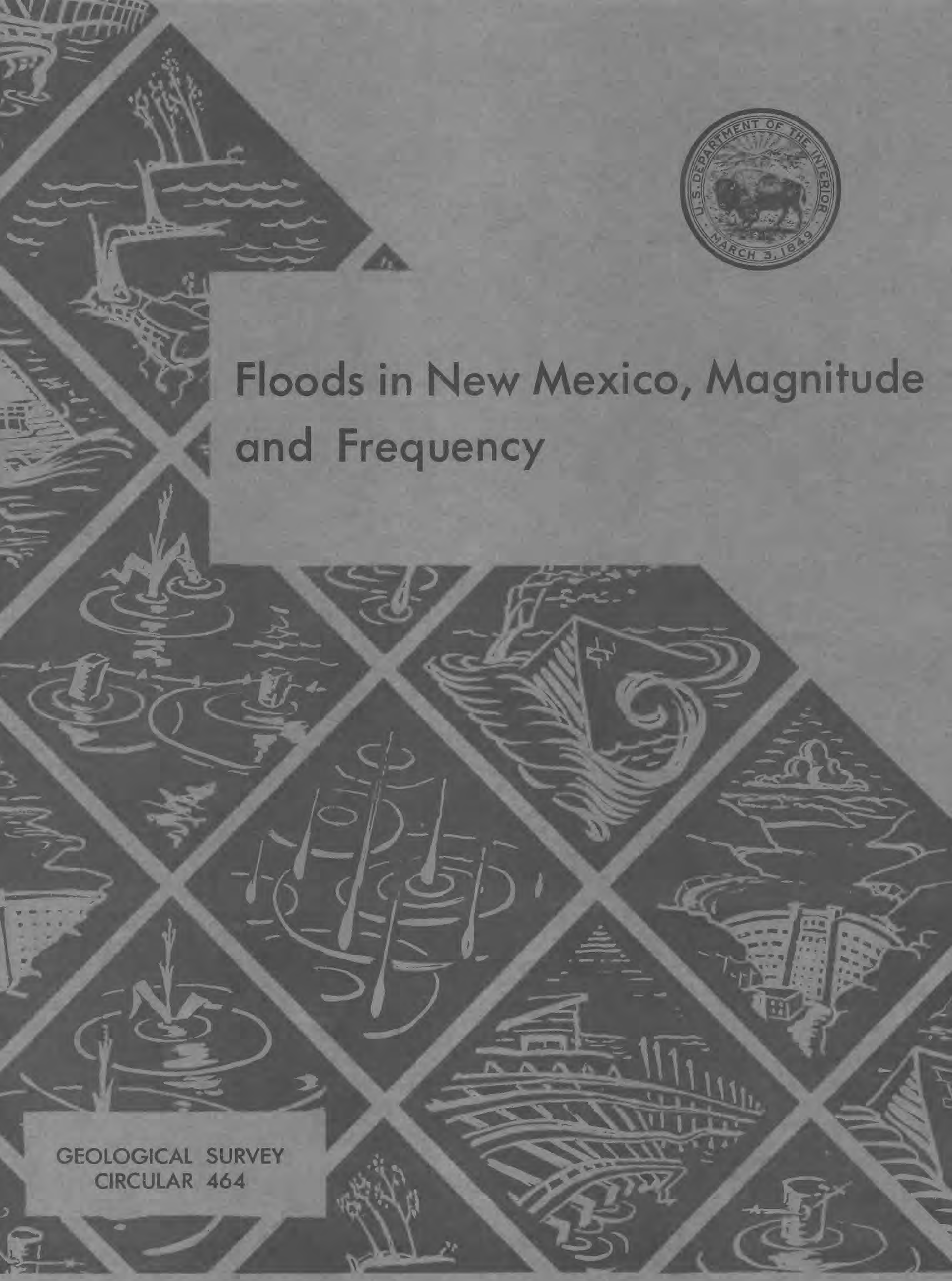

Floods in New Mexico, Magnitude and Frequency

GEOLOGICAL SURVEY CIRCULAR 464

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By Leon A. Wiard

Prepared in cooperation with the New Mexico State Highway Department

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ABSTRACT

This report presents a method of determining the magnitude and frequency of floods that can be expected in New Mexico The discharge of the mean annual flood for various regions in the State is defined. Curves relate mean annual flood and drainage area. Drainage area was the only basin characteristic found to have an appreciable effect on discharge of the mean annual flood except in two regions where a relation with altitude also is defined. Composite frequency curves relate discharge of the mean annual flood to the discharge of floods having recurrence intervals from 1.1 to 50 years. These relationships are based on records 5 or more years in length from gaging stations that had flow essentially unregulated.

INTRODUCTION

The location, design, construction, and insurance of structures in, over, or adjacent to streams require consideration of flood hazards. For most structures, except where probable loss of life is involved, design is usually based on economy. An important element of an economic evaluation is knowledge of the magnitude and frequency of floods to be expected.

This report describes methods and presents curves by which the magnitude and frequency of floods may be estimated for most sites in New Mexico. Extrapolation of the curves as presented is not justified.

The effect on flood peaks of various basin characteristics such as drainage area, site elevation, channel slope, and mean annual runoff, was investigated. Drainage area was used as a factor throughout the State. The other factors had no apparent effect, with the exception of site elevation which was found to be important in the Canadian and San Juan River basins. All streamflow records in the State not affected by excessive regulation or diversion, and of duration greater than 5 years, were used in the analysis. In addition, several streamflow records for Arizona, Colorado, and Texas were included.

The report was prepared in the Santa Fe Office of the U.S. Geological Survey under the direction of Wilbur L. Heckler, district engineer, Surface Water Branch, in cooperation with the New Mexico State Highway Department. The author was materially assisted in the Rio Grande basin part of the analytical study and in the preparation of this report by E. Hogue, R. Lamke, K. Medina, and Miss Massie Ortiz of the Santa Fe office.

The analysis for the Canadian River basin was made by J. L. Patterson of the Fort Smith, Ark., office of the U.S. Geological Survey as part of a flood-frequency study of the lower Mississippi River basin. Credit is given to personnel of the Floods Section, Surface Water Branch, U.S. Geological Survey, Washington, D. C., for the analysis of the Colorado River basin, a part of which was utilized in the preparation of this report.

Results of the studies mentioned above for the lower Mississippi, Rio Grande, and Colorado River basins will be published in Water-Supply Papers 1681 (Part 7), 1682 (Part 8), and 1683 (Part 9) respectively, each of which will be one of a series of water-supply papers on the magnitude and frequency of floods in the conterminous United States.

Data for New Mexico streams used in the study were collected through investigations financed in whole or in part by the New Mexico State Highway Department, the New Mexico State Engineer's Office, the Interstate Streams Commission, the Rio Grande Compact Commission, the Pecos River Commission, the Costilla Compact Commission, the Pecos Valley Conservancy District, the Corps of Engineers, the Bureau of Reclamation, and various municipalities. Similar local, State, and

Federal agencies and commissions have been responsible for the financing of gaging stations in Arizona, Colorado, and Texas, for which flood data were used in this study to augment the New Mexico data. Credit for the work of these various agencies is given in the annual series of water-supply papers of the U.S. Geological Survey entitled "Surface Water Supply of the United States."

Engineers and hydrologists have made other studies of the magnitude-frequency relation of floods. One such study by M. A. Benson (written communication, 1962) discusses the factors affecting the occurrence of floods in the Southwest. In Benson's study, formulas are presented which enable evaluation of the effects of nine independent variables. The variables included are contributing drainage area, main-channel slope, storage of lakes and ponds, rainfall intensity, length of main channel, average annual number of thunderstorm days, runoff/precipitation ratio, mean annual precipitation, and basin elevation index.

Results obtained by methods described in this report and by Benson's methods may differ considerably for a selected site, however, average results for sites throughout New Mexico should be comparable.

DESCRIPTION OF THE STATE

Various physical factors of a drainage basin which affect the magnitude of floods are integrated by the flood peaks. The effects of land slope, stream length and density, altitude, latitude, and relation to mountain ranges and oceans are reflected in the hydrograph of the flood peak.

New Mexico, where elevations range from less than 3,000 feet to over 13,000 feet, is bisected in a north-south direction by the Sangre de Cristo, Manzano, San Andres, and Organ Mountains. This chain of mountains forms the eastern divide of the Rio Grande Valley in New Mexico. The Pecos River rises in the southern end of the Sangre de Cristo Mountains. The Canadian River has its headwaters on the eastern slopes of this same range, along the Colorado-New Mexico border. Ranges forming the west divide of the Rio Grande Valley are the San Juan and Valle Grande, or Jemez Mountains, in the north and the San Mateo Mountains and Black Range in the south. The wide valleys of the Rio Puerco and Rio Salado basins separate these northern and southern ranges. The Sacramento Mountains are the major range in the southeastern part of the State. The Guadalupe Hills are an extension of these mountains to the southeast. Although of relatively low altitude these hills are an important contributing cause of floods in the lower part of the Pecos Valley. In the southwestern corner of the State, the Mogollon and Tularosa Mountains join to form an important mountain system. The Chuska Mountains are farther to the north, on the Arizona-New Mexico border.

Leopold (1944) and Dorroh (1946) describe in detail the air masses producing precipitation in New Mexico and the effects of the ranges and basins upon distribution of precipitation. Of particular interest is the fact that highest intensities for a particular storm are usually to be found at or near the base of mountain slopes as exemplified by the Alamogordo storm of August 17, 1959. A maximum of more than 3 inches of precipitation was recorded in about $2\frac{1}{2}$ hours close to the base of the Sacramento Mountains east of Alamogordo. Only half an inch was recorded at a site less than $1\frac{1}{2}$ miles from the storm center.

Extensive lava flows are an important geologic feature affecting floodflows. Precipitation of cloudburst intensity on an area of lava flows may cause little or no flood runoff. These areas also absorb floodflows discharged onto or adjacent to them from a surrounding area. Thus, the absorptive characteristic of lava beds tends to reduce the effective drainage area of a stream in regard to floods.

Streams in New Mexico fall into two distinct categories—the perennial streams with year-around flow, and the ephemeral streams which carry flow only during periods of precipitation or snowmelt. The majority of the streams are of the latter type and have two characteristics which are important in flood studies: (a) they carry infrequent flows of short duration but of high maximum discharge in relation to total flood volume; and (b) channel losses are significant, with a high rate of loss within a few miles.

STREAMFLOW DATA

Streamflow records 5 or more years in length from 102 continuous-record gaging stations and crest-stage gages in New Mexico, not appreciably affected by regulation or diversion, were used in the analysis. In that part of the analysis made in the Santa Fe office, 1 additional gaging-station record in Arizona, 3 in Texas, and 16 in Colorado were also used. If drainage areas for stations on the same stream are within 25 percent of each other, the longer record was used.

FLOOD-FREQUENCY DATA

Gaging-station records are random samples of streamflow, whether daily, monthly, annual, or instantaneous peaks are being considered. It follows that a frequency curve based on records from several stream-gaging stations in a region reflects the variable characteristics of the region more adequately than do the individual station frequency curves. However, flood-frequency curves for the individual sites are necessary as a preliminary step in deriving the regional curves.

A common base period is used in making a regional flood-frequency analysis so that all records will be comparable. In the analysis made in the Santa Fe office, the period 1938–59 was used. Although slightly different periods were used for the Colorado and the Canadian River basins, the difference should have little effect on results. To provide a basis for extension beyond the base period, peak discharges outside the base period were used where such peaks exceeded those within the base period.

Flood-frequency relations were not defined for the area between the Rio Grande and the San Andres Mountains, and for that to the east of the Pecos River south of the 34th parallel (shown crosshatched on figure 1) because of inadequate base data.

Flood data for use in a flood-frequency analysis may be compiled into one of two series, either annual or partial-duration. An annual flood is defined as the maximum instantaneous discharge occurring during a given annual period, usually the water year October 1 through September 30. The annual flood series, based on these annual maximums, has the disadvantage that when several high floods occur in the same water year, some floods higher than many annual floods are disregarded. The partial-duration series overcomes this objection because it contains all peaks above a selected base discharge, which is usually selected so that in general 3 or 4 peaks per year will exceed the base. The floods in the partial-duration series, however, may not be entirely independent events; it is possible that one flood will set the stage for another.

There is a basic difference between the two series. The annual series enables one to predict the average interval of recurrence of a given event, as an annual maximum. The recurrence interval defined by the partial-duration series is the average interval between events of a given size regardless of their relationship to a given time period. For the larger floods, the recurrence interval is very nearly equal for both series. The following table by Langbein (1949) shows the relation between recurrence intervals by the two series:

Recurrence intervals in years

Annual flood series	*Partial-duration series*
1.16	0.5
1.58	1.0
2.00	1.45
2.54	2.00
5.52	5.0
10.5	10.0
20.5	20.0
50.5	50.0
100.5	100.0

It should be stressed that a recurrence interval of, say, 50 years does not mean that the given event will recur every 50 years. It is quite possible for two 50-year floods to occur within a short period of time, or many more than 50 years may elapse before the occurrence of one 50-year flood.

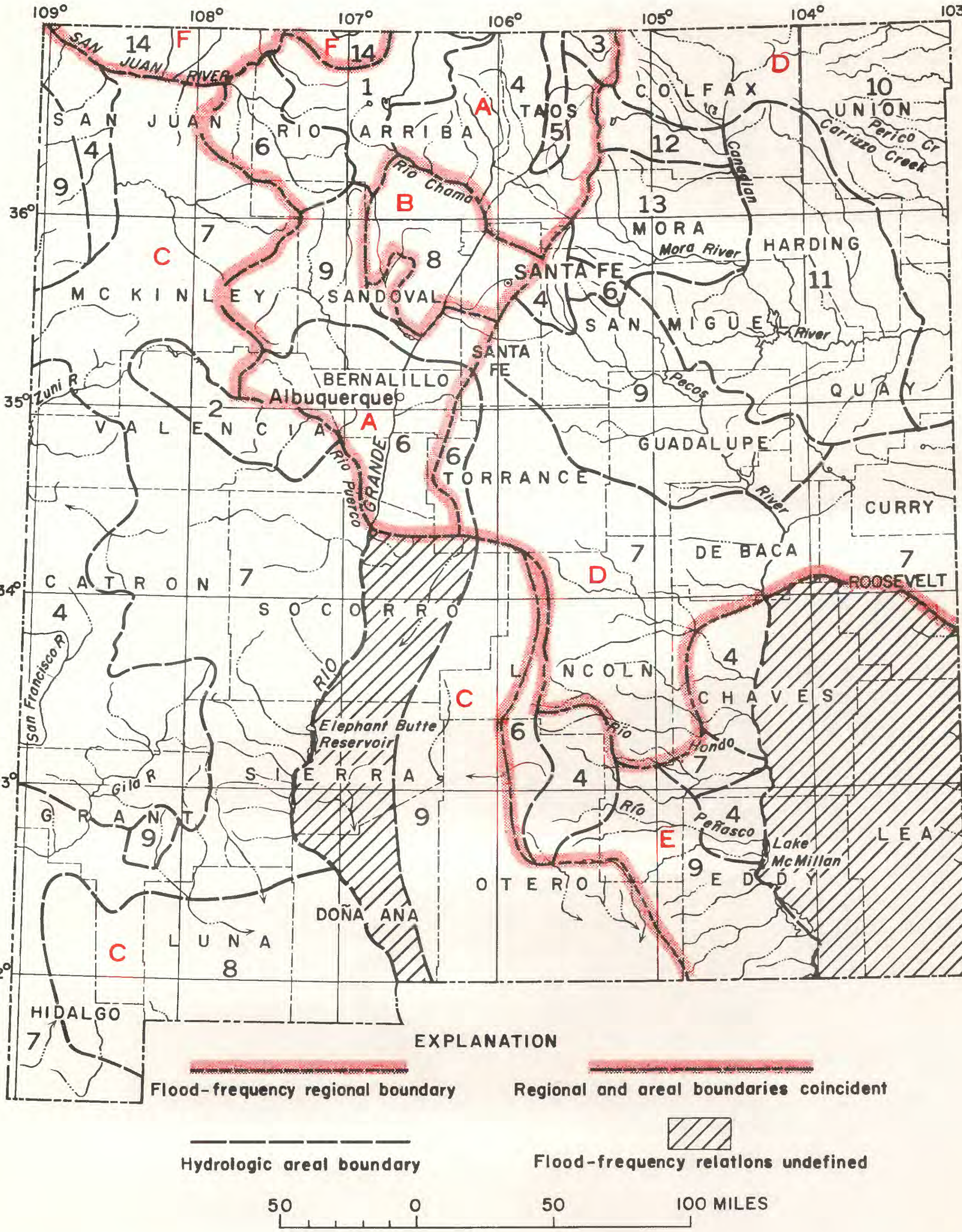

Figure 1.—Map of New Mexico showing flood-frequency regions and hydrologic areas.

FLOOD-FREQUENCY ANALYSIS

Procedures followed in drawing the curves presented are explained by Dalrymple (1960). Certain items are briefly discussed so that one can properly use and interpret the charts.

Regions were established in which records for all gaging stations show similar flood-frequency characteristics, the criterion being the ratio of the 10-year to the mean annual, or 2.33-year, peak discharge. An average value of this ratio was obtained for a group

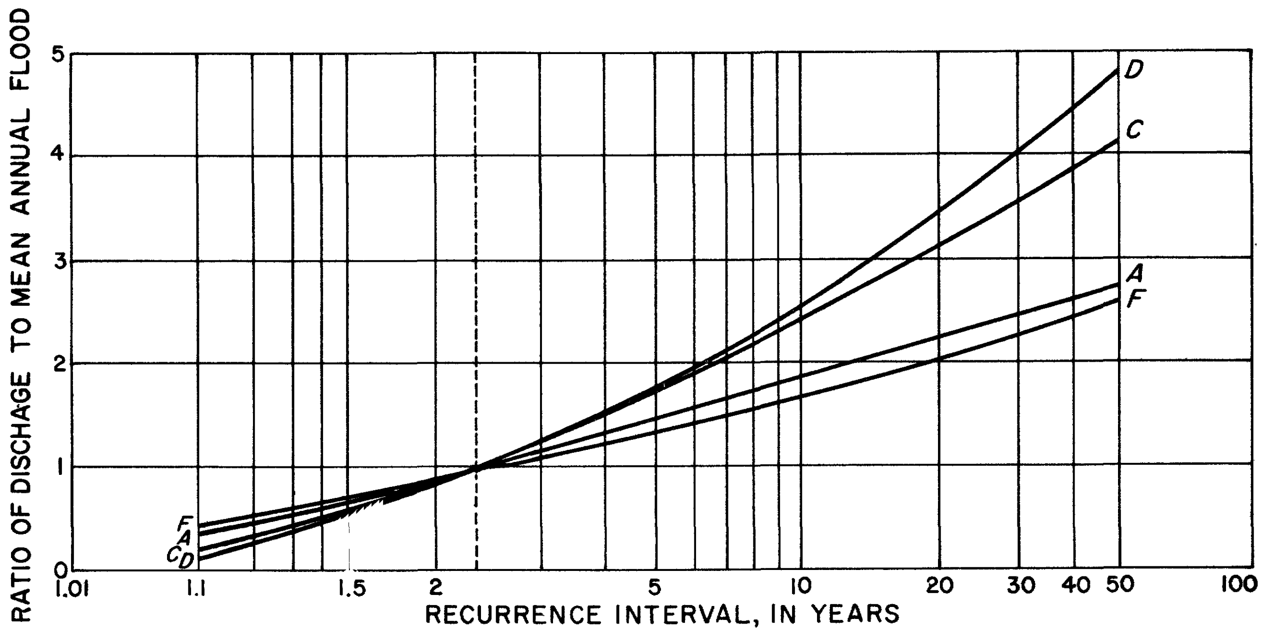

Figure 2.—Composite frequency curves for regions A, C, D, and F.

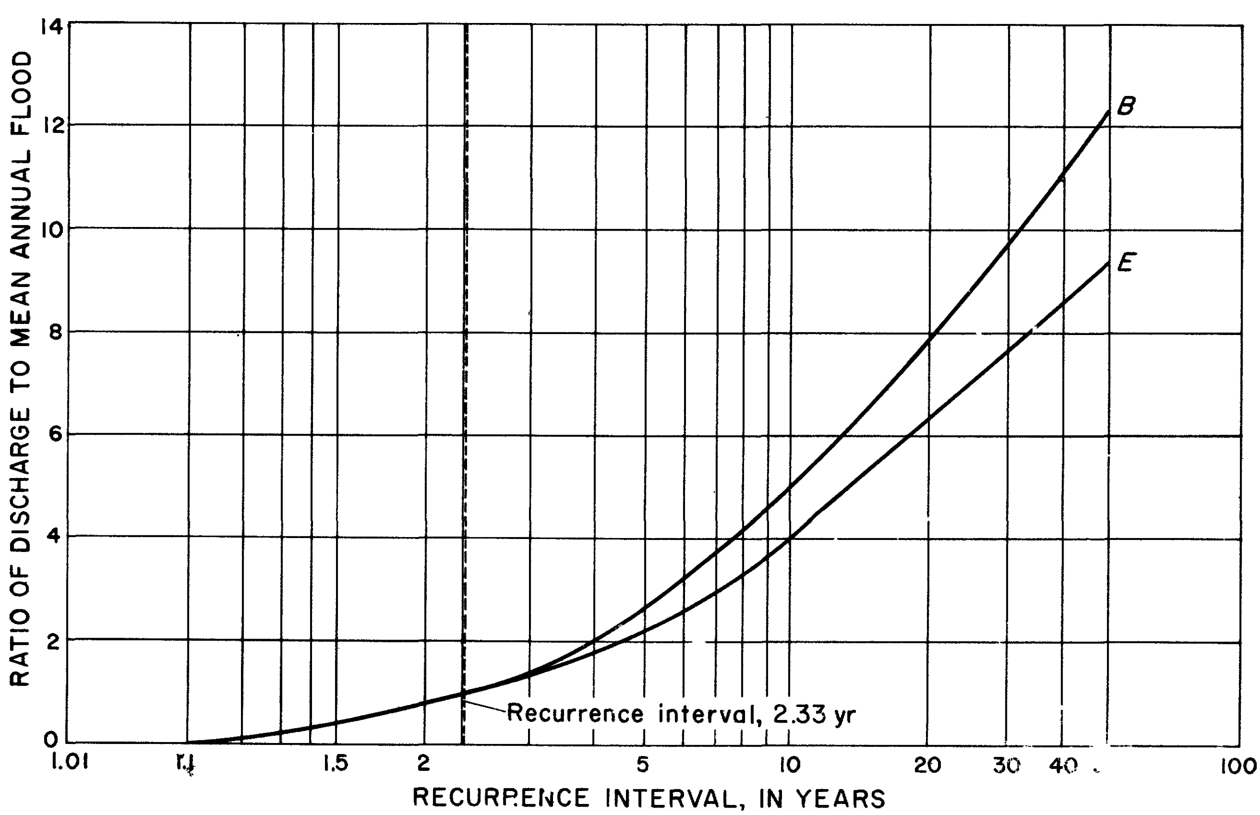

Figure 3.—Composite frequency curves for regions B and E.

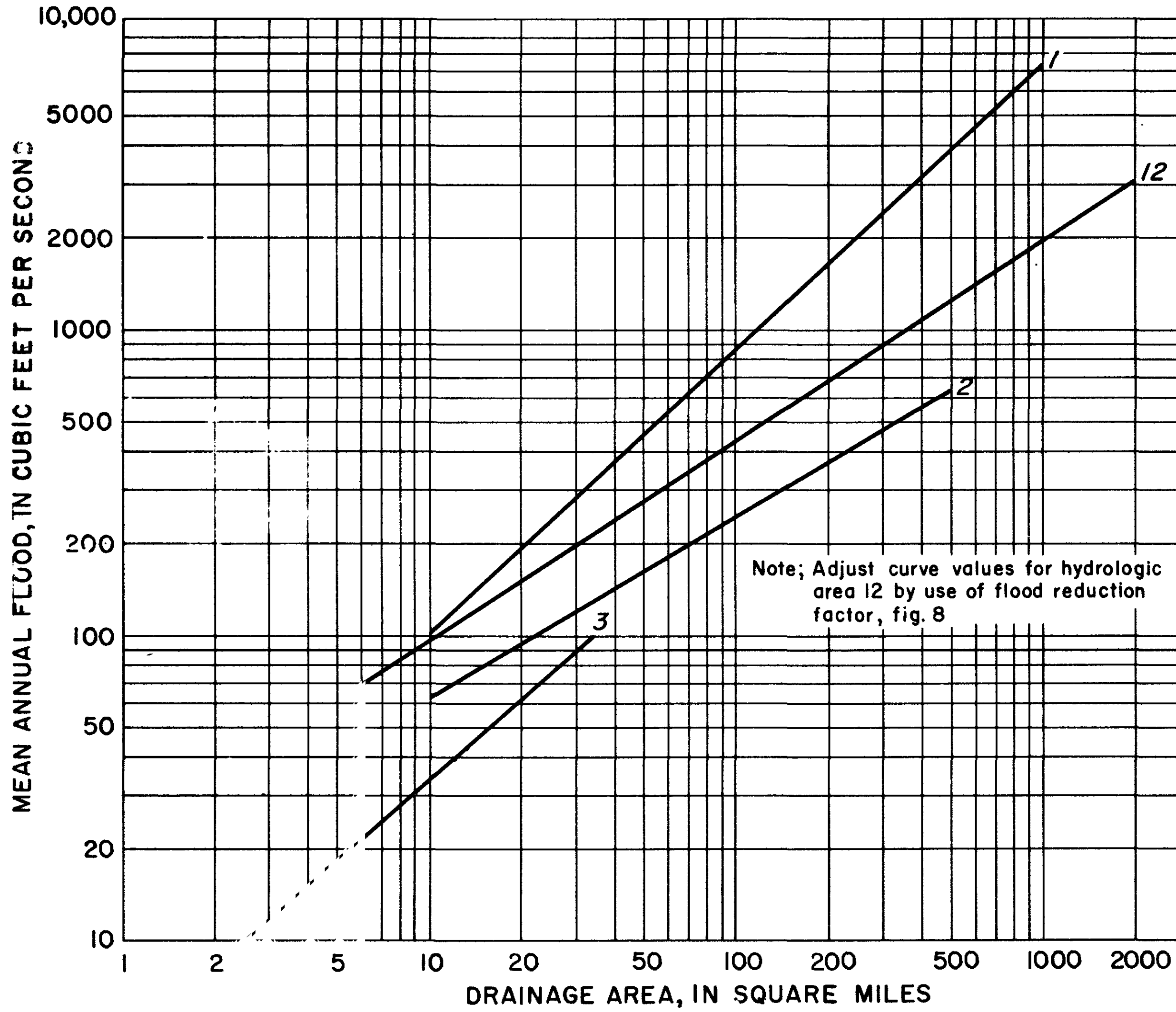

Figure 4.—Relation of mean annual flood to drainage area in hydrologic areas 1–3, and 12.

of stations in a given area, assumed to be homogeneous. The mean annual discharge at the individual stations was multiplied by this average and the recurrence interval noted from the station frequency curve. This recurrence interval was plotted versus the effective length of record on a specially designed test graph. The effective length of record was defined as the number of years of actual record plus one-half the number of years of record computed by correlative methods. The test graph was constructed on a 95 percent confidence level to indicate homogeneity 19 times out of 20. If the points tested are distributed normally on the test graph the region is considered to be homogeneous. It may be that the original area can be enlarged. In that case, a new average of the ratios of the 10-year to mean annual flood is recomputed and the process repeated.

Available records define six flood-frequency regions in New Mexico. These regions are shown on the map (fig. 1). Regional or composite frequency curves, derived from the median values of ratios of the 1.1-year, 10-year, 25-year, and 50-year floods to the mean annual flood for the individual stations, are shown in figures 2 and 3.

The composite frequency curves show ratios of floods of various magnitudes to the mean annual flood. It is therefore necessary to define the mean annual flood in terms of some easily measured or determined basin

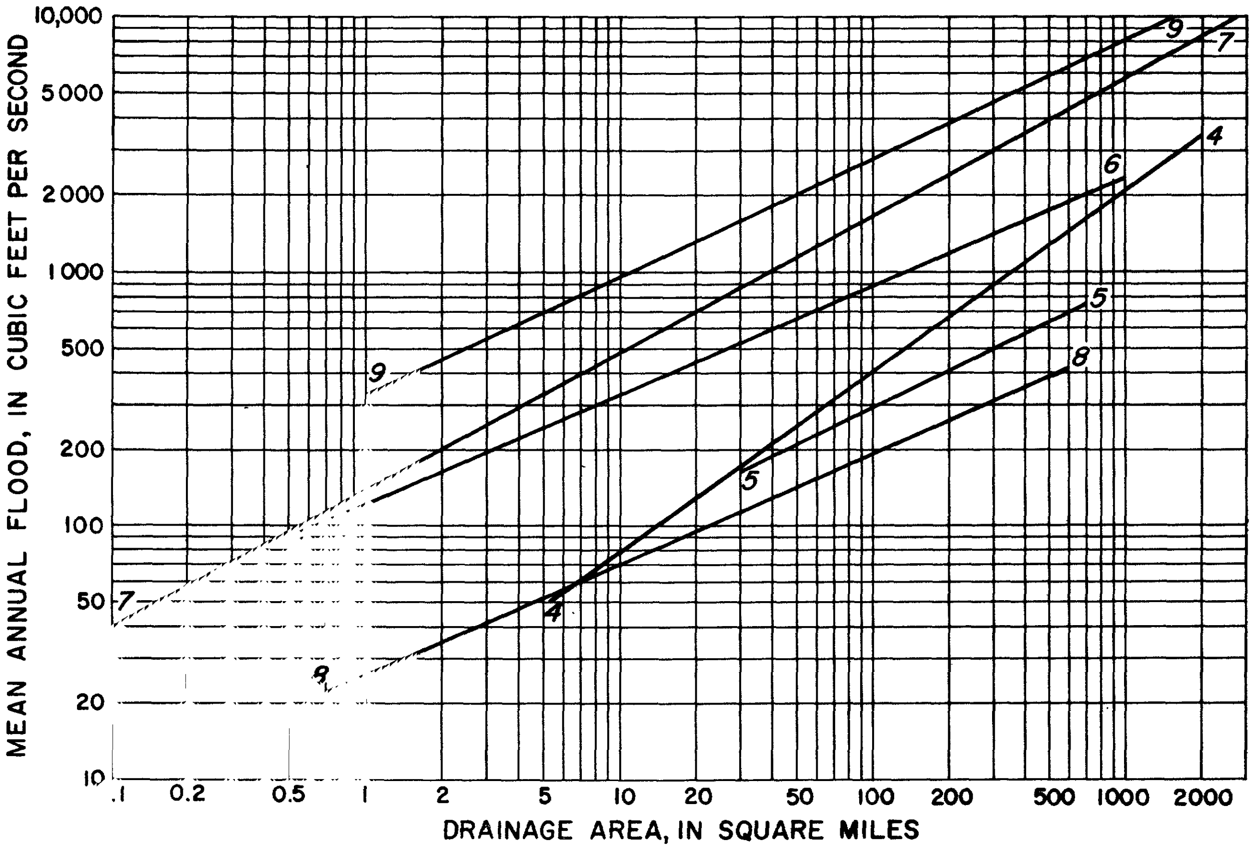

Figure 5.—Relation of mean annual flood to drainage area in hydrologic areas 4–9.

characteristic. The characteristic or parameter most easily measured, and fortunately the most effective, is drainage area.

The separate hydrologic areas were determined by trial. Curves of relationship between mean annual flood and drainage area were established for individual areas, 14 in number, each containing streams of similar flood-producing characteristics. These curves are shown in figures 4–7. Like-numbered areas to which they apply are outlined on figure 1.

Altitude, as well as drainage area, is an effective parameter in areas 10–14, the Canadian and San Juan River basins. An adjustment curve for use with the curves for areas 10–13 (figs. 4 and 6) is shown in figure 8. This curve gives the relation between the ratio of adjusted mean annual flood, $Q_{2.33}$, and computed mean annual flood, $Q_{c\ 2.33}$, and site altitude. Curves of relation between mean annual flood, drainage area, and site altitude, for use in area 14 are shown in figure 7.

Although gaging stations on the Rio Grande, Rio San Jose, Rio Puerco, and the Canadian, Pecos, Gila, and San Juan Rivers have been used in the analysis, use of the area curves should be limited to the headwaters of these streams. Curves of relation between peak discharge for selected frequencies and mileage upstream from a given point are shown in figures 9–14. These curves are to be used rather than the curves of relation between mean annual flood, drainage area, and site elevation for the part of each mainstem stream indicated in figures 9–14. Generally, hydrologic effects on a large stream have become so integrated that it is sometimes better to consider such streams on the basis of their individual flood-frequency characteristics.

In preparing figures 9–14, every effort was made to eliminate the effects of storage and flood-control reservoirs, thereby placing the frequencies on a natural basis, as far as possible. The effects of manmade changes should be considered in using results obtained from the curves presented.

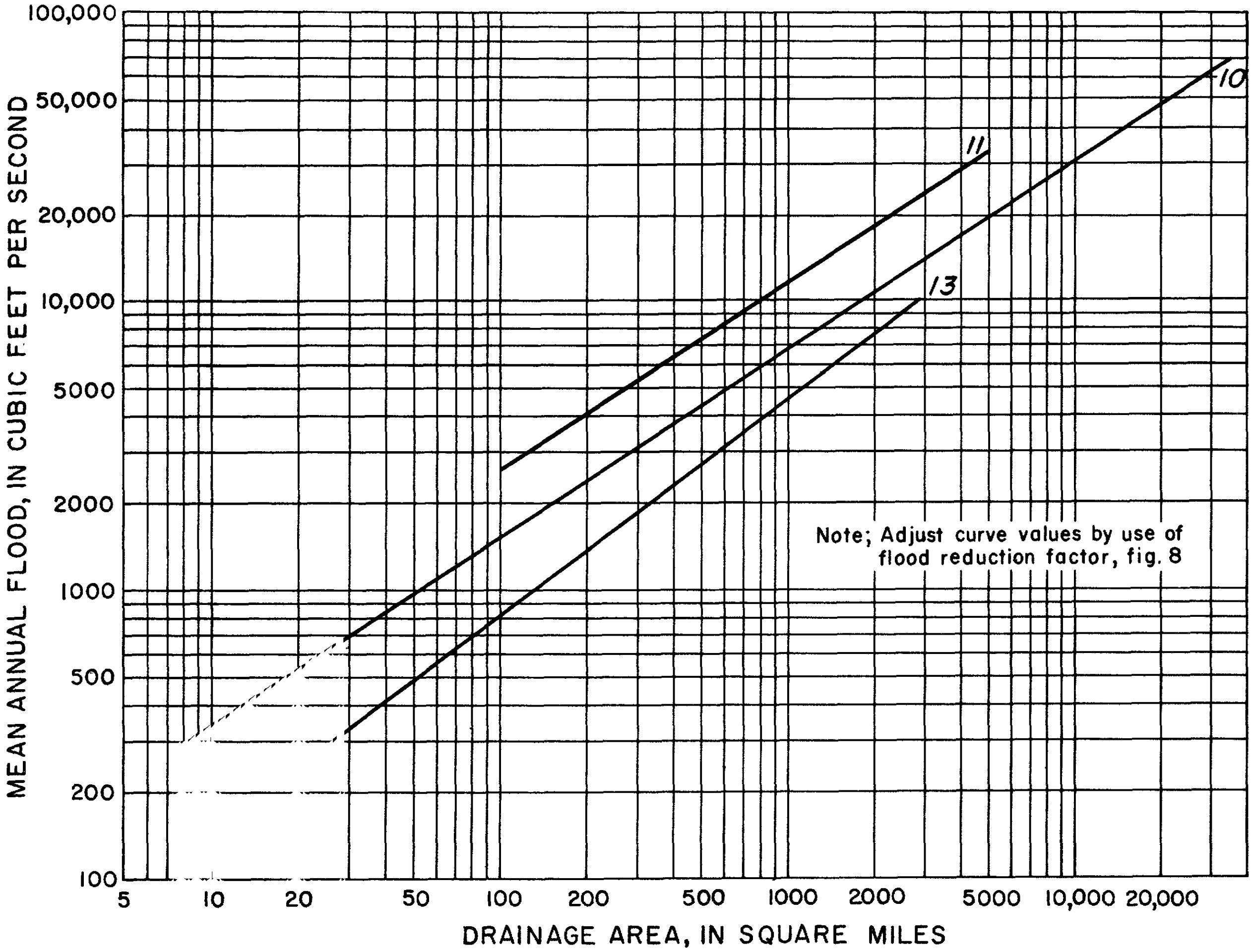

Figure 6.—Relation of mean annual flood to drainage area in hydrologic areas 10, 11, and 13.

Flood records for the area below Elephant Butte and Caballo Reservoirs provide a good example of the effects of manmade changes. An analysis of flood records below Caballo Reservoir shows that normal operation of the reservoir would provide 50-year flood discharges not in excess of 3,200 cfs, on the basis of 21 years of record. However, in one of these years of record, 1942, when Elephant Butte and Caballo Reservoirs spilled, a maximum daily mean discharge of 7,650 cfs occurred. Therefore, to define the natural peak discharges of the lower Rio Grande in New Mexico, discharges for the period of record at San Marcial and data from International Boundary Commission Report no. 6 for their El Paso gage were used.

APPLICATION OF CURVES

Two general sets of curves are presented for use in obtaining the magnitude of floods of given recurrence intervals at any specific site. These are the composite frequency curves and the curves of relation between mean annual flood and drainage area, with altitude involved as a parameter in one case. Both the mean annual flood versus drainage area curves and the composite frequency curves were drawn to limits warranted by the base data. Extension of any curve shown is not recommended, because values thus obtained may be considerably in error. When flood magnitudes are to be determined at sites on the main stems of certain large streams, a third set of curves is presented (figs. 9–14). To use the curves the following steps should be followed:

1. Determine if the selected site is in the reach of a main-stem stream shown in figures 9–14. If so, determine the peak discharge directly from the appropriate one of the curves in figures 9–14. If not, proceed as follows:

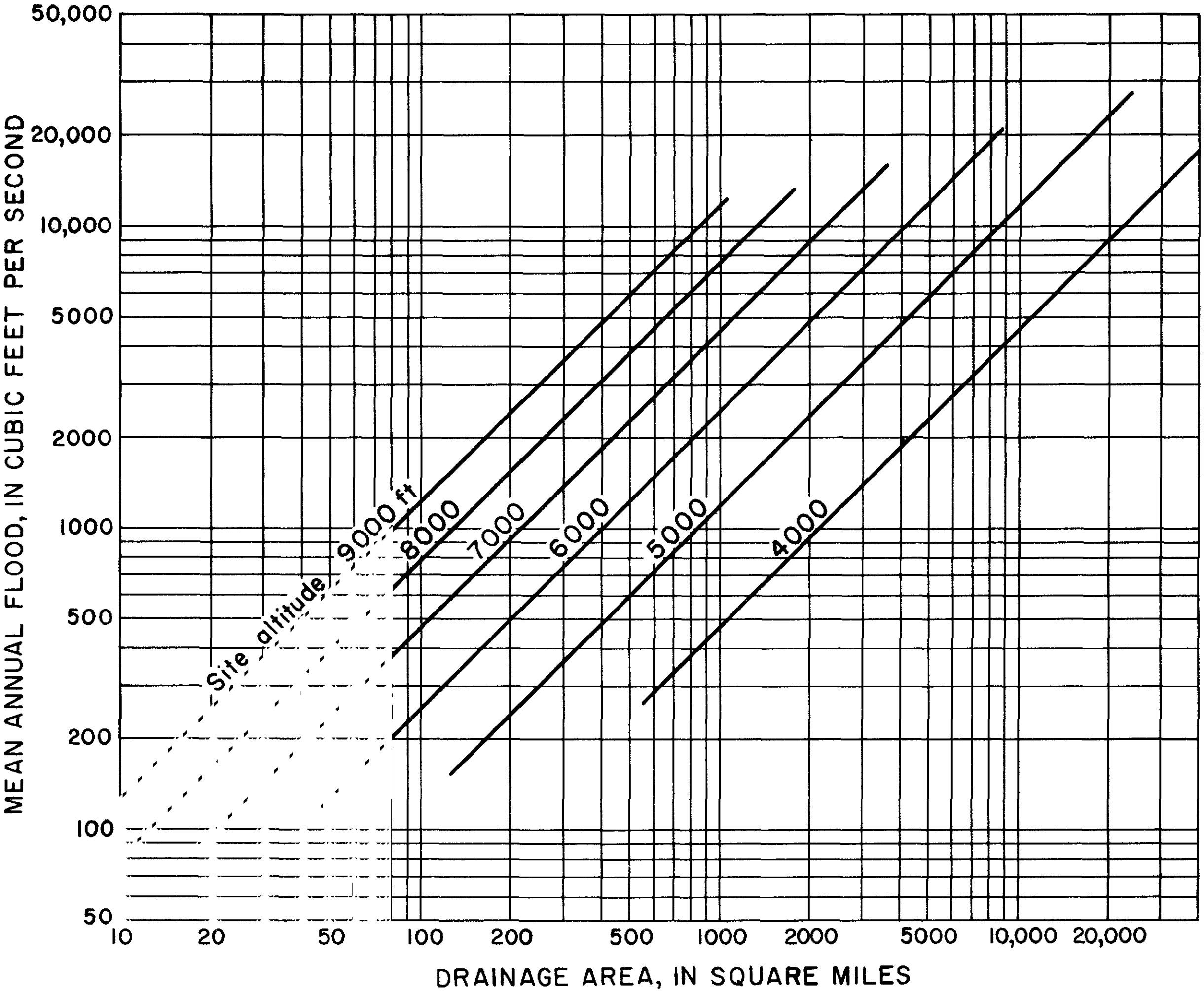

Figure 7.—Relation of mean annual flood to drainage area and site altitude in hydrologic area 14.

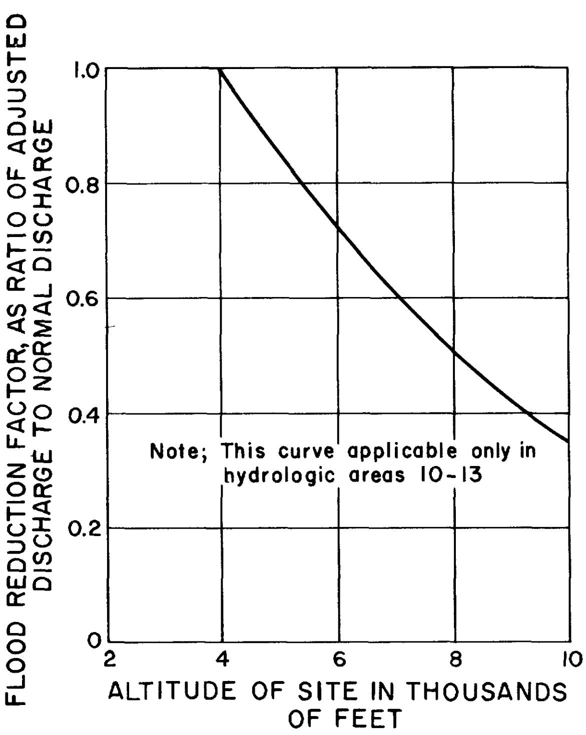

Figure 8.—Relation of altitude at site to reduction of mean annual flood.

2. From available maps, preferably quadrangle maps published by the U.S. Geological Survey, determine the drainage area above the selected site.

3. From figure 1, determine the region and hydrologic area in which the site is located.

4. Determine, from figures 4–7 the mean annual flood corresponding to the drainage area above the site, using the curve for the area within which the site is located. Apply adjustment coefficients for site elevation through use of the curve in figure 8 for areas 10–13. The mean annual flood for sites in area 14 can be obtained from figure 7.

5. Determine the ratio of peak discharge to mean annual flood for the selected flood frequency for the region in which the site is located, using curves of figures 2 or 3.

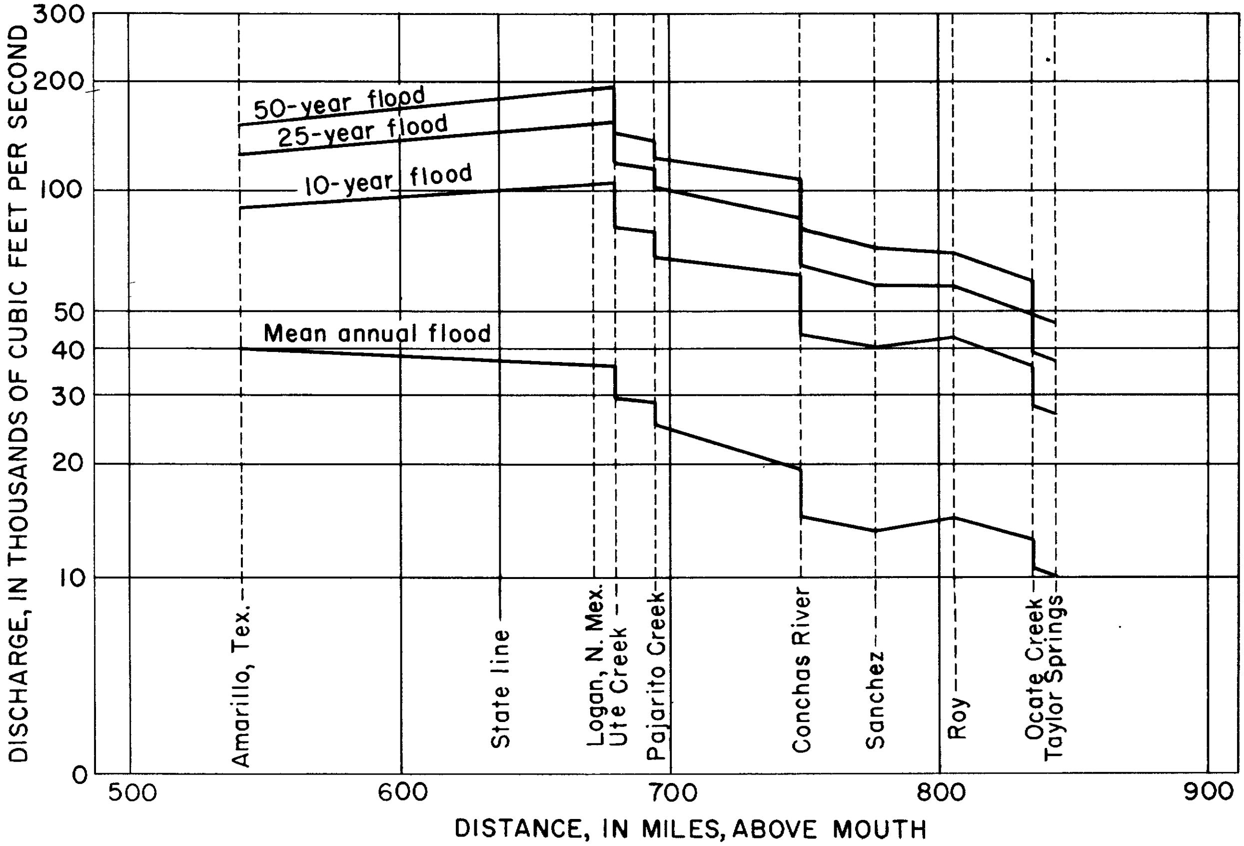

Figure 9.—Relation of discharge for selected flood frequencies to miles above mouth, Canadian River main stem below Cimarron Creek.

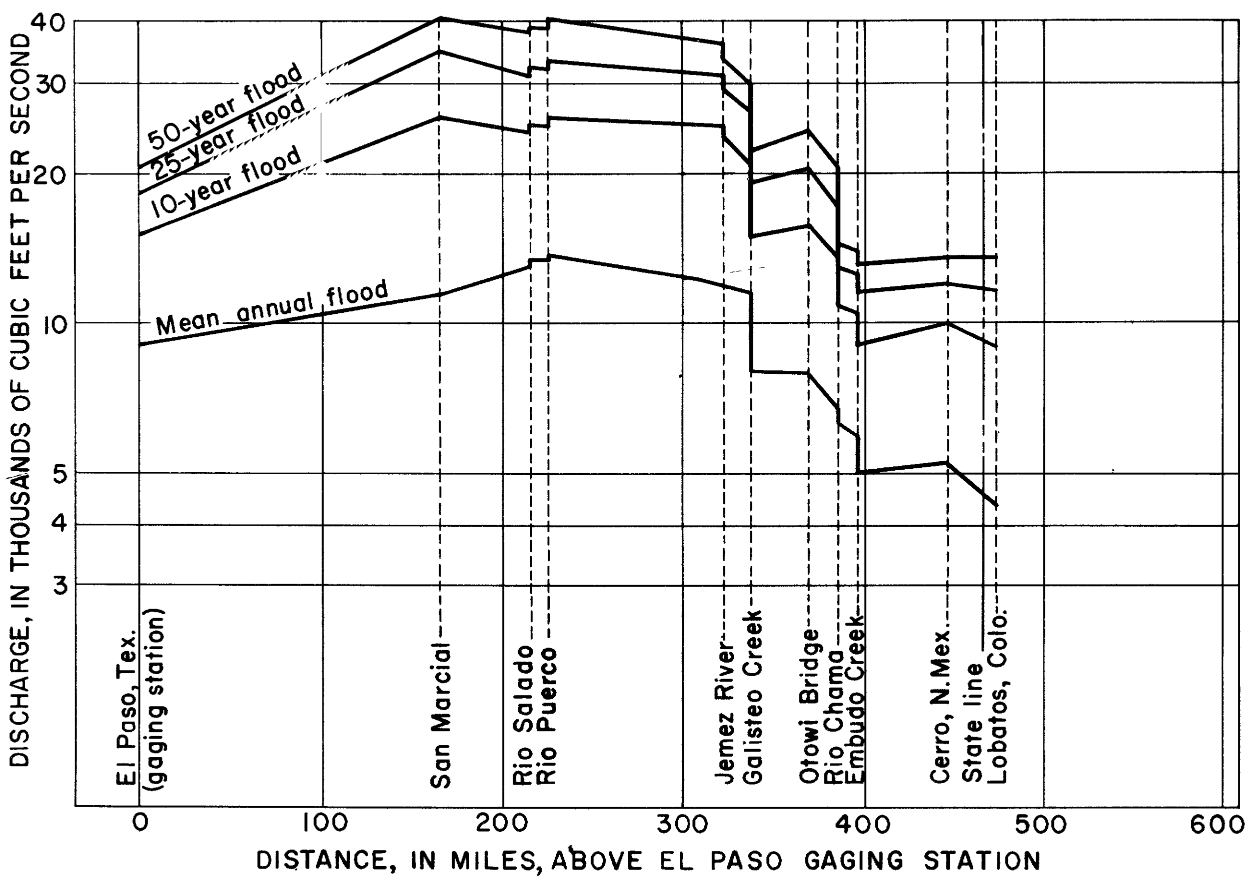

Figure 10.—Relation of discharge for selected flood frequencies to miles above El Paso gaging station, Rio Grande main stem below Lobatos, Colo.

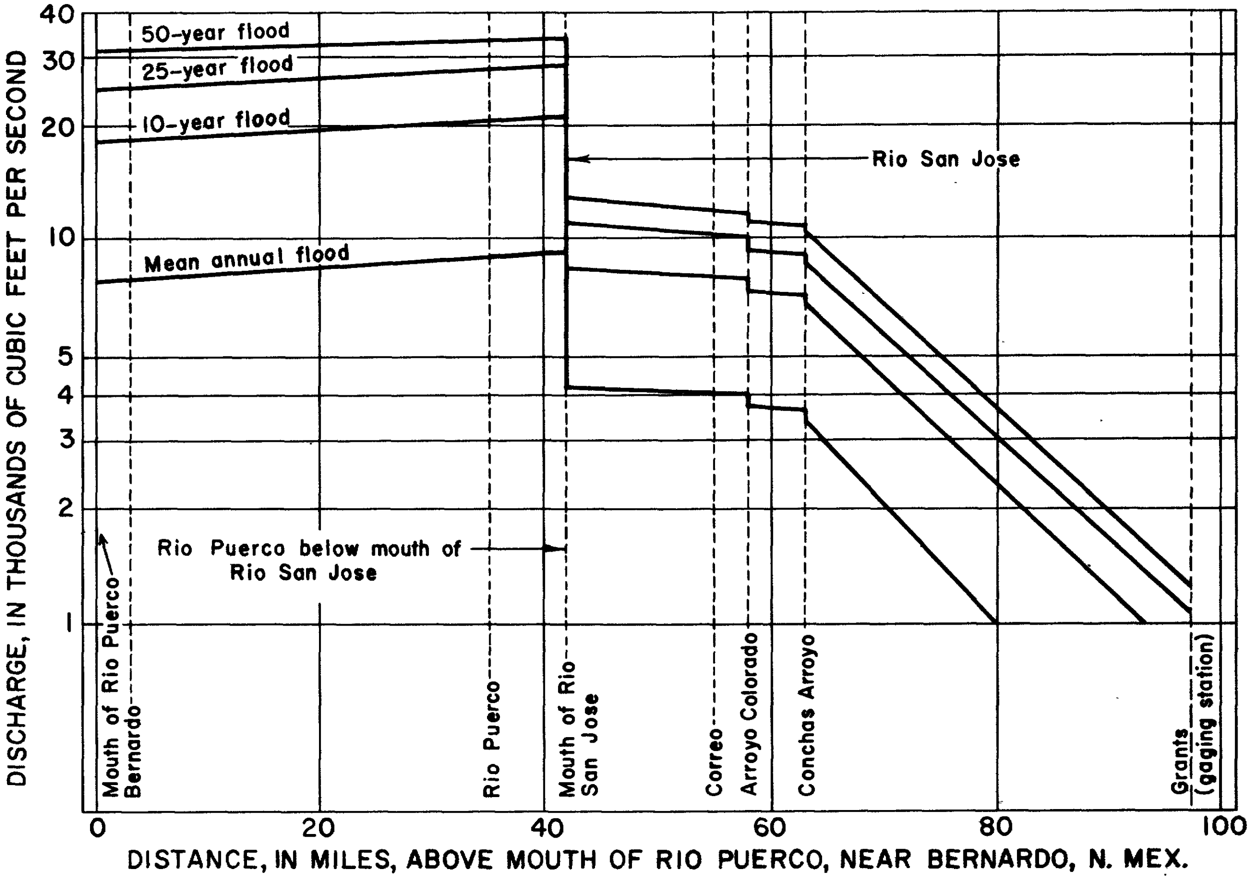

Figure 11.—Relation of discharge for selected flood frequencies to miles above mouth of Rio Puerco, Rio San Jose and Rio Puerco main stem below mouth of Rio San Jose.

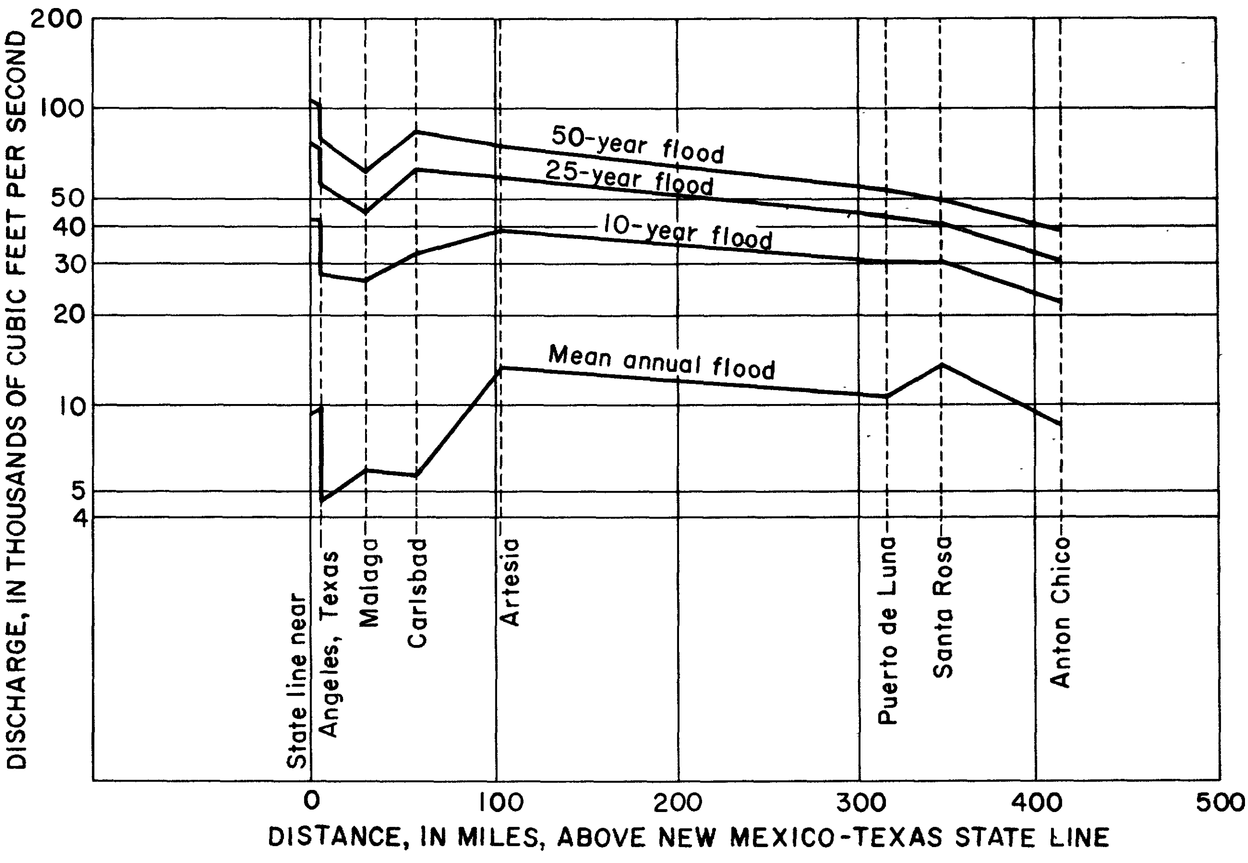

Figure 12.—Relation of discharge for selected flood frequencies to miles above State line, Pecos River main stem below Anton Chico gaging station.

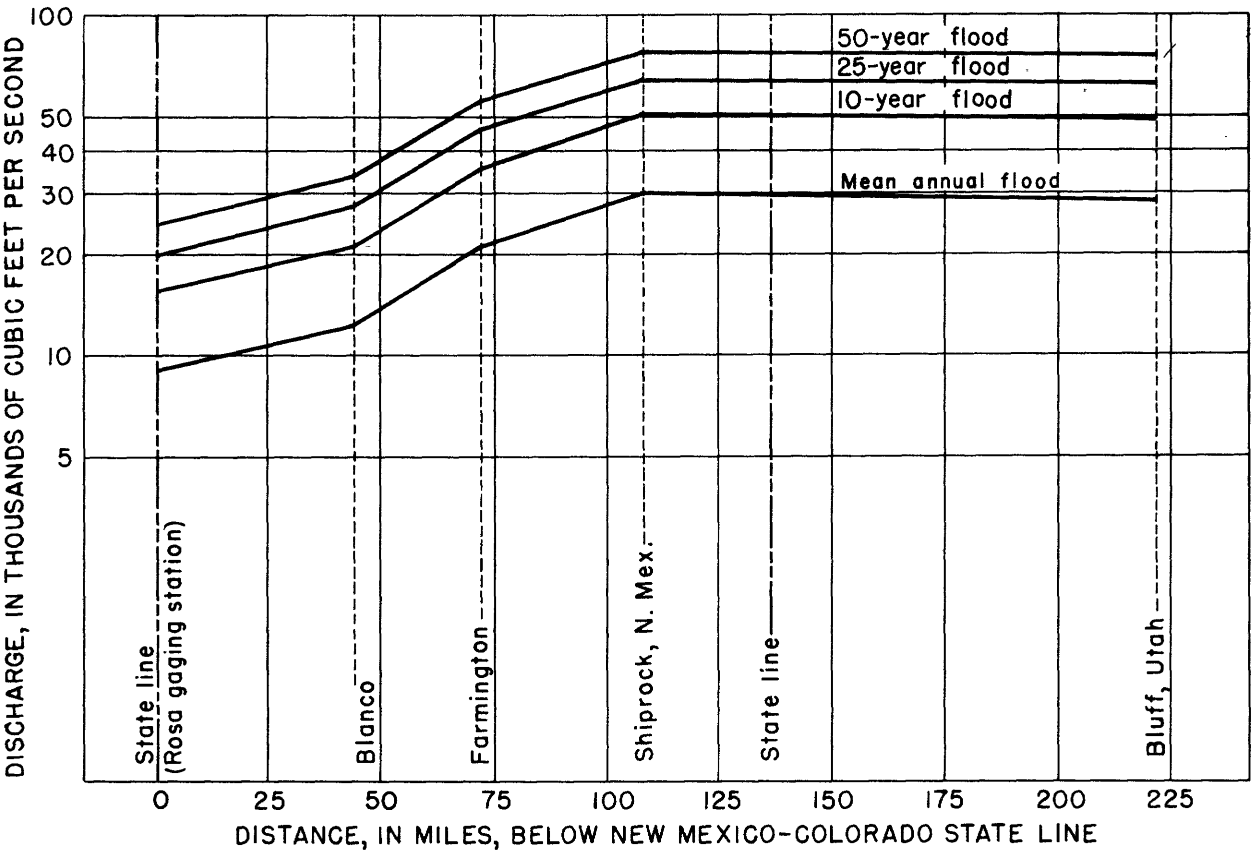

Figure 13.—Relation of discharge for selected flood frequencies to miles below State line, San Juan River main stem below Rosa gaging station.

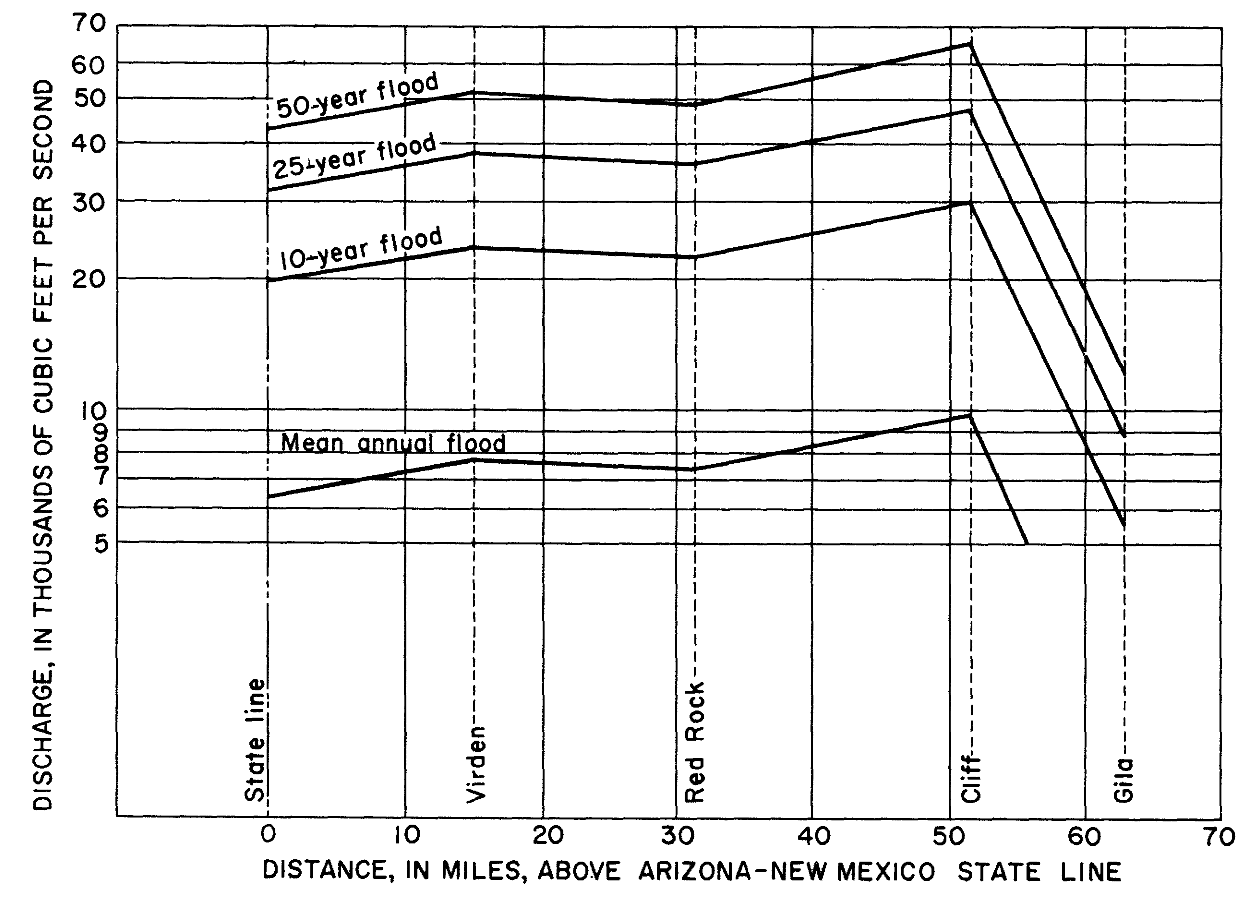

Figure 14.—Relation of discharge for selected flood frequencies to miles below State line, Gila River main stem below Gila River near Gila gaging station.

6. Multiply the mean annual flood obtained in step 4 by the ratio determined in step 5 to determine the peak discharge.

7. A complete frequency curve for a site may be constructed by repeating steps 5 and 6 for several selected frequencies and drawing a smooth curve through the plotted points.

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