not influenced adversely by the chance inclusion or exclusion of a major flood, as is the simple arithmetic mean.

It should be noted that only a few of the stations shown in table 2 have a record covering the full 21-year period. For purposes of this study the record of the other stations is expanded to the 21-year period by the methods discussed below.

The graphical mean annual flood for each of the 15 stations is determined by plotting the 1930-50 record on frequency charts and drawing the best fitted curve for a short interval on either side of the 2.33-year line. However, to do this the recurrence intervals computed for each flood of a record shorter than the 21-year base period must be the same as they would have been had the record been complete for this period.

The method by which recurrence intervals for a short record may be adjusted to the longer period consists of computing a figure for each year of the base period for which no record was obtained. The record would then be considered complete for the purpose of determining the graphic mean (and for making a test for homogeneity). The computed figures are not considered true discharges; they are "computation figures," inserted to avoid bias in the computation of the mean annual floods. These computed figures are obtained by comparison of records for the short-term station with records for a long-term station by means of a graph correlating annual floods of the same year at both stations.

An order number is assigned to each flood observed or computed and recurrence intervals computed for each observed flood runoff. The floods are then plotted on frequency charts and a curve drawn to obtain the 2.33-year, or graphical mean, flood runoff.

Each annual flood that was actually measured is divided by the graphical mean. This ratio expresses all floods in dimensionless terms and places them on a comparable basis; that is, all are measured in relation to the station mean flood for the standard period 1930-50.

The flood frequency graphs for the 1930-50 period referred to above do not have the same slope at each station. If it can be established that the difference in slopes is no greater than might be expected from random errors or vagaries of sampling, then several records may be combined to obtain an average flood frequency curve that will be more dependable than any one of the individual curves and that can, therefore, be applied throughout a region.

The test requires a study of the 10-year floods as estimated at each station. The 10-year flood obtained from the frequency graphs for each station is divided by the mean flood to get the 10-year ratio. These ratios are averaged. Then for each station there is listed the length of record in years and the recurrence interval corresponding to a discharge equal to the average 10-year flood ratio times the mean flood, (see table 2).

If it is assumed that each station represents a different sample from a single homogeneous record, then the recurrence intervals will not differ among themselves by an amount greater than can be attributed to chance. A chart (see fig. 2) has been set up to test this supposition. It shows what range of recurrence interval can be expected for the estimated 10-year flood, 19 chances out of 20. In using the chart the effective length of record may be taken as $N_o + 0.5 N_e$, in which N_o is the number of years of observed record, and N_e is the number of years for which "computed values" for annual flood volumes were estimated. The recurrence intervals taken from table 2 are plotted against the effective length of record on figure 2. It will be seen that all points lie between the limiting curves and, therefore, there is no reason to presume that the records lack homogeneity.

Having tested the homogeneity of the 15 records which are to be combined, the flood ratios for each station were then listed in order of magnitude.

Order number one, of course, refers to the greatest measured flood at each station, number two the second highest, and so on. For each order number the median flood ratio together with the corresponding recurrence interval were tabulated and then plotted on a frequency chart (see fig. 3). The curve defined by these plotted points showing flood volumes in ratio to the mean annual flood volume may be considered as representing the most likely flood-frequency values for the region for recurrence intervals up to about 20 years.

Since major interest is centered upon rare floods of at least 50-year magnitude, it was necessary to extrapolate the curve shown in figure 3 beyond the 20-year recurrence interval. The station-year method was used to guide this extrapolation. If, for example, 5 records of 20 years each can be combined to obtain a 100-year record, then the accuracy of predictions can be increased through reduction of the sampling errors. In applying the method to flood frequency studies, it is required that the flood frequency characteristics be comparable and that the data be independent.

It has been shown that the longer records for the region appear to be homogeneous. Since the floods under consideration almost invariably result from localized thunder storms, they may be considered as independent events rather than floods produced by extensive general storms.

A form of station-year analysis appears on Table 3. Here the maximum flood of record is listed for each of 16 stations selected from those listed in table 1 whose aggregate record equals 336 years. The dates show that the maximum floods occurred in different storms, and thus may be considered independent events. The maximum flood is divided by the mean annual flood and a recurrence interval assigned to the flood ratios in accordance with the formula $T = \underline{336 + 1}$ in which M is the order number of the flood ratio, 1 being assigned to the greatest ratio, and 336 is the sum of the periods of record observed at each station. These ratios were plotted on figure 3 to define the upper end of the curve.

The flood-frequency distribution computed as above may be applied to the ephemeral streams draining the desert range lands of the Rio Puerco and Mimbres basins in New Mexico and that area in Arizona south of Gila River between Santa Cruz River and Peloncillo Mountains along the Arizona-New Mexico state line. It may also be applicable to the eastern part of the Little Colorado River basin. Moenkopi Wash near Tuba is comparable to Rio Puerco and southeast Arizona stations, but this is the only long-term record available for the desert basin part of the watershed. Figure 3 should not be applied to small drainage areas in higher mountainous areas of the region. Precipitation is appreciably greater on these areas than on the intermountain basins, and floods from small areas in the mountains may be considerably greater than floods from comparable areas on the lower plains.

Application to ungaged areas

In order to apply the flood frequency distribution curve to ungaged areas, it is necessary to estimate the mean annual flood for each area. This involves a correlation analysis of the observed mean floods with drainage basin characteristics.

Assuming that the region is meteorologically homogeneous, the most important basin factors which affect the mean flood volume are area, topography, and soil infiltration capacity. The mean flood peak rates are also influenced by additional factors such as shape of drainage basin and channel storage. Of these the most important appears to be area, the factor on which information is most readily available. Measuring other basin features is more difficult and, unless good topographic maps and information on infiltration rates are available, it may be impossible.

The region considered in this study has not been adequately mapped for the most part, hence, basin area is the only feature which may readily be correlated with mean floods. The correlation employed is a simple plotting of annual mean floods against drainage area on logarithmic paper.

As some of the station records were obtained prior to the base period 1930-50 used in developing the combined frequency graph on figure 3 and some short records would not correlate with any of the longer records, not all values for mean annual floods to be related to drainage area were adjusted to a common period. In each case, however, the probable range in values for the mean annual flood was computed. The range varies inversely with the length of record. The computation is based on the table below where N is the length of record and T is recurrence interval in years.

Limits
(one standard deviation)

N	Upper T	Lower T
3	4.7	1.45
4	4.3	1.5
5	4.0	1.5
6	3.8	1.5
7	3.6	1.6
8	3.5	1.6
9	3.4	1.6
10	3.3	1.7
15	3.1	1.8
20	3.0	1.8
25	2.9	1.9
30	2.85	1.9
35	2.8	1.9
40	2.75	1.9

An example will illustrate the use of the table. Station No. 2, Rio Puerco near Cabezon, has a 6-year record. The annual floods were plotted on a frequency chart and a curve fitted by inspection. From the preceding table it was found that the mean annual flood value may be expected to lie between flood values whose recurrence intervals are 1.5 and 3.8 years. One enters the frequency curve, based on the observed 6-year record, at recurrence intervals 1.5 and 3.8 years and derives values of 440 and 660 cfs-days. These figures define the probable range of the mean annual floods at Rio Puerco near Cabezon. The mean flood is not, therefore, plotted against drainage area as a point, but as a line extending from 440 to 660 cfs-days (see fig. 4). Such range lines were plotted on figures 4 and 5 for all stations. It was evident that two curves would average the observed data.

Mean annual flood volumes recorded at gaging stations in western New Mexico and in San Simon Creek, Arizona, for areas of more than 10 square miles, line up fairly well when plotted against drainage areas, as shown on figure 4. The solid line on figure 4 is presented as an average of the plotted floods, the longer-term records being given greater weight. For the purpose of estimating mean annual flood volumes from ungaged areas, it may be assumed that figure 4 is applicable to Areas 1, 2, 3, and 4, shown on the drainage map, Plate I.

Figure 5 is a similar curve applicable to Area 5, which includes the Santa Cruz and San Pedro River basins and the mountainous area near the southeast corner of Arizona at the headwaters of San Simon Creek and Whitewater Draw. Considerably greater flood volumes may be expected from this area as compared with Areas 1 to 4.

Frequency analysis of flood-peak discharges

As was mentioned previously a frequency analysis of flood peak discharges was made using the same methods as those employed in dealing with annual consecutive 3-day volumes. The gaging station records used in the analysis are listed in Table 1. The generalized flood frequency curve derived from these data appears as figure 7. It is applicable to the same region as the flood-volume frequency curve with the exception of Area 4, this exception to be discussed later. Figures 8 and 9 show the relation between mean annual peak discharges and drainage areas, from which mean annual peak discharges for ungaged basins may be estimated. Figure 8 applies to Areas 1, 2, and 3; and figure 9 applies to Area 5.

An inspection of figures 4, 5, 8, and 9 reveals that, in general, relatively low peak discharges are associated with low flood volumes in Areas 1, 2, 3, and 4; whereas high rates and large volumes occur in Area 5. Convectional storms apparently are characterized by higher intensities and higher total precipitation in Area 5 as compared to the other parts of the region.

Precipitation intensity data for the region are meagre, but the data that are available illustrate this trend. Leopold's (1944) values for average summer maximum 24-hour precipitation clearly indicate greater severity of summer storms over the Santa Cruz, San Pedro, and Sulphur Springs basins as compared to the Middle Rio Grande and San Simon Creek. Soil Conservation Service studies (Dorrah, 1945) of precipitation intensities made by the regional office at Albuquerque also show southeast Arizona to be a center of greater convectional storms. It should be noted that San Simon Creek lies within this region of greater storms but has no recorded floods comparable to those observed on San Pedro and Santa Cruz Rivers. The San Simon basin topography may be such that storms tend to override the area.

There are other flood anomalies which can best be discussed by further consideration of figures 4, 5, 8, and 9 relating mean floods to drainage areas. Beginning with figure 4, it will be noted that the San Jose River Stations No. 6

and 7 plot considerably below the mean curve, indicating very low flood volumes for these stations. Flow from the upper 215 square miles of the San Jose watershed is almost completely regulated by the Bluewater-Tolte Reservoir (capacity 46,000 acre-feet). This has been taken into account by reducing the drainage area for Stations 6 and 7 by 215 square miles. Between Bluewater Reservoir and Station 6 there are 5,100 acres irrigated by diversion from the river or by ground water withdrawals. Between Stations 6 and 7 there are three small storage reservoirs serving an irrigated area of 3,500 acres. This irrigation activity reduces flood flows to some extent although the principal reason for the low San Jose flood volumes is believed to be due to excessive channel losses. The San Jose River flows through fissured lava beds from a point considerably above Grants to Laguna. It is thought that losses through the permeable lava in this reach are great enough to reduce flood volumes substantially.

The probable range of values for mean annual flood volumes at Station 30, San Simon Creek near Rodeo, also extends considerably below the mean curve on figure 4. The Rodeo records are of dubious quality. This station as well as Stations 32, 33, 34, 39, and 40 were operated by the University of Arizona from 1920 to 1925. All were operated as non-recording stations, and it is not known how well flood stages may have been observed. Moreover, it may be said that it is nearly impossible to obtain reliable volume data on flash floods without recording instruments. Returning again to the plotted flood data, it is seen that, whereas the range line for Station 30 drops to a very low value on figure 4, the range lines for Stations 23, 39, and 40 extend well above the mean curve on figure 5. Since all four stations are relatively near each other, it seems most unlikely that flood volumes would be very low at one station and very high at the other three. Little weight should be given the results obtained at these stations individually.

Turning to the flood peak graph, figure 8, it is evident that the San Jose River Stations 6 and 7 exhibit very low flood peak rates. This may be attributed to excessive channel losses and irrigation diversions which were discussed previously in connection with flood volume anomalies. It is not known why the Soil Conservation Service Station 13 near Santa Fe shows such a low peak flood rate.

The high peak discharges observed at most of the Mexican Springs stations, Nos. 18-26, as well as Tijeras Creek near Albuquerque, No. 15, and Soil Conservation Service Station 36 near Safford are probably related to topographic features of their respective drainage basins. With the exception of Mexican Springs Station 24, all these drainage basins possess steep prevailing slopes which favor high peak discharges. Although flood volumes at these stations are similar to the volumes observed at other stations in Areas 1 to 4, the peak rates are comparable to those observed in Area 5. The range lines are plotted on the Area 5 mean annual peak rate curve, figure 9, as dashed lines to demonstate this.

Use of figure 8 in estimating the flood discharge for Whitewater Draw near Douglas, Arizona, Station 41, has been found to give erroneous results. However, in testing for homogeneity, figure 6, table 4, it was found that peak rates at Station 41 are not comparable to those observed elsewhere, hence the regional frequency curve, figure 7, cannot be used in that vicinity. The frequency curve defined by the Station 41 record indicates flood peaks of much lower magnitude than does the regional frequency curve for recurrence intervals beyond 2 years. In this regard it is significant to note that the highest peak of record at Whitewater Draw near Douglas lies close to the regional frequency curve while the next lower annual peak lies far below the regional curve. The No. 1 peak is almost three times as great as the No. 2 peak. It may be that this represents one of those odd samples whose idiosyncracy is due to chance alone and that with time this station's flood experience will approach the regional norm.

As a check on the upper end of the regional flood peak frequency curves, a plot of discharge against drainage area was made of the highest floods of record for the region (see Table 5 and 6, fig. 10). The 100-year flood peak curves are shown on this figure. It will be seen that the estimated 100-year floods lie among the higher floods of record.

Use of the method in estimating flood volumes and peak discharges.

To illustrate the use of the foregoing frequency data in estimating floods at an ungaged site, the following examples are presented: Suppose a 50-year flood peak and volume is required for a tributary of the Chico Arroyo in Area 1. Assume the drainage basin above the point of interest is 10 square miles. If there are no exceptional basin abnormalities, the mean or middle curves on figures 4 and 8 are entered at 10 square miles, and a mean annual flood volume and peak flow rate are found to be respectively 24 cfs-days and 320 cfs. Figure 3 is then entered at the 50-year recurrence interval to obtain a ratio of 50-year to mean annual flood volume of 3.72. The 50-year flood volume is then 24 cfs-days multiplied by 3.72, or 89 cfs-days. Similarly, figure 7 is entered at the 50-year recurrence interval for a ratio of 50-year to mean annual peak of 3.65. The mean annual flood peak of 320 cfs is multiplied by this ratio, 3.65, to obtain 1,170 cfs as the 50-year peak discharge.

The accuracy of flood frequencies computed in this manner are chiefly dependent on the accuracy of the estimated mean annual flood. Other characteristics, aside from area, are known to influence flood flows. These will be studied in a correlation analyses planned for the future in an effort to increase the accuracy of flood estimates for ungaged areas.

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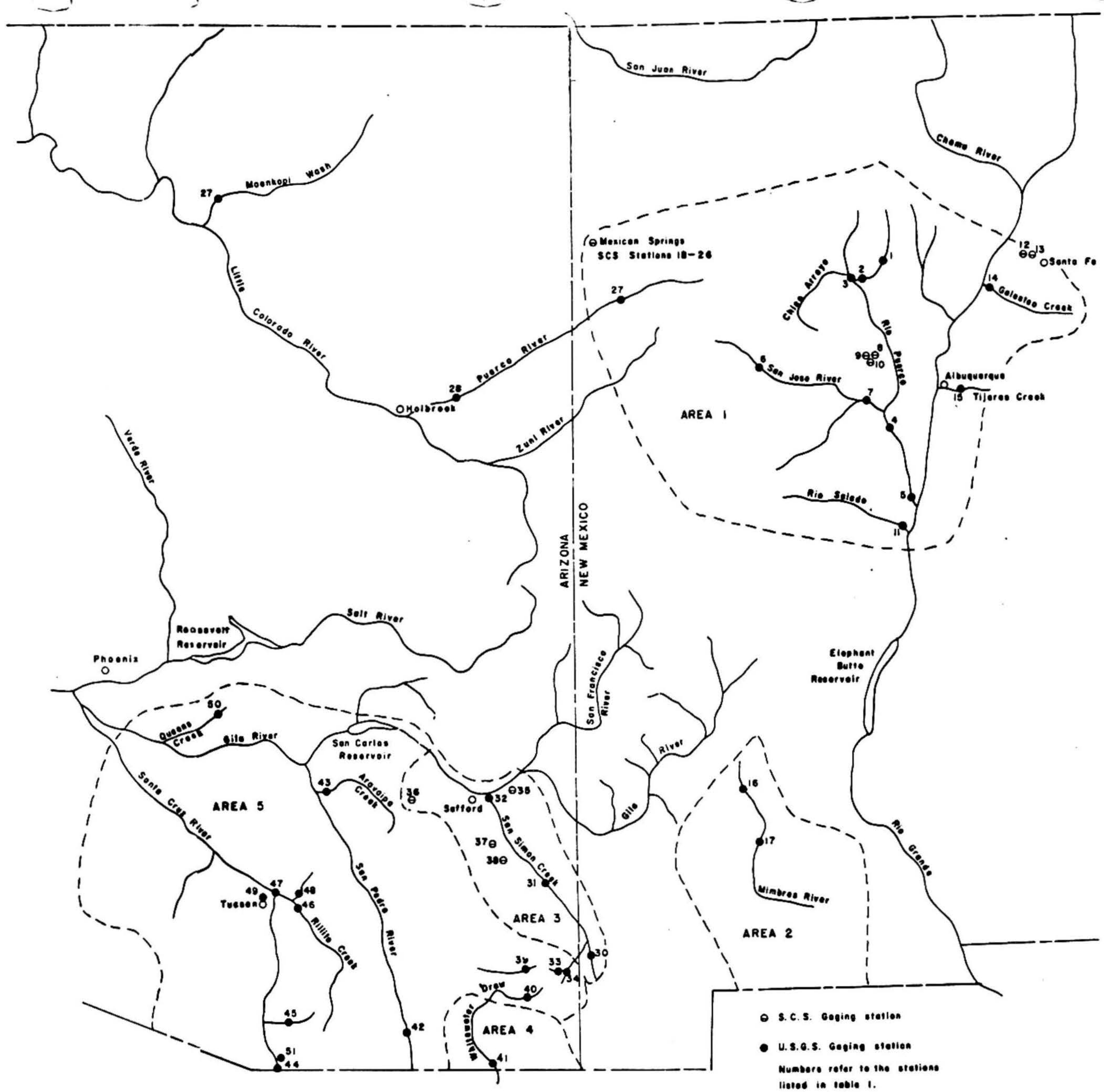

Plate I

Map of eastern Arizona and western New Mexico showing location of gaging stations for which flood records were available for this study and showing areas of comparable flood characteristics.

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Table 1.--Stations with record of summer flood flows

Sta. No.	Gaging Station	Period of Record	Drainage Area sq. miles	Mean Annual Flood Q 2.33 Volume cfs days	Q 2.33 Peak Rate cfs
	NEW MEXICO				
1	Rio Puerco nr. Cabezon	1943-50	360	556	2,130
2	Rio Puerco at Cabezon	1946-51	397	556	1,600
3	Chico Arroyo nr. Guadalupe	1944-51	1,390	2,100	7,100
4	Rio Puerco at Rio Puerco	1913-51	5,160	5,700	10,800
5	Rio Puerco nr. Bernardo	1940-51	5,860	5,900	8,700
6	San Jose River nr. Grants	1937-51	875[a]	122	260
7	San Jose River at Correo	1910-13, 1943-51	2,415[a]	910	2,700
8-10	SCS stations on Montano Grant nr. Albuquerque				
8	W-1	1939-52	0.125	0.68	47
9	W-2	1939-52	0.063	0.37	21
10	W-3	1940-52	0.242	0.56	18
11	Rio Salado nr. San Acacia	1948-51	1,380	825	5,500
12&13	SCS stations nr. Santa Fe				
12	W-1	1939-48	0.22	0.72	38
13	W-2	1940-49	1.23	0.80	13
14	Galisteo Cr. nr. Domingo	1942-51	640	775	5,500
15	Tijeras Cr. nr. Albuquerque	1921, 1943-48	74	70	2,500
16	Mimbres River nr. Mimbres	1922-25, 1927 1929-50	183	265	800
17	Mimbres River nr. Faywood	1917-19, 1930-50, 1908-10	485	680	4,000
18-26	SCS station at Navajo Experiment Station				
18	Parshall Wash	1937-40, 1942	0.95	4.0	310
19	Mexican Springs	1937-42	32.7	82	2,000
20	Catron Wash	1937-40, 1942	26.9	72	2,000
21	Figueredo Wash	1937-39, 1942	72.0	130	2,250
22	Norcross Wash	1937-39, 1942	3.98	5.3	170
23	Black Creek	1937-39, 1942	7.41	18.8	390

a - Drainage area above station has been reduced 215 sq. miles (see text for explanation).

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Table 1. (Continued) (2)

Sta. No.	Gaging Station	Period of Record	Drainage Area sq. miles	Mean Annual Q 2.33 Volume cfs days	Flood Q 2.33 Peak Rate cfs
24	Horsepasture Wash	1938-42	0.29	0.37	28
25	Lower Crevasse	1938-40, 1942	13.3	20	800
26	Chusca Wash	1940-42	8.67	16	820
27	Puerco River nr. Gallup	1940-45	558	620	2,550
	ARIZONA				
28	Puerco River nr. Adamana	1940-49	2,760	5,100	13,400
29	Moenkopi Wash nr. Tuba	1927-50	2,270	2,340	6,000
30	San Simon Cr. nr. Rodeo	1920-25	454	170	c
31	San Simon Cr. nr. San Simon	1920-25,	803	740	3,150
		1931-33,			
		1935-40			
32	San Simon Cr. nr. Solomon	1931-33,	2,280	1,660	7,000
		1935-50			
33	E. Turkey Fork nr. Paradise	1920-25	8.2	92	c
34	Cave Cr. nr. Paradise	1920-25	39	550	c
35-38	SCS stations nr. Safford				
35	W-1	1939-52	0.81	4.6	90
36	W-2	1940-52	1.07	6.5	470
37	W-4	1939-50	1.19	3.6	113
38	W-5	1939-52	1.13	3.2	103
39	W. Turkey Fork nr. Light	1920-25	19.0	680	c
40	Whitewater Draw nr. Rucker	1920-25	40.0	610	c
41	Whitewater Draw nr. Douglas	1915, 1918,	1,023	1,250	2,570
		1931-33,			
		1935-50			
42	San Pedro River at Charleston	1913-14,	1,220	4,250	9,000
		1915-33,			
		1935-50			
43	Aravaipa Cr. nr. Feldman	1919-21,	540	1,850	7,300
		1931-41			
44	Santa Cruz R. nr. Nogales	1914-19,	542	1,190	4,150
		1931-50			

c = No instantaneous flood peak data available

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Table 1. (Continued) (3)

Sta. No.	Gaging Station	Period of Record	Drainage Area sq. miles	Mean Annual Flood Q 2.33 Volume cfs days	Q 2.33 Peak Rate cfs
45	Sonoita Cr. nr. Patagonia	1930-33, 1935-50	210	530	3,500
46	Rillito Cr. nr. Wrightstown	1940-45	221	650	2,300
47	Rillito Cr. nr. Tucson	1914-50	916	1,550	6,300
48	Sabino Cr. nr. Tucson	1932-50	35	405	1,040
49	Tucson Arroyo at Tucson	1944-50	21.5	132	1,200
50	Queen Cr. nr. Superior	1916-17, 1948-50	143	570	4,950
51	Nogales Wash at Nogales	1931-33	30	b	3,350

Note: Period of record indicates periods for which records were processed when this report was prepared.

b - Only 2 years of record available for flood vols.

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Period: 1930-50

Table 2.--Test for homogeneity, annual maximum consecutive 3-day vols. (cfs days)

Sta. No.	Gaging Station	Drainage Area sq. miles	Mean Annual Flood Q2.33	10-year Flood Q10	Q10 / Q2.33	Q2.33 x 2.39	R.I for Col.7	Effective Length of Record
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	NEW MEXICO							
4	Rio Puerco at Rio Puerco	5,160	6,350	11,600	1.83	15,200	30	19
8	Montano Grant, W-1	0.125	0.73	1.44	1.97	1.74	20	16
14	Galisteo Cr. at Domingo	640	1,050	2,110	2.01	2,510	18	14
16	Mimbres R. nr. Mimbres	183	270	840	3.11	645	6	21
17	Mimbres R. nr. Faywood	485	835	2,380	2.85	2,000	7	21
	ARIZONA							
28	Puerco R. nr. Adamana	2,760	5,800	13,500	2.33	13,800	11	16
29	Moenkopi Wash nr. Tuba	2,270	2,230	5,100	2.29	5,330	11	21
32	San Simon Cr. nr. Solomon	2,280	1,700	3,800	2.24	4,060	12	20
38	Safford W-5	1.13	3.45	6.2	1.80	8.24	33	16
41	Whitewater Draw nr. Douglas	1,023	1,230	2,270	1.85	2,940	26	20
42	San Pedro R. nr. Charleston	1,220	4,560	8,480	1.86	10,900	19	20
43	Aravaipa Cr. nr. Feldman	540	1,000	3,500	3.50	2,390	6	16
44	Santa Cruz R. nr. Nogales	542	1,220	2,760	2.26	2,920	12	20
45	Sonoita Cr. nr. Potogonia	210	610	1,600	2.62	1,460	7	21
47	Rillito Cr. nr. Tucson	916	1,260	3,800	3.01	3,010	6	21
48	Sabino Cr. nr. Tucson	35.0	440	1,210	2.75	1,050	8	20
				16 /	38.28			
			mean	ratio	2.39			

Note: This table includes all stations with 10 years or more of record, with the exception that where two or more stations were close by, only one of the group has been entered.

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Table 3.--Three-day volumes--Station-year frequency tabulation

Sta. No.	Station	Years of Record	Q Max cfs	Q Max days	Mean annual flood Q2.33 cfs	Mean annual flood Q2.33 days	Q Max / Q2.33	Recur. Int. (years)
	NEW MEXICO							
4	Rio Puerco at Rio Puerco	28	31,100		5,700		5.45	89
8	SCS sta W-1 nr. Albuquerque	14		1.88		0.68	2.77	26
12	SCS sta W-1 nr. Santa Fe	10		3.12		0.72	4.33	71
14	Galisteo Cr. at Domingo	10	2,180		775		2.82	27
17	Mimbres R. nr. Faywood	34	4,950		680		7.28	119
	ARIZONA							
28	Puerco R. nr. Adamana,	10	13,600		5,100		2.67	24
29	Moenkopi Wash nr. Tuba,	24	9,510		2,340		4.06	51
32	San Simon Cr. nr. Solomon	19	5,300		1,660		3.19	32
37	SCS sta W-4 nr. Safford	14		10.4		3.6	2.89	30
41	Whitewater Draw nr. Douglas	21	5,230		1,250		4.19	60
42	San Pedro R. nr. Charleston	36	54,000		4,250		12.70	178
43	Aravaipa Cr. nr. Feldman	14	6,490		1,850		3.50	40
44	Santa Cruz R. nr. Nogales	26	3,010		1,190		2.53	22
45	Sonoita Cr. nr. Patogonia	20	1,740		530		3.28	36
47	Rillito Cr. nr. Tucson	37	20,000		1,550		12.90	357
48	Sabino Cr. nr. Tucson	19	1,630		405		4.02	45
TOTAL		336						

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Table 4.--Test for homogeneity, annual peak rates, period 1931-50

Sta. No. (1)	Gaging Station (2)	Dr. Area (3)	Mean Annual Flood Q2.33 cfs (4)	10-year Flood Q10 cfs (5)	Q10 / Q2.33 (6)	Q2.33 x 2.29 (7)	R.I for Col.7 (8)	Effective Length of Record (9)
	NEW MEXICO							
4	Rio Puerco at Rio Puerco	5,160	10,800	22,800	2.11	24,700	11	18.5
8	SCS station W-1 nr. Albuquerque	0.125	53	151	2.85	121	7	16
14	Galisteo Cr. at Domingo	640	4,950	9,400	1.90	11,300	21	14.5
16	Mimbres R. at Mimbres	183	800	1,870	2.34	1,830	10	20
17	Mimbres R. nr. Faywood	485	4,160	8,040	1.93	9,530	19	19.5
	ARIZONA							
28	Puerco R. nr. Adamana	2,760	14,500	30,500	2.10	33,200	13	15
29	Moenkopi Wash nr. Tuba	2,490	5,400	11,200	2.07	12,400	15	20
32	San Simon Cr. nr. Solomon	2,280	7,000	12,700	1.82	16,000	26	20
38	SCS station W-5 nr. Safford	1.13	126	340	2.70	289	7	16
42	San Pedro R. at Charleston	480	9,200	21,200	2.30	21,100	11	20
43	Aravaipa Cr. nr. Feldman	540	5,760	9,600	1.67	13,200	46	15.5
44	Santa Cruz R. nr. Nogales	542	4,650	9,150	1.97	10,600	19	20
45	Sonoita Cr. nr. Patogonia	210	3,500	9,960	2.84	8,020	8	20
46	Rillito Cr. nr. Tucson	221	5,850	12,700	2.17	13,400	12	20
48	Sabino Cr. nr. Tucson	35.0	960	2,800	2.92	2,200	6	19
49	Tucson Arroyo nr. Tucson	21.5	1,370	4,000	2.92	3,140	6	15.5
				16/	36.61			
			Mean	ratio	2.29			
41	Whitewater Draw nr. Douglas	1,023	2,460	3,530	1.43	5,510	200+	19.5
				17 /	38.04			
					2.24			
					2.24 x 2,460 = 5,510			

Note: Whitewater Draw is not homogeneous with the above stations.

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Table 5.--Station year frequency tabulation--annual maximum peak rates

Sta. No.	Gaging Station	Years of Record	Max. Flood cfs	Date	Mean Annual Flood Q2.33 cfs	Q Max. / Q2.33	Recur. Int. (years)
	NEW MEXICO						
4	Rio Puerco at Rio Puerco	18	28,000	Aug.21,1935	10,800	2.59	24
8	SCS sta. W-1 nr. Albuquerque	14	155	Sept.8,1947	47	3.30	39
13	SCS sta. W-2 nr. Santa Fe	10	123	Aug. 8,1944	13	9.50	156
14	Galisteo Cr. at Domingo	10	10,500	Aug. 3,1949	5,500	1.91	20
16	Mimbres R. nr. Mimbres	20	2,230	Aug.19,1944	800	2.79	28
	ARIZONA						
28	Puerco R. nr. Adamana	10	30,000	Aug.12,1946	13,400	2.24	21
29	Moenkopi Wash nr. Tuba	26	15,100	Aug. 4,1929	6,000	2.52	22
32	San Simon Cr. nr. Solomon	20	27,500	Aug. 9,1931	7,000	3.93	52
38	SCS sta. W-5 nr. Safford	14	428	Aug.11,1952	103	4.15	78
42	San Pedro R. nr. Charleston	35	98,000	Sept.28,1926	9,000	10.90	313
43	Aravaipa Cr. nr. Feldman	14	20,000	Aug. 2,1919	7,300	2.74	26
44	Santa Cruz R. nr. Nogales	27	12,000	Aug.31,1935	4,150	2.89	31
45	Sonoita Cr. nr. Patagonia	23	14,000	Sept.30,1946	3,500	4.00	63
47	Rillito Cr. nr. Tucson	38	28,000	Dec.23,1914	6,300	4.44	104
48	Sabino Cr. nr. Tucson	20	3,200	Mar. 3,1938	1,040	3.08	35
49	Tucson Arroyo nr. Tucson	13	4,100	July24,1948	1,200	3.42	45
TOTAL		312					

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Table 6.--Summary of high summer flood discharges for Arizona and western New Mexico

Sta. No.	Gaging Station	Drainage Area sq. miles	Discharge cfs	Source of Record
	NEW MEXICO			
1	Rio Puerco nr. Cabezon	360	4,400	a
2	Rio Puerco at Cabezon	397	2,440	a
3	Chico Arroyo nr. Guadalupe	1,390	12,700	a
4	Rio Puerco at Rio Puerco	5,160	39,000	a
5	Rio Puerco nr. Bernardo	5,860	18,800	a
6	San Jose R. nr. Grants	875	1,330	a
7	San Jose R. at Correo	2,415	11,000	a
8	Montano Grant W-1	0.125	155	b
9	Montano Grant W-2	0.063	100	b
10	Montano Grant W-3	0.284	158	b
11	Rio Salado nr. San Acacia	1,380	27,400	a
12	Santa Fe W-1	0.22	181	b
13	Santa Fe W-2	1.23	123	b
14	Galisteo Cr. at Domingo	640	10,500	a
15	Tijeras Cr. nr. Albuquerque	74	4,810	a
16	Mimbres R. at Mimbres	183	2,230	a
17	Mimbres R. nr. Faywood	485	8,580	a
18	Parshall Wash nr. Mex. Springs	0.95	517	b
19	Mexican Springs Wash	32.7	4,500	b
20	Catron Wash nr. Mexican Springs	26.9	4,710	b
21	Figuerado Wash nr. Mexican Springs	72.0	3,280	b
22	Norcross Wash nr. Mexican Springs	3.98	268	b
23	Black Cr. Wash nr. Mexican Springs	7.41	754	b
24	Horsepasture Wash nr. Mexican Springs	0.29	60.4	b
25	Lower Crevasse nr. Mexican Springs	13.3	1,500	b
26	Chusca Wash nr. Mexican Springs	8.67	1,250	b
27	Puerco R. at Gallup	558	3,700	a
	ARIZONA			
28	Puerco R. nr. Adamana	2,760	30,000	a
29	Moenkopi Wash nr. Tuba	2,490	15,100	a
31	San Simon Cr. nr. San Simon	803	5,020	a

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Table 6.--(Continued) (2)

Sta. No.	Gaging Station	Drainage Area sq. miles	Discharge cfs	Source of Record
32	San Simon Cr. nr. Solomon	2,280	27,500	a
34	Cave Cr. nr. Paradise	39	3,360	a
35	Safford W-1	0.81	436	b
36	Safford W-2	1.07	1,000	b
37	Safford W-4	1.19	189	b
38	Safford W-5	1.13	428	b
41	Whitwater Draw nr. Douglas	1,023	9,050	a
42	San Pedro R. at Charlestown	1,480	98,000	a
43	Aravaipa Cr. nr. Feldman	540	20,000	a
44	Santa Cruz R. nr. Nogales	542	12,000	a
45	Sonoita Cr. nr. Patagonia	210	14,000	a
46	Rillito Cr. nr. Wrightstown	221	9,000	a
47	Rillito Cr. nr. Tucson	916	28,000	a
48	Sabino Cr. nr. Tucson	35.0	3,200	a
49	Tucson Arroyo at Tucson	21.5	4,100	a
50	Queen Cr. nr. Superior	143	13,200	a
51	Nogales Wash at Nogales	30.0	4,400	a
	NEW MEXICO			
52	San Cristobal Arroyo nr. Lamy	1.5	2,660	c
53	Unnamed wash Estancia Valley	3.0	3,560	c
54	Unnamed wash Estancia Valley	16	4,660	c
55	Tajique Cr. at Tajique	12	1,110	c
56	Santa Fe Cr. at Santa Fe	7.0	4,600	c
57	El Rancho Arroyo nr. Pojaque	6.7	47,000	c
58	Arroyo Ramon Matinez nr. Pojaque	0.8	1,780	c
59	Santa Fe Cr. nr. Santa Fe	22	3,200	a
60	Arroyo Hondo nr. Santa Fe	13.5	2,830	a
61	Unnamed wash nr. San Ysidro	5.0	4,150	d
62	Unnamed wash nr. San Ysidro	5.25	14,000	d
63	Abo Wash nr. Scholle	257	18,300	d
	ARIZONA			
64	Big Springs Wash nr. Safford	16.2	5,500	e

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Table 6.--(Continued) (3)

Sta. No.	Gaging Station	Drainage Area sq. miles	Discharge cfs	Source of Record
65	Billingsley Wash nr. Safford	3.4	3,300	e
66	Five O'clock Wash nr. Safford	15.6	2,920	e
67	Packer Wash nr. Safford	14.0	2,300	e
68	Sheldon Wash nr. Safford	9.9	1,120	e
69	Blackfield Wash nr. Safford	7.1	586	e
70	Picocho Wash nr. Yuma	41.5	37,000	f
71	Unnamed wash Hulaipi Res.	1.3	1,500	f
72	Big Sandy Cr. nr. Wellton	270	49,000	f
73	Gila R. at Winkleman	390	55,000	f
74	Pinal Cr. at Globe	27	11,200	f
75	Chase Cr.	20	12,940	f
76	Peterson Cr. nr. Safford	25.7	4,600	f
77	Unnamed Wash nr. Yuma	35.3	5,000	f
	NEW MEXICO			
79	Embudo Arroyo at Albuquerque	18	3,350	f
80	Rio Hondo nr. Arroyo Hondo	73	2,510	f
81	El Rito Cr. nr. El Rito	12	1,240	f
82	Rio Santa Cruz at Cundiyo	38	2,610	f
83	Rio de Arenas nr. Hurley	16	2,660	f
84	Cameron Cr. nr. Hurley	46	5,490	f
85	Unnamed arroyo nr. Santa Fe	3.2	1,920	f
86	Polomas R. nr. Hermosa	52	8,680	f
87	Trujillo Arroyo nr. Hills boro	22	20,800	f

a. U. S. Geological Survey Water Supply Papers

b. U. S. Soil Conservation Service files and reports

c. Files of W. F. Somers, U.S.G.S., Salt Lake City, Utah

d. Files of H. M. Hudson, U.S.G.S., Santa Fe, New Mexico

e. Duncan - Safford Report by Turner and others.

f. Maximum flood flows in Western United States by L. W. Furness

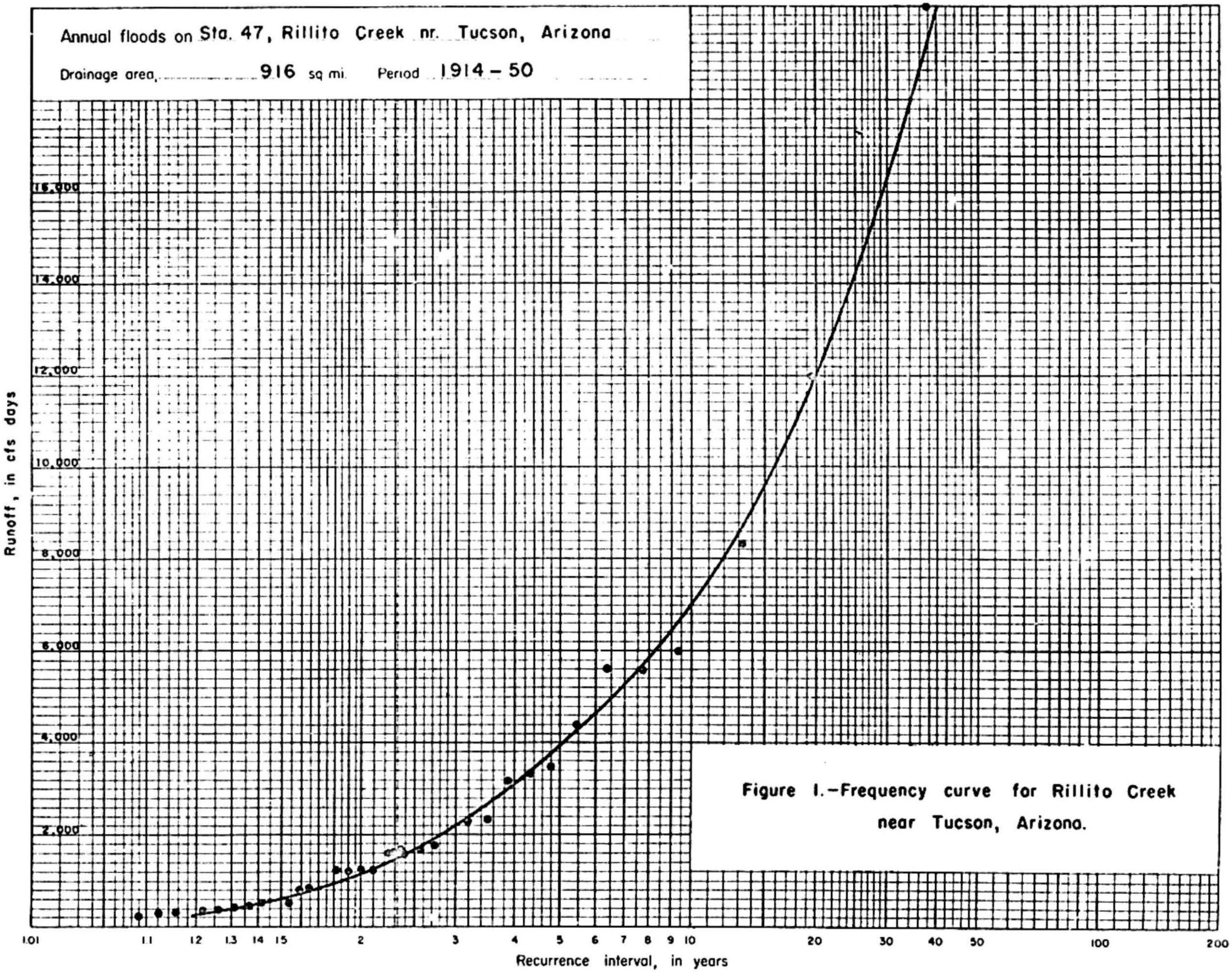

Figure 1.–Frequency curve for Rillito Creek near Tucson, Arizona.

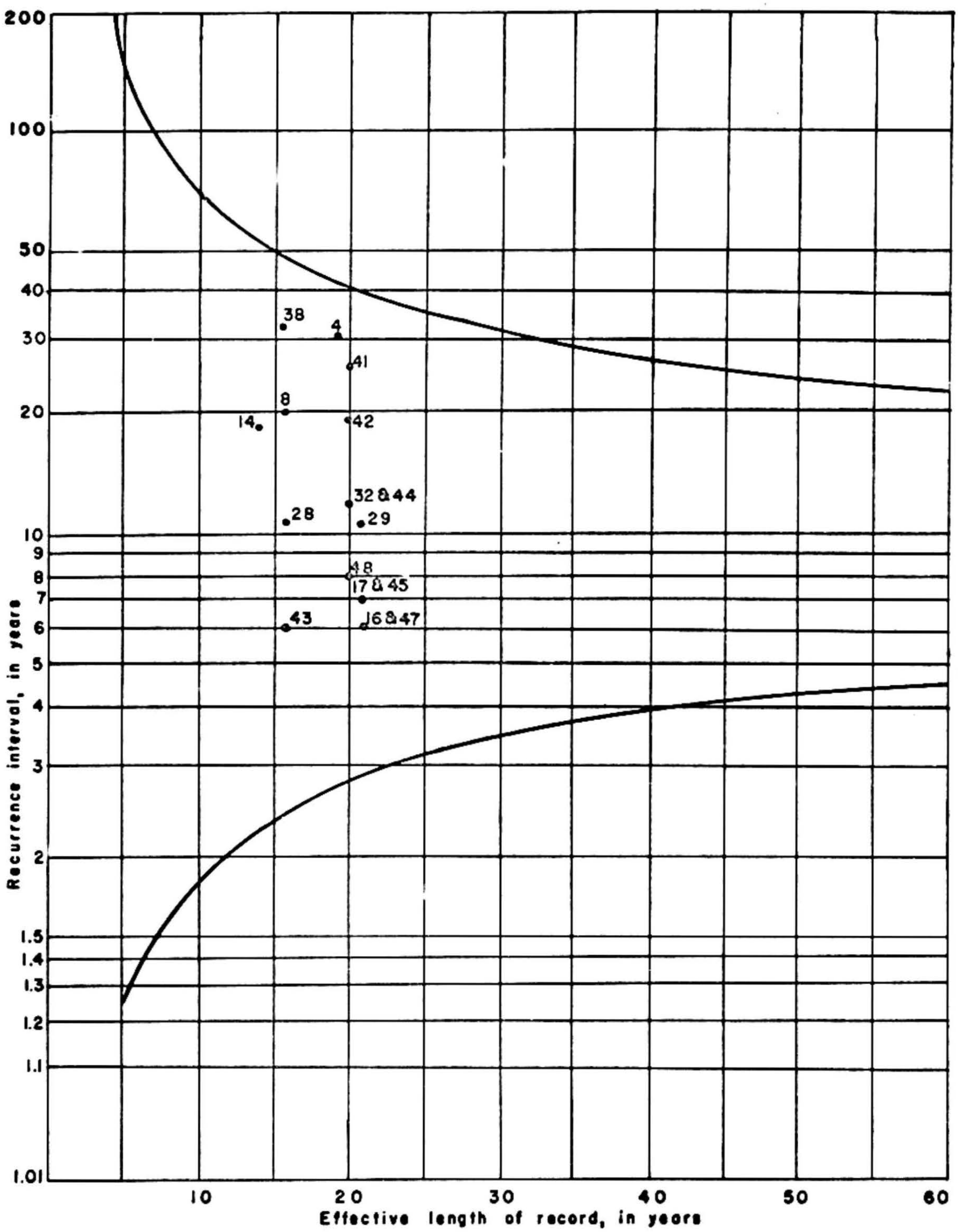

Figure 2. Homogeneity test, flood volumes.

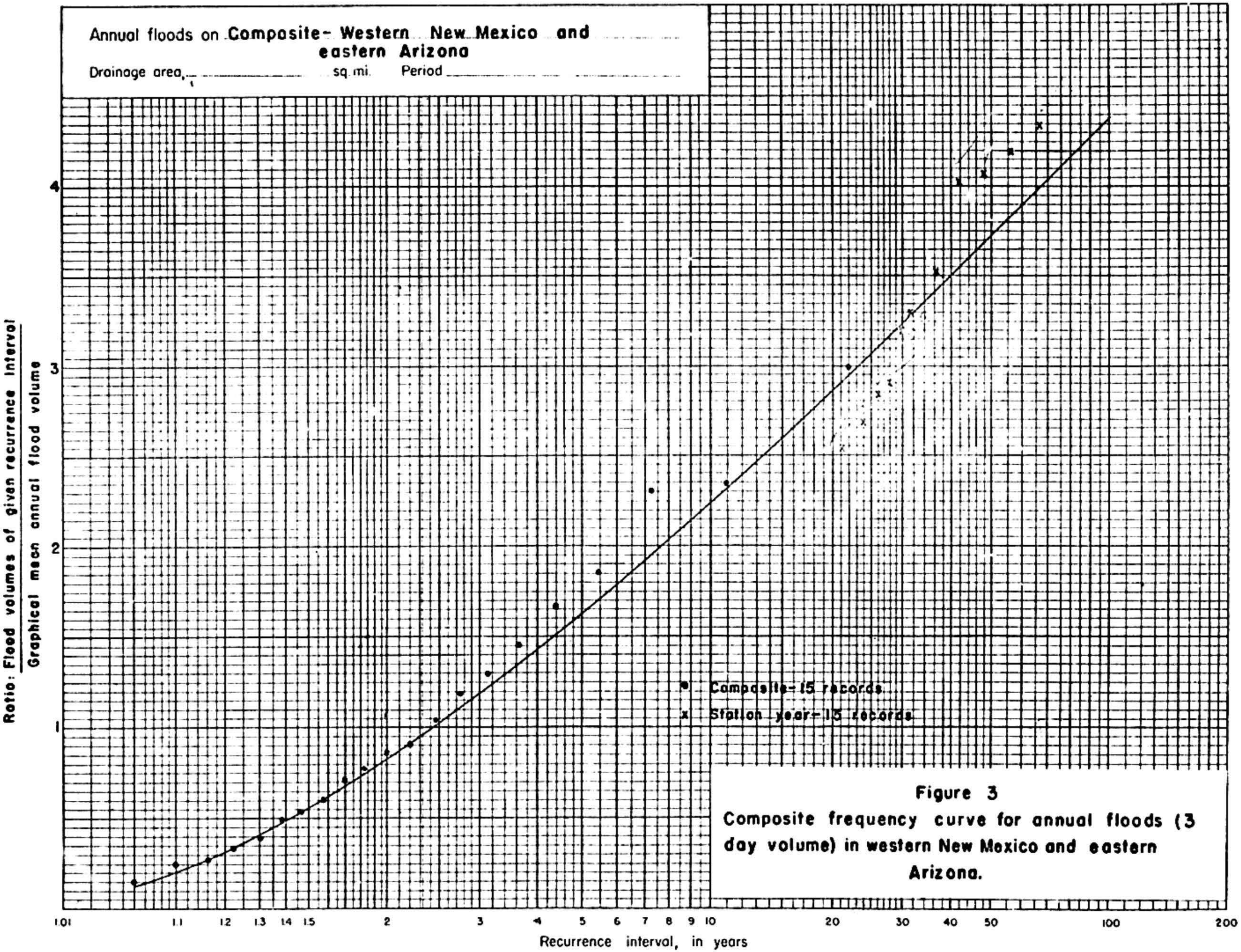

Figure 3
Composite frequency curve for annual floods (3 day volume) in western New Mexico and eastern Arizona.

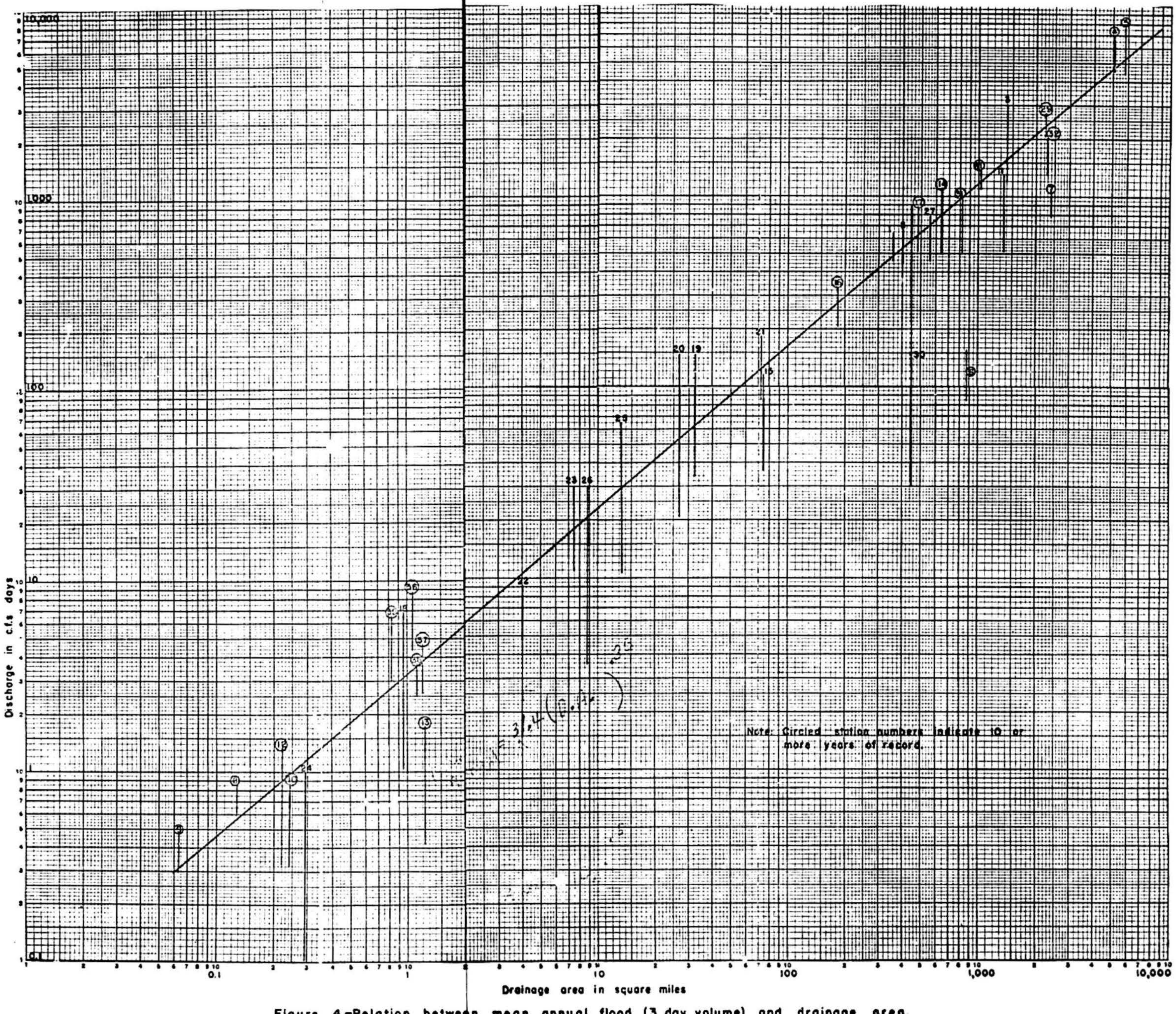

Figure 4.-Relation between mean annual flood (3 day volume) and drainage area. Areas 1, 2, 3, and 4.

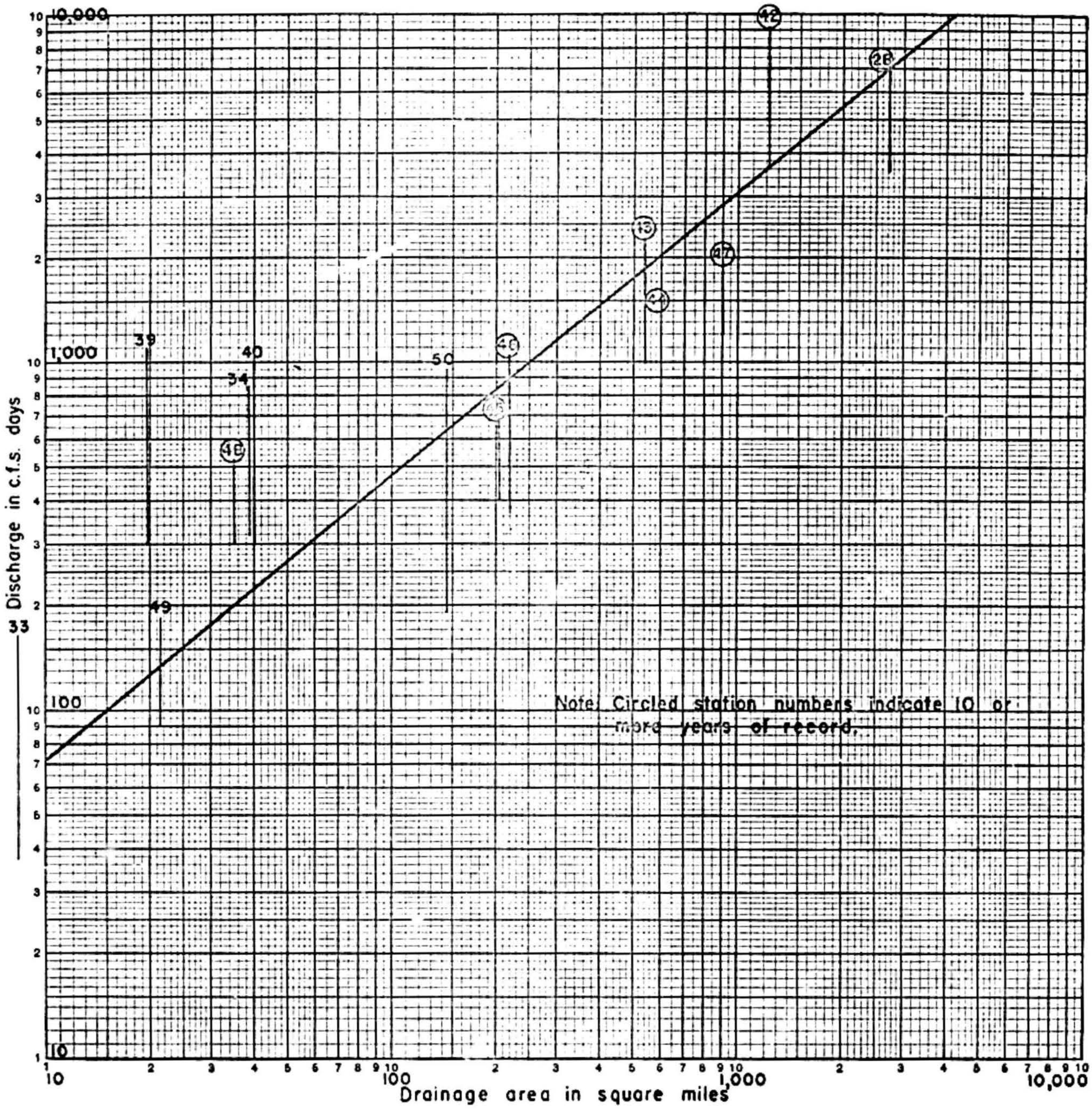

Figure 5.- Relation between mean annual flood (3 day volume) and drainage area.
Area 5

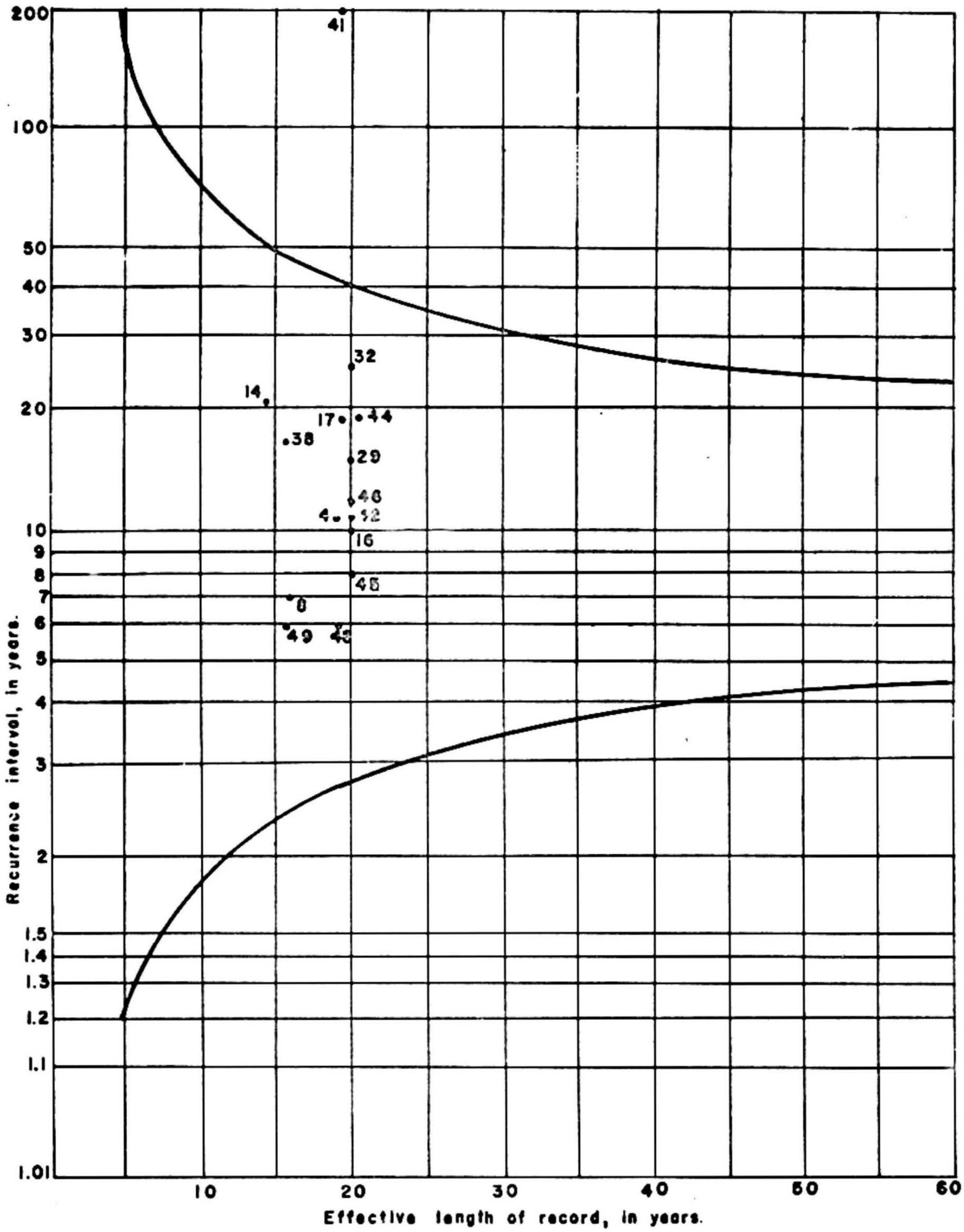

Figure 6. Homogeneity test, peak rates.

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Flood data plot
(March 1949)

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File Number

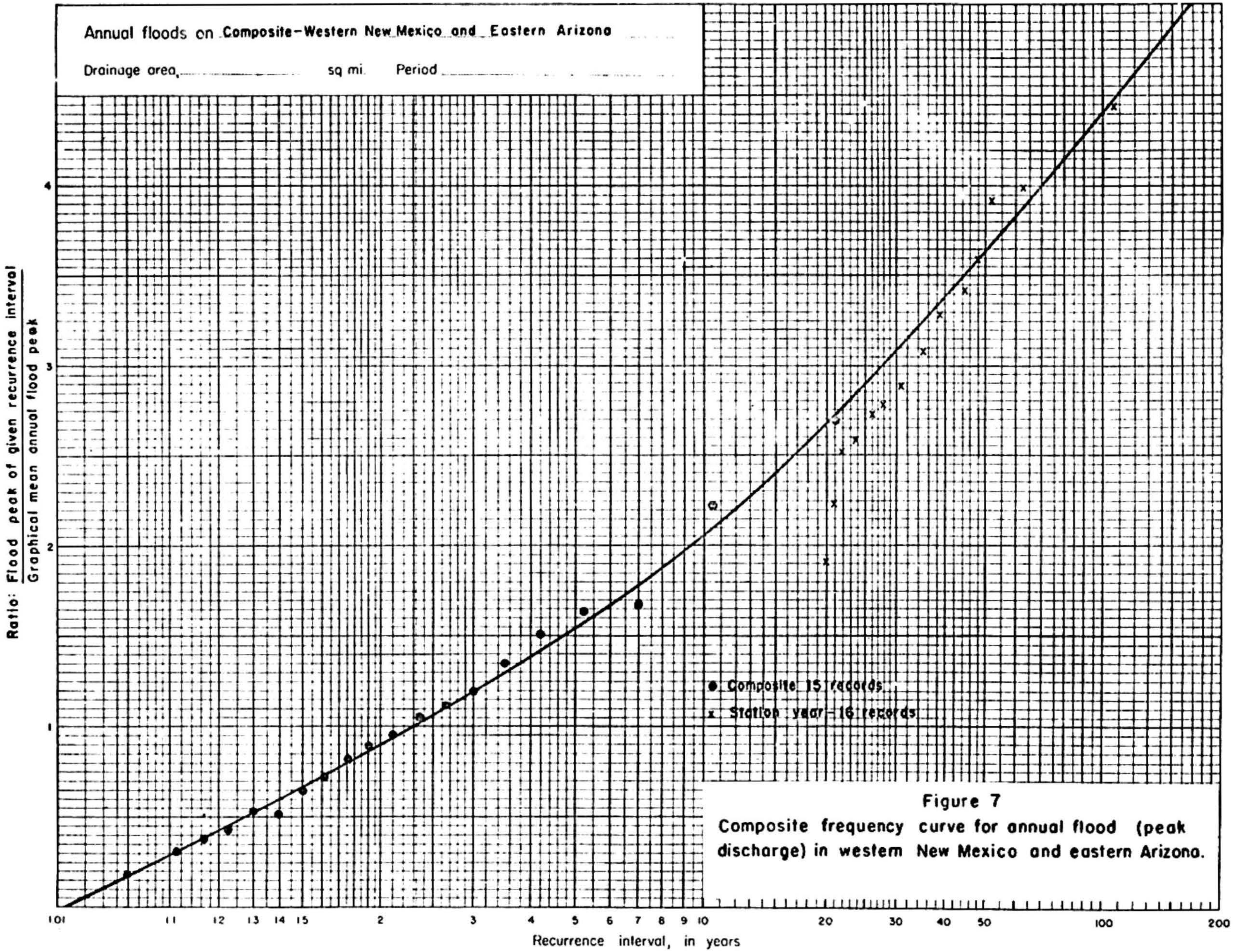

Figure 7
Composite frequency curve for annual flood (peak discharge) in western New Mexico and eastern Arizona.

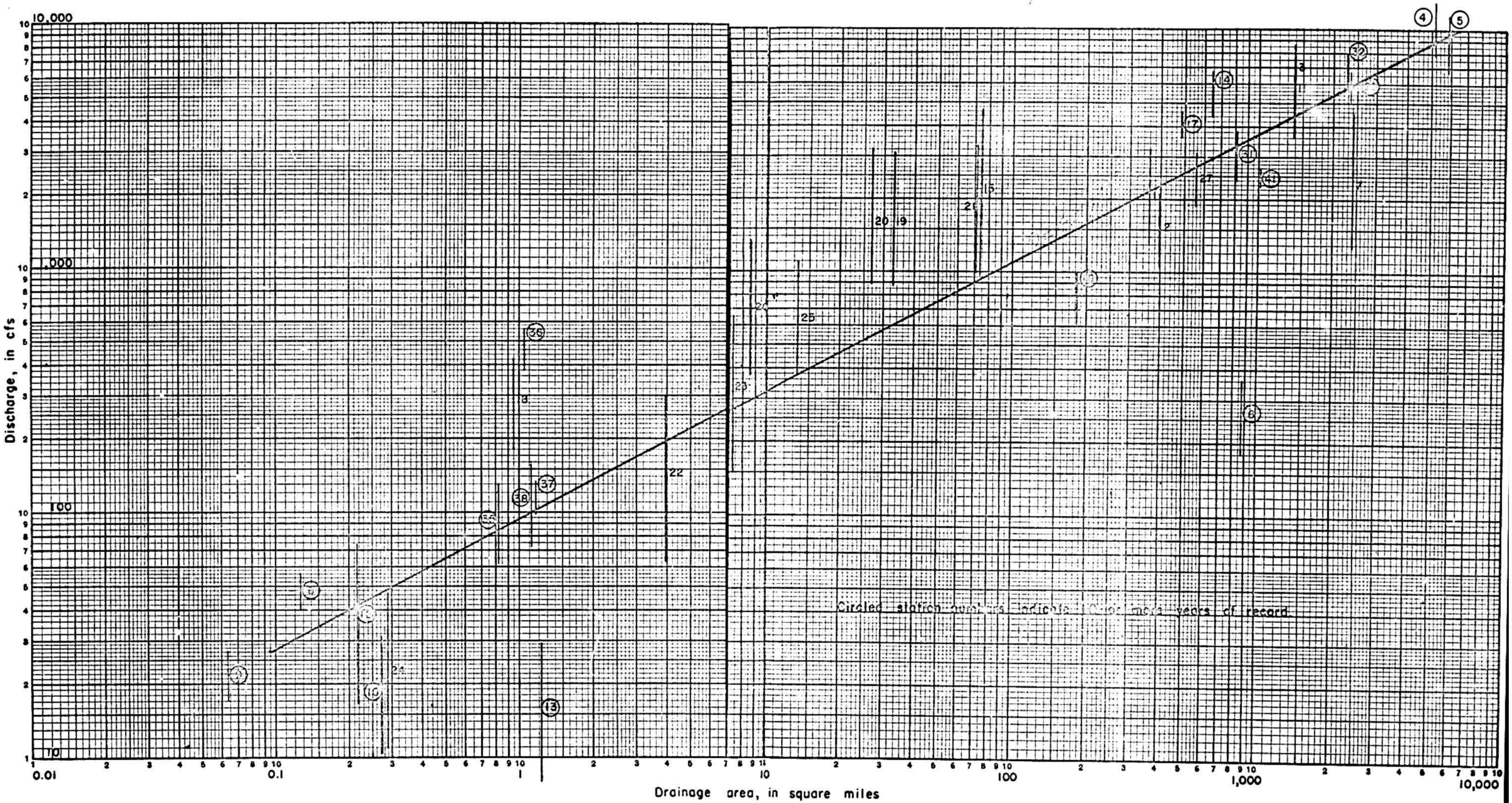

Figure 8.-Relation between mean annual flood (peak discharge) and drainage area.
Areas 1, 2, and 3 Arizona and New Mexico.

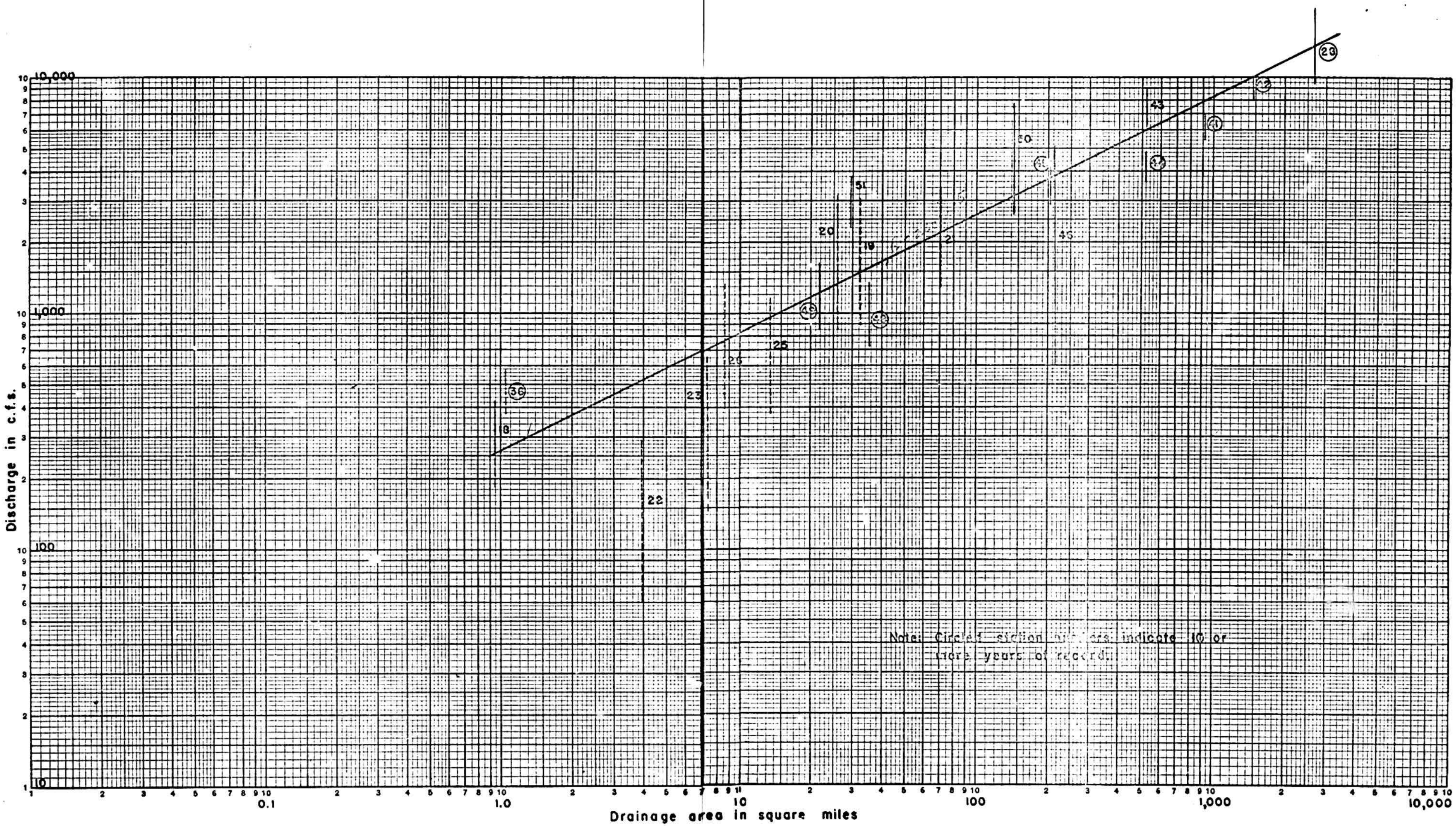

Figure 9.-Relation between mean annual flood (peak discharge) and drainage area.
Area 5.-Arizona

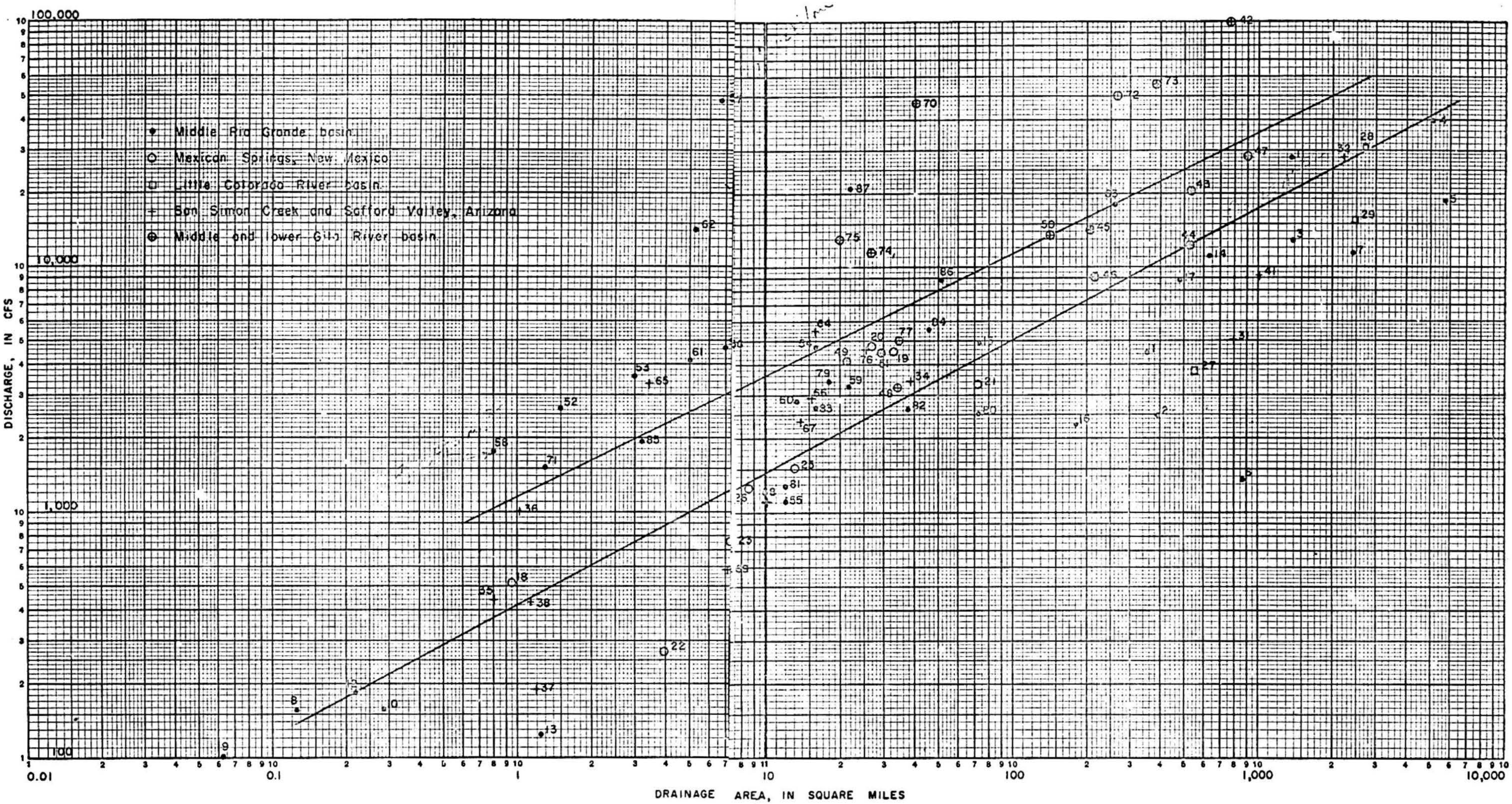

Figure 10.- Relation between observed peak discharge and drainage area for summer floods, Arizona and western New Mexico

REFERENCES

Leopold, Luna B., 1944, Characteristics of heavy rainfall in New Mexico and Arizona. Transactions American Society of Civil Engineers, Vol. 109, p. 837-892

Dorrah, J. H., 1945, Certain hydrologic and climatic characteristics of the Southwest region, Regional Bulletin No. 98, Engineering Series 9, U. S. Soil Conservation Service.