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# TECHNIQUE FOR ESTIMATING THE MAGNITUDE AND FREQUENCY OF FLOODS IN TEXAS

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# CONTENTS

# ILLUSTRATIONS

# TECHNIQUE FOR ESTIMATING THE MAGNITUDE
# AND FREQUENCY OF FLOODS IN TEXAS

By
E. E. Schroeder and B. C. Massey

## ABSTRACT

Drainage area, slope, and mean annual precipitation were the only factors that were statistically significant at the 95-percent confidence level when the characteristics of the drainage basins were used as independent variables in a multiple-regression flood-frequency analysis of natural, unregulated streams in Texas. The State was divided into six regions on the basis of the distribution of the residuals from a single statewide regression of the 10-year flood. Equations were developed for predicting the magnitude of floods with recurrence intervals of 2, 5, 10, 25, 50, and 100 years in each of the six regions. These equations are applicable to unregulated rural streams with drainage basins ranging in area from 0.3 square mile to about 5,000 square miles in some regions. Regression equations were not developed for several areas, particularly in south Texas, because of the lack of definition of the flood-frequency characteristics.

# INTRODUCTION

A reasonable estimate of the magnitude and frequency of occurrence of peak discharges is required for proper design of structures on the flood plain of a stream. This information is also necessary for flood-plain management and for determining flood-insurance rates. This report presents a method for determining the magnitude and frequency of peak discharges on natural streams in Texas.

Flood-frequency relations presented in this report were defined by currently accepted analytical techniques utilizing all applicable flood-flow data collected in Texas through September 30, 1974. They provide the basis for reliable estimates of the magnitude of floods with recurrence intervals of 2, 5, 10, 25, 50, and 100 years for unregulated, ungaged rural streams in Texas.

## Acknowledgments

This report was prepared by the U.S. Geological Survey in cooperation with the Texas State Department of Highways and Public Transportation. The research study was supported, in part, by highway planning and research funds provided by Texas State Department of Highways and Public Transportation and the Federal Highway Administration. The research results are based on data collected and published by the Geological Survey for many years in cooperation with State, federal, and local agencies. Much of the data on small streams were collected by the Geological Survey through a special project in cooperation with the Texas State Department of Highways and Public Transportation and the Federal Highway Administration. The opinions, findings, and conclusions expressed in this report, however, are not necessarily those of the Federal Highway Administration.

## Previous Reports

Johnson and Sayre (1973) defined the relations for estimating flood peaks for the Houston metropolitan area, and Dempster (1974) defined similar relations for the Dallas metropolitan area. In the Houston or Dallas urban areas, those relations should produce more applicable estimates of flood peaks than the relations presented in this report.

An interim report by Schroeder (1974) developed equations for predicting the magnitudes of the 10-, 25-, and 50-year floods for small streams in East Texas. These equations are superseded by those presented in this report.

Previous statewide studies by Benson (1964) and Patterson (1963) defined the relations for estimating flood peaks at sites with rural drainage areas greater than 20 to 50 square miles. The study by Gilbert and Hawkinson (1971) also defined relations for larger drainage areas.

The equations and graphs in this report are based on English units of measurement only. To obtain discharge in cubic meters per second, multiply the English units by the factor 0.02832.


## FLOOD-FREQUENCY ANALYSIS

Annual peak data at 289 sites were used in this analysis to develop flood-frequency relations for unregulated rural streams (fig. 1). At 249 sites, recorded annual peak data were used in the analysis, and at 40 sites annual peaks derived from a rainfall-runoff simulation model (Massey and Schroeder, 1977) were used.

The peak discharges of floods with recurrence intervals of 2, 5, 10, 25, 50, and 100 years were computed at all stations by using the procedures outlined by the Hydrology Committee of the United States Water Resources Council (U.S. Water Resources Council, 1976). These guidelines recommend using the log-Pearson type III distribution and contain suggestions for dealing with skew weighting, high and low outliers, historical peak information, zero-flow years, and peaks below a base.

The current (1976) version of the Geological Survey's log-Pearson computer program contains options to facilitate skew weighting, conditional-probability adjustment, and historic-peak adjustment. A flood-frequency relationship was computed for most of the sites by using the Water Resources Council guidelines. The low-outlier test, however, was not beneficial because the level for rejection was set too low.

The data from several stations could not be used because the data array indicated two populations of floods, one population resulting from normal continental storms and the other population resulting from tropical storms or hurricanes originating in the Gulf of Mexico.

Because of the need for better definition of flood-frequency relations for small drainage areas (less than 50 square miles) in Texas, the rainfall-runoff simulation model developed by Dawdy, Lichty, and Bergmann (1972) was used to extend short-term records on small drainage areas so that the magnitude and frequency of floods with recurrence intervals as high as 100 years could be defined (Massey and Schroeder, 1977). The parameters developed from calibration of the simulation model, together with long-term rainfall and evaporation records, were used to simulate an array of annual peaks at each of 40 sites on small drainage areas with short-term records. Flood-frequency curves for each of these sites, using the synthesized peaks, were defined by fitting the log-Pearson type III distribution.

Most of the flood-frequency curves derived from synthesized data exhibited a characteristic regression effect of having a smaller standard deviation than the curves obtained by use of recorded data from several

REGION ④
REGION ③
REGION ②
REGION ①
REGION ⑥
REGION ⑤

OKLAHOMA
TEXAS
NEW MEXICO
MEXICO
LOUISIANA
GULF OF MEXICO

Amarillo
Lubbock
Midland
Odessa
Big Spring
San Angelo
Waco
Temple
Austin
San Antonio
Bryan
Houston
Beaumont
Galveston
Victoria
Corpus Christi
Kingsville
Laredo
McAllen
Harlingen
Wichita Falls
Fort Worth
Dallas
Brownwood
Brady

LAKE MEREDITH
GREENBELT RESERVOIR
WHITE RIVER RESERVOIR
LAKE J. B. THOMAS
LAKE COLORADO CITY
RED BLUFF RESERVOIR
E.V. SPENCE RESERVOIR
SAN ANGELO LAKE
TWIN BUTTES RESERVOIR
CHAMPION CREEK RESERVOIR
OAK CREEK RESERVOIR
FORT PHANTOM HILL RESERVOIR
HUBBARD CREEK RESERVOIR
LAKE STAMFORD
POSSUM KINGDOM RESERVOIR
LAKE GRAHAM
BRIDGEPORT RESERVOIR
LAKE KEMP
DIVERSION LAKE
LAKE KICKAPOO
LAKE ARROWHEAD
FARMERS CREEK RESERVOIR
MOSS LAKE
LAKE TEXOMA
LAKE WICHITA
LAKE WEATHERFORD
LAKE PALO PINTO
LAKE MINERAL WELLS
LAKE GRANBURY
WHITNEY LAKE
PROCTOR LAKE
LAKE LEON
LAKE CISCO
LAKE CLYDE
COLEMAN RESERVOIR
HORDS CREEK LAKE
BRADY CREEK RESERVOIR
BUCHANAN RESERVOIR
LAKE LYNDON B. JOHNSON
LAKE TRAVIS
CANYON LAKE
MEDINA LAKE
VICTOR BRAUNIG LAKE
AMISTAD RESERVOIR
INTERNATIONAL FALCON RESERVOIR
LOMA ALTA RESERVOIR
MONTE ALTO RESERVOIR
LAKE CORPUS CHRISTI
LAKE MEXIA
BELTON LAKE
STILLHOUSE HOLLOW LAKE
SOMERVILLE LAKE
NAVARRO MILLS LAKE
BARDWELL LAKE
CEDAR CREEK RESERVOIR
RICHLAND CREEK LAKE
LAKE PAT CLEBURNE
HOUSTON COUNTY LAKE
LIVINGSTON RESERVOIR
B. A. STEINHAGEN LAKE
SAM RAYBURN RESERVOIR
TOLEDO BEND RESERVOIR
CADDO LAKE
LAKE O' THE PINES
ELLISON CREEK RESERVOIR
LAKE CHEROKEE
MURVAUL LAKE
LAKE STRIKER
LAKE TYLER
LAKE PALESTINE
LAKE JACKSONVILLE
PAT MAYSE LAKE
TEXARKANA RESERVOIR
LAKE TAWAKONI
LAKE WINNSBORO
ADDICKS RESERVOIR
BARKER RESERVOIR
BRAZORIA RESERVOIR
BIG HILL RESERVOIR
ANAHUAC LAKE

CANADIAN RIVER
RED RIVER
BRAZOS RIVER
COLORADO RIVER
PECOS RIVER
RIO GRANDE
NUECES RIVER
TRINITY RIVER
SABINE RIVER
NECHES RIVER
SAN ANTONIO RIVER
GUADALUPE RIVER
LLANO RIVER

EXPLANATION

▲ 770   STREAMFLOW OR RESERVOIR-CONTENT STATION

△ 414   FLOOD-HYDROGRAPH, LOW-FLOW, OR CREST STAGE PARTIAL-RECORD STATION

–  –  –   RIVER BASIN DIVIDE

AREAS—In which flood-frequency relations are undefined

PLAYA—LAKE AREA—In which the equations do not apply

0  20  40  60  80  100 MILES

sites with more than 20 years of record (Massey and Schroeder, 1977).
Adjustments were made by using a method proposed by W. H. Kirby (oral
commun., 1975). This adjustment is included in an experimental version
of the Geological Survey's log-Pearson computer program.


## REGRESSION ANALYSIS

Multiple linear-regression techniques were used to develop the equa-
tions for predicting the selected t-year discharges. The values of the
variables were transformed to base 10 logarithms prior to making the regres-
sion analysis. The base 10 logarithms of the variable values produce rela-
tions that have a higher degree of linearity than the untransformed values.

The basic logarithmic regression model has the following form:

$$Q_t = a \ B_1{}^{b_1} B_2{}^{b_2} \cdots B_n{}^{b_n}$$

where $Q_t$ = discharge in cubic feet per second for recurrence interval t;
$B_1$, $B_2$, $\cdots B_n$ are independent variables; $b_1$, $b_2$, $\cdots b_n$ are regression
coefficients; and a is the regression constant.

The independent variables used in this analysis were drainage area,
slope, length, elevation, mean annual precipitation (fig. 2), 24 hour-2
year rainfall intensity, and evaporation. Only those variables that were
significant at the 95-percent confidence level (drainage area, slope, and
mean annual precipitation) were retained.

The six flood-frequency regions of the State (fig. 1) were determined
on the basis of a plot of the residuals (the difference between the com-
puted and the observed discharge values) from the equation of the 10-year
flood for all 289 sites. A separate regression analysis was then made
for each t-year event in each flood-frequency region, and regression equa-
tions were developed for each event in each region. Drainage area and
slope remained significant in regions 1, 2, 4, and 5; drainage area alone
was used in region 3; and in region 6, drainage area and mean annual pre-
cipitation were used. The residuals for these equations were plotted and
no overall bias or areal trends were indicated.


## APPLICATION OF REGRESSION EQUATIONS

The regression equations shown in the following table or on the graphs
(figs. 3-13) for each flood-frequency region provide a method for computing
the magnitudes of floods having recurrence intervals of 2, 5, 10, 25, 50,
and 100 years at ungaged rural sites on streams in Texas where unregulated
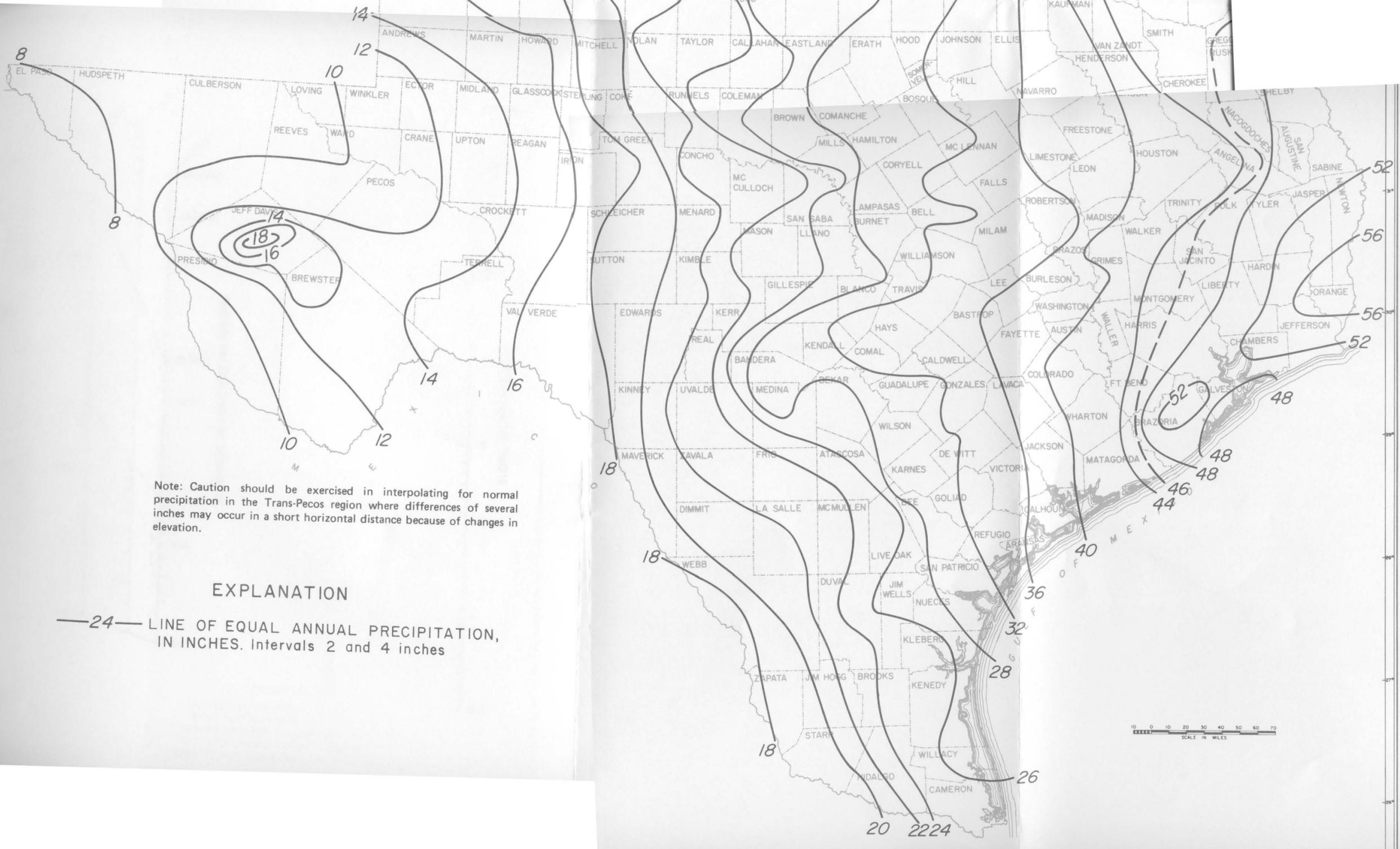flow conditions prevail.

The flood-frequency region in which a site is located is determined
from figure 1, and the appropriate set of equations or graphs are selected.
Drainage area (A), in square miles, is obtained by planimetering the area

Based on U.S. Department of Commerce, National Oceanic
Atmospheric Administration Environmental Data S
"Climatography of the United States No. 81 (Texas)" for the
1941-1970.

Weather Modification and Technology Division
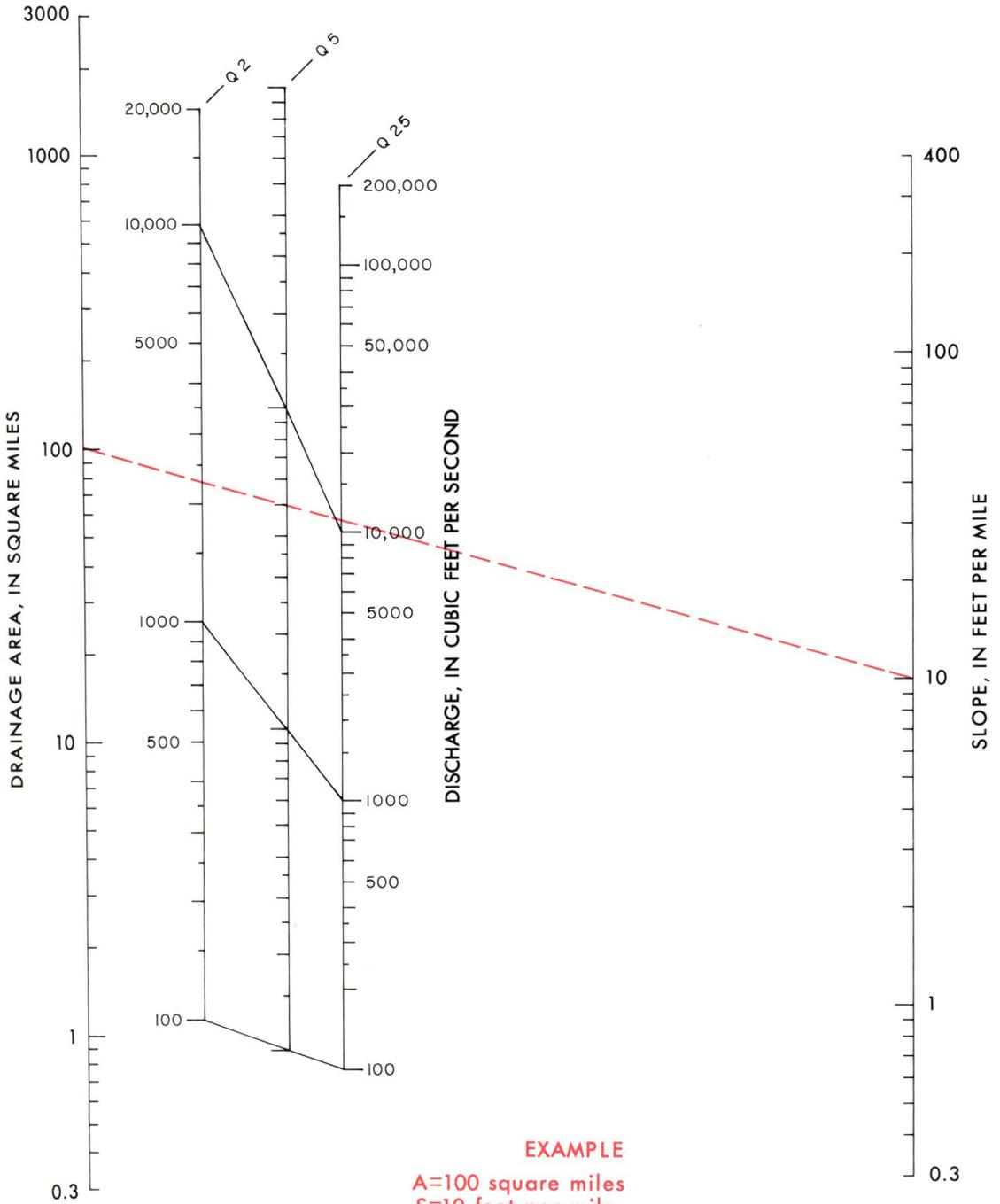Texas Water Development Board
July 1974

Note: Caution should be exercised in interpolating for normal
precipitation in the Trans-Pecos region where differences of several
inches may occur in a short horizontal distance because of changes in
elevation.

EXPLANATION

—24— LINE OF EQUAL ANNUAL PRECIPITATION,
IN INCHES. Intervals 2 and 4 inches

FIGURE 3.-Nomograph for determining peak discharges of floods with recurrence
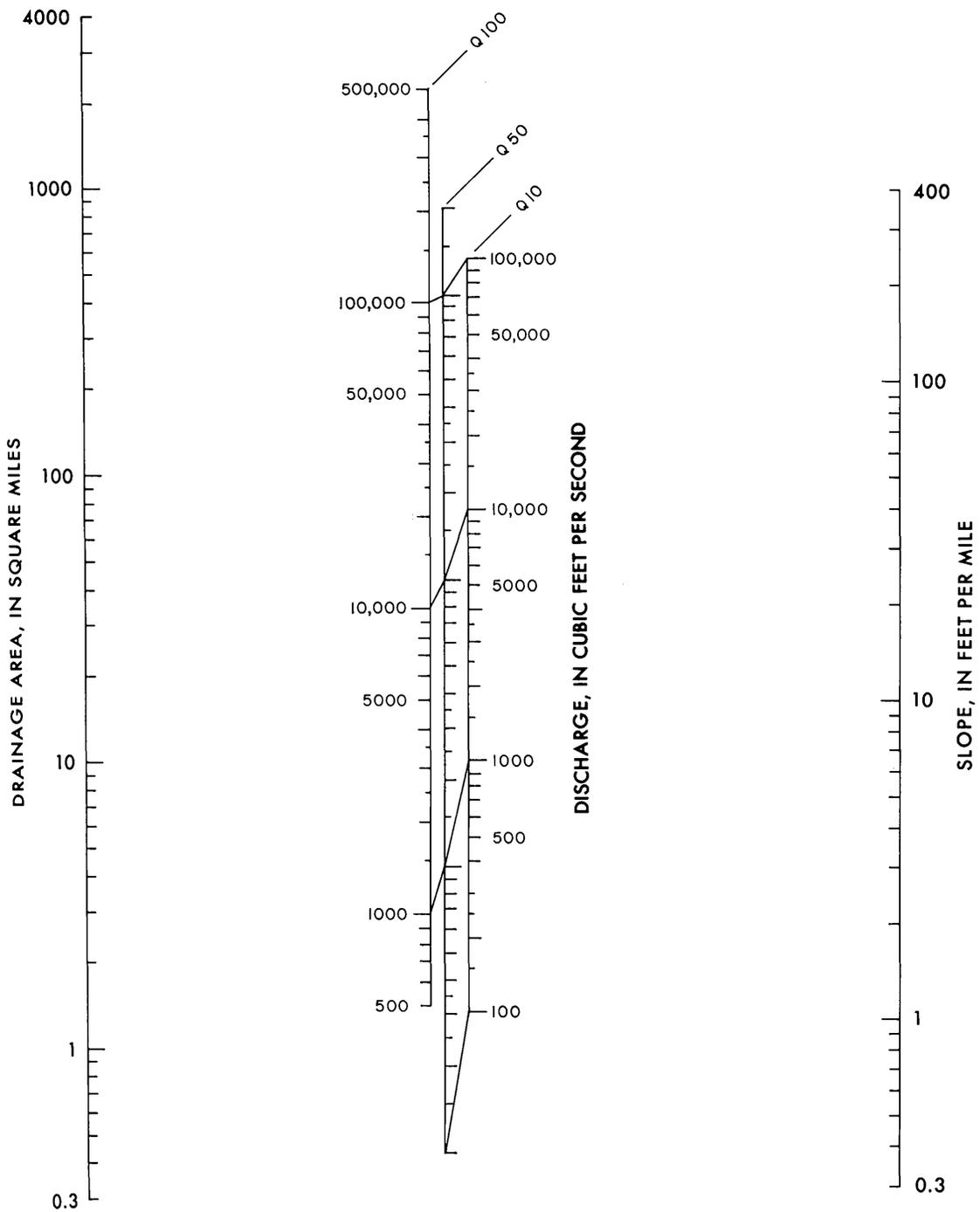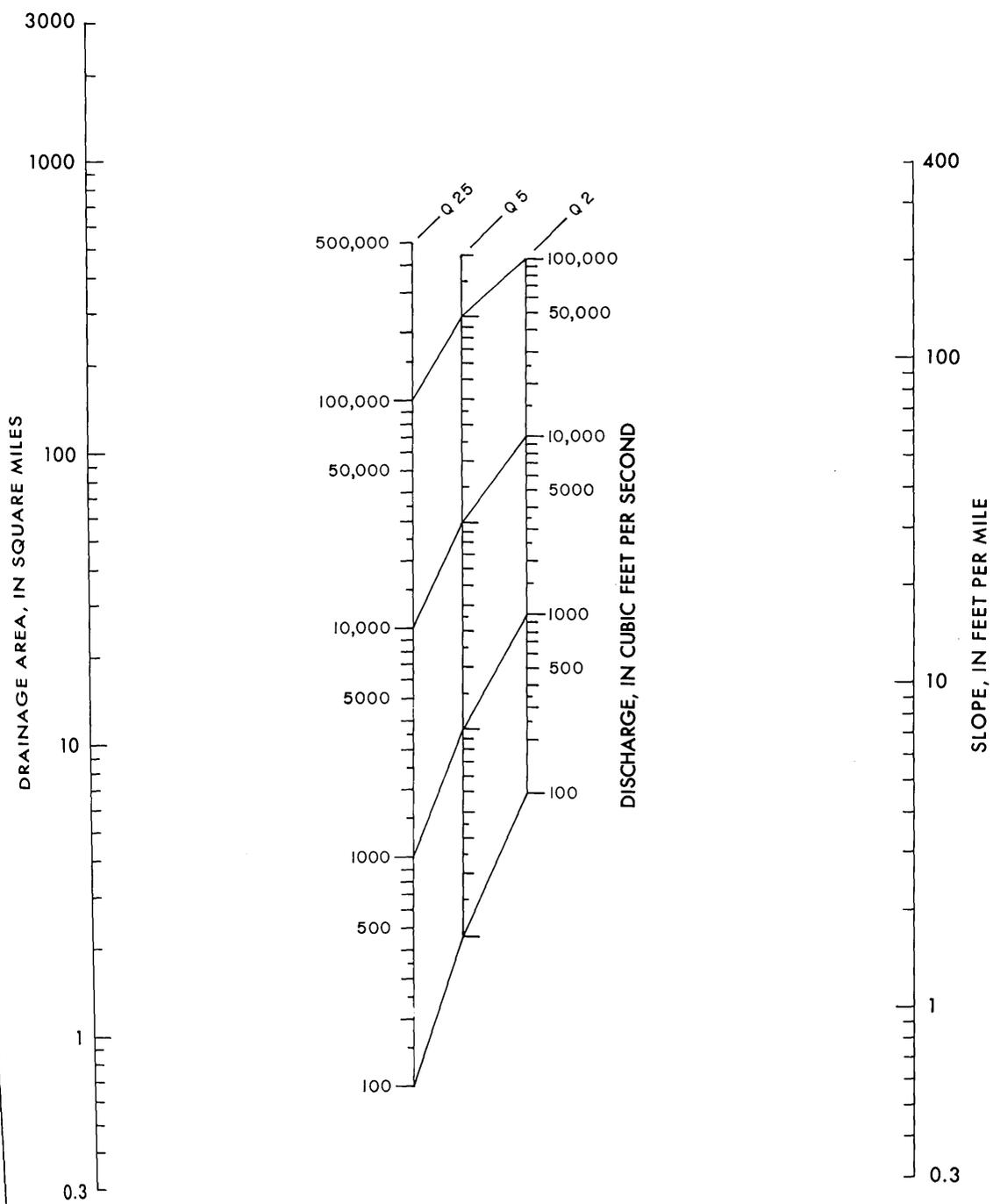intervals of 2, 5, and 25 years in region 1
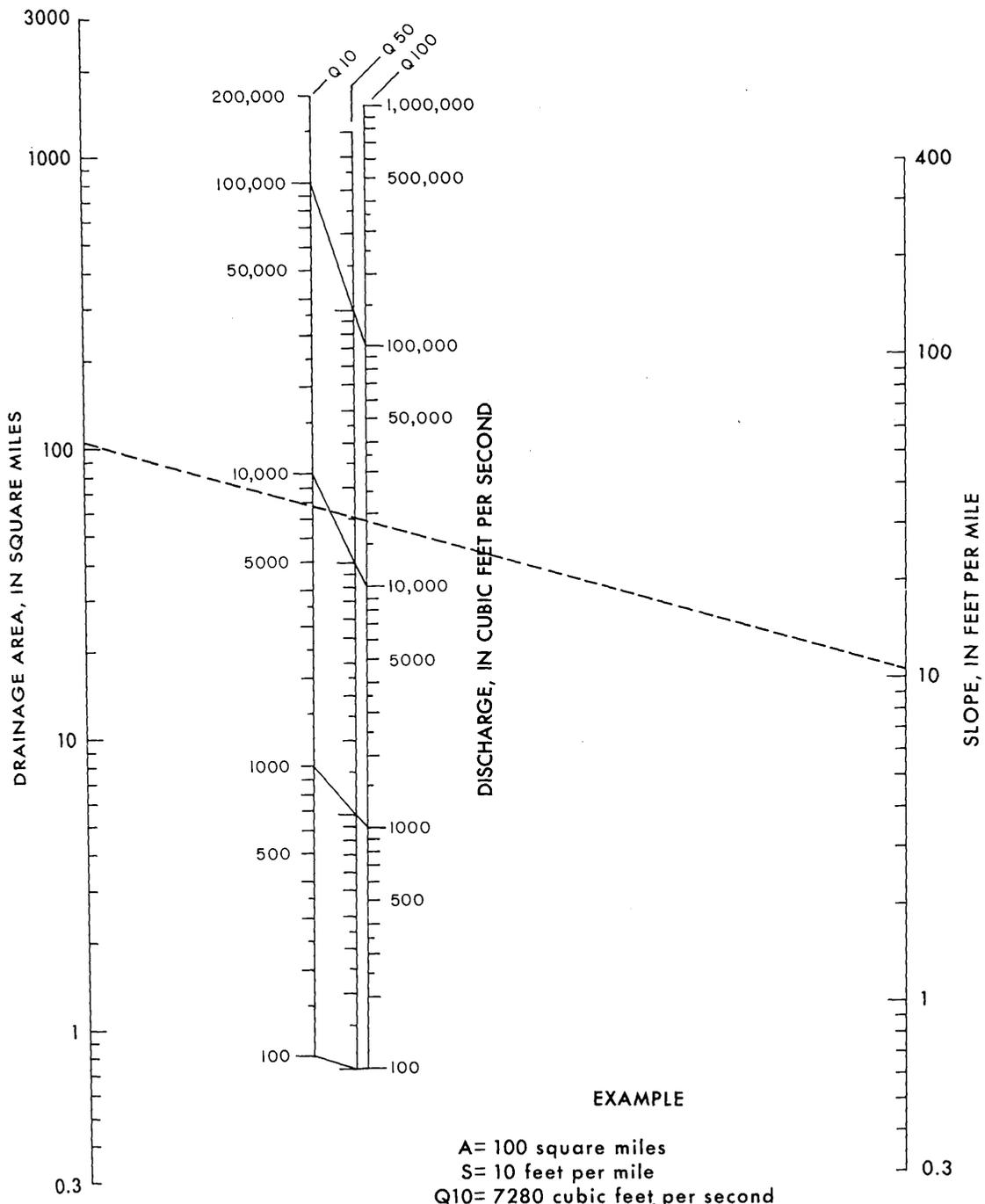
FIGURE 4.-Nomograph for determining peak discharges of floods with recurrence intervals of 10, 50, and 100 years in region 1
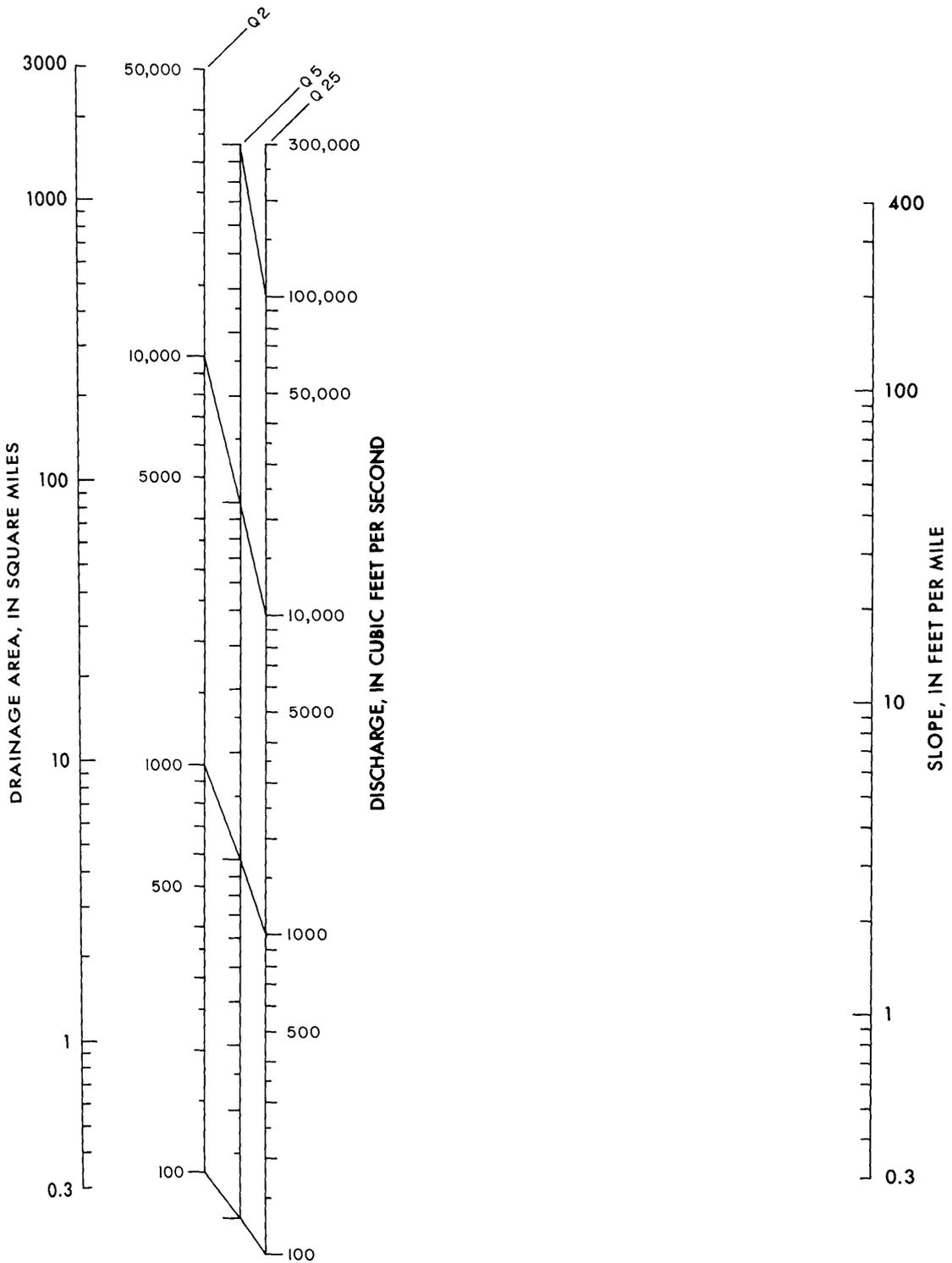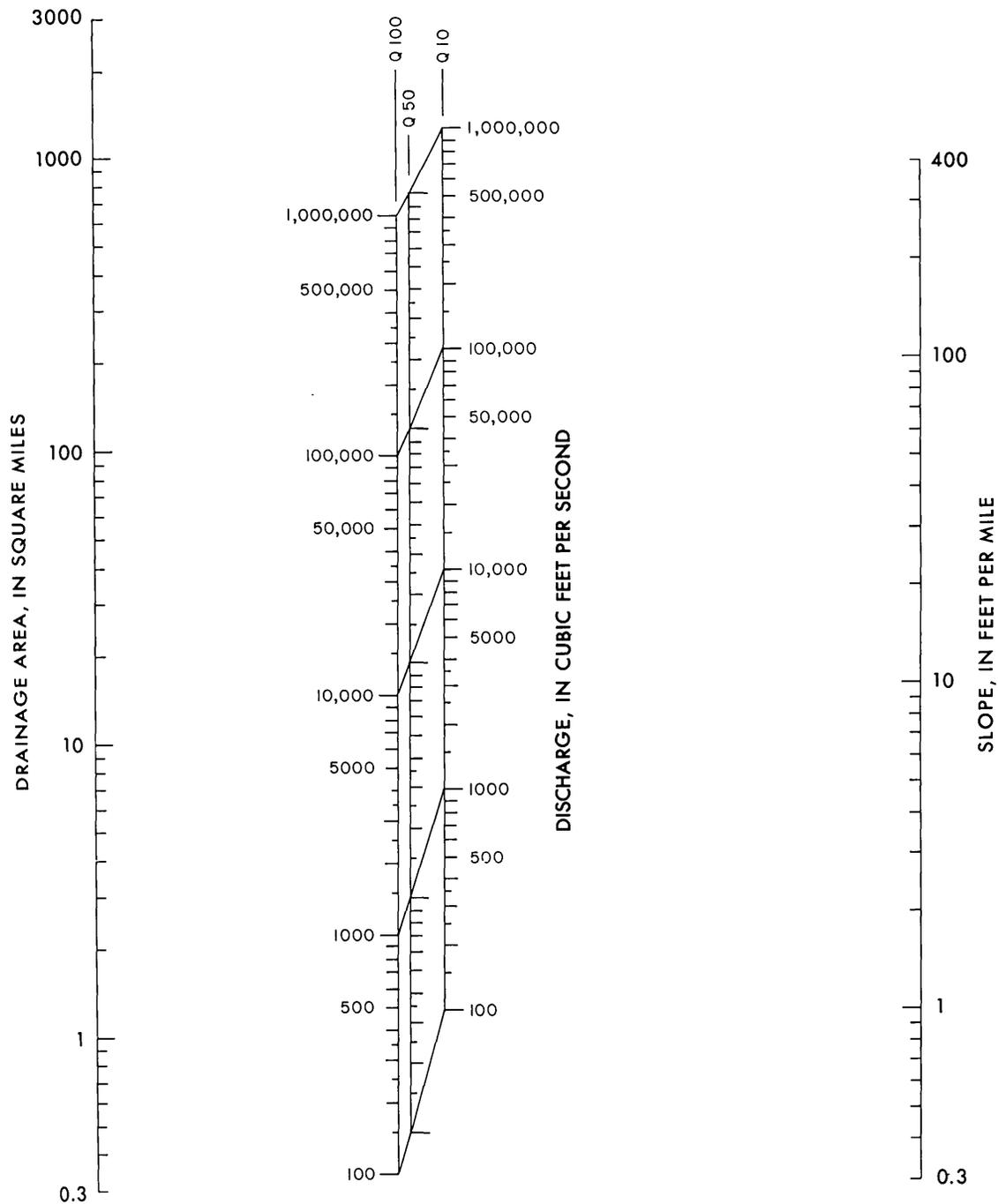
FIGURE 5.-Nomograph for determining peak discharges of floods with recurrence intervals of 2, 5, and 25 years in region 2
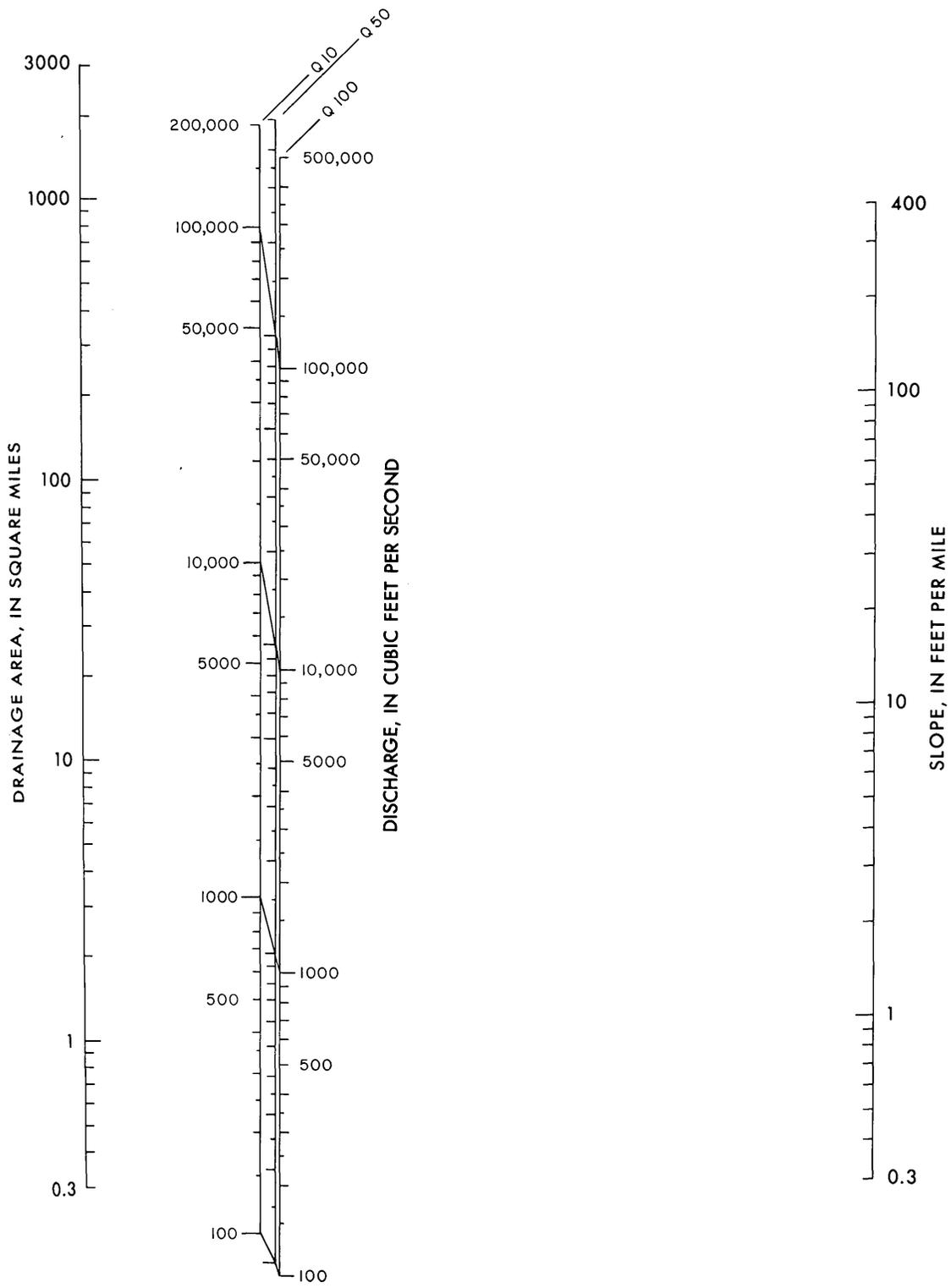
FIGURE 6.-Nomograph for determining peak discharges of floods with recurrence intervals of 10, 50, and 100 years in region 2
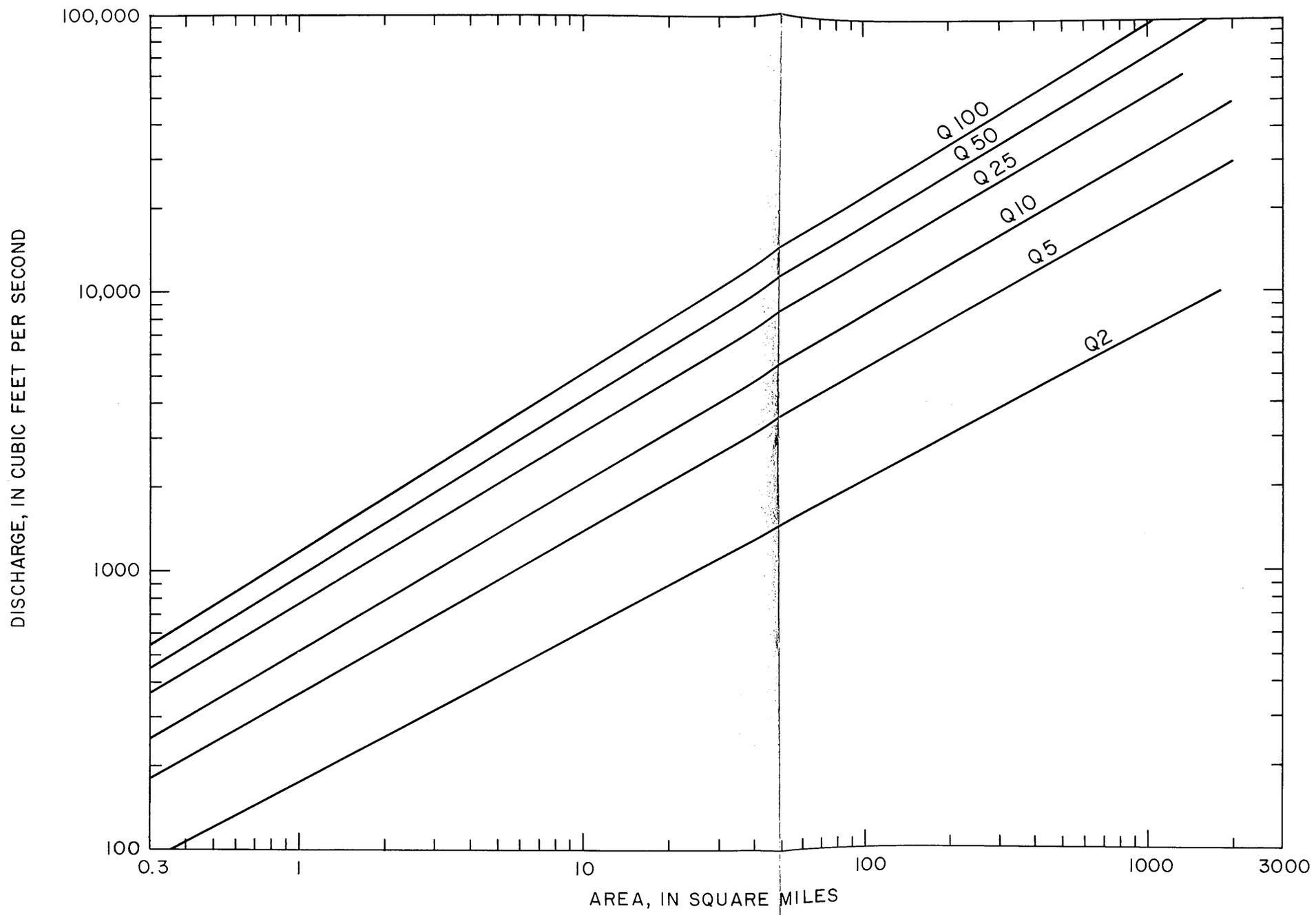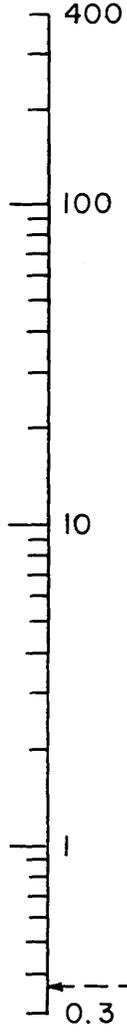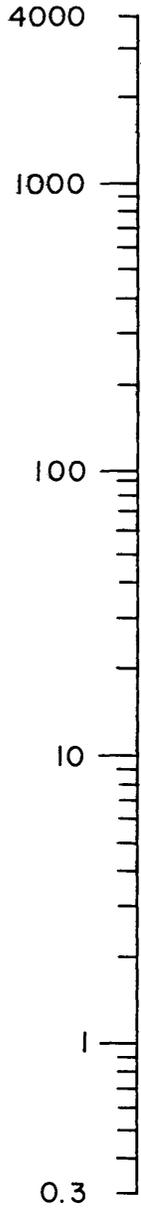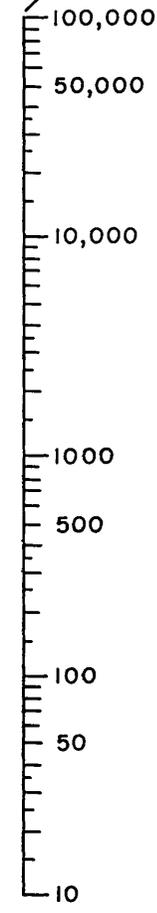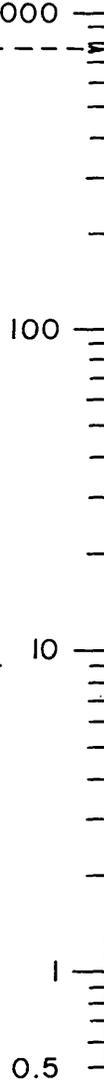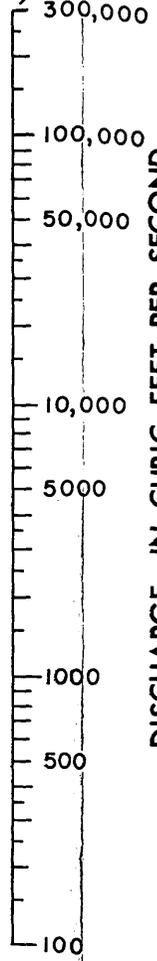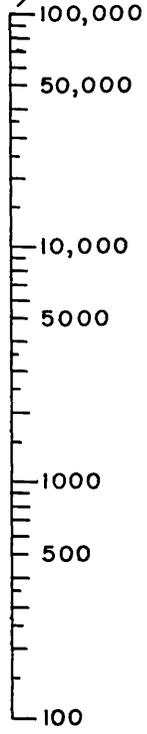
FIGURE 9.-Nomograph for determining peak discharges of floods with recurrence intervals of 10, 50, and 100 years in region 4

FIGURE 10.-Nomograph for determining peak discharges of floods with recurrence
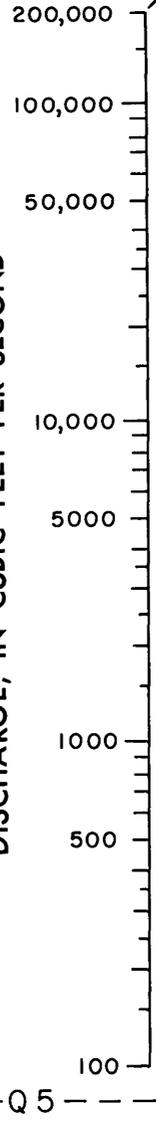intervals of 2, 5, and 25 years in region 5

FIGURE 11.-Nomograph for determining peak discharges of floods with recurrence intervals of 10, 50, and 100 years in region 5
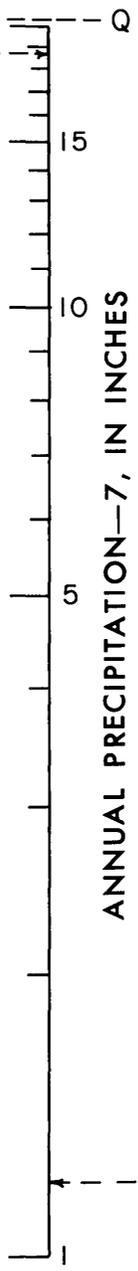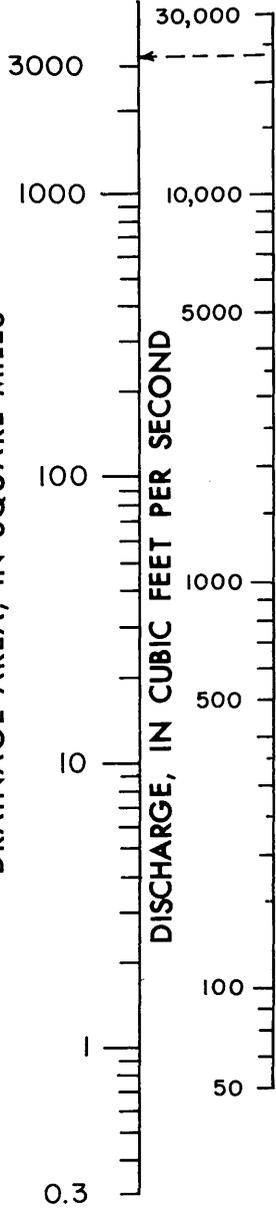
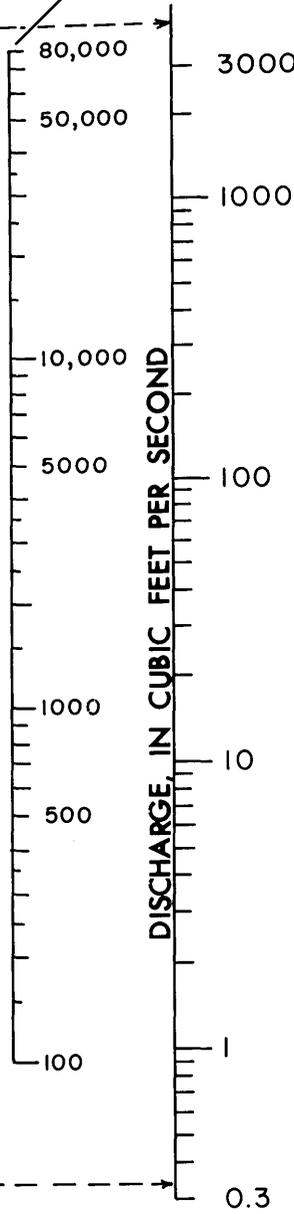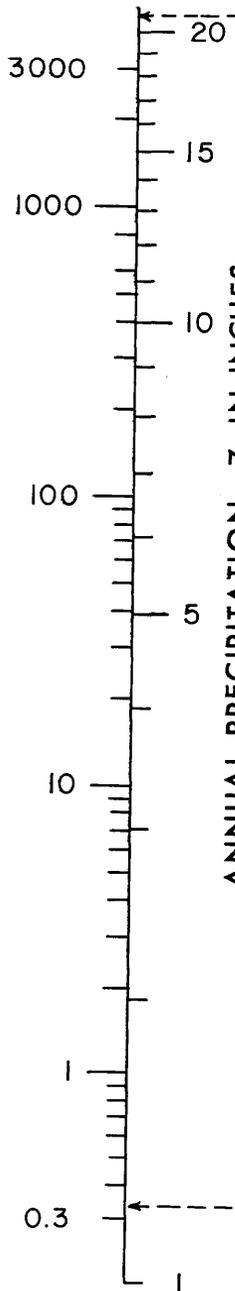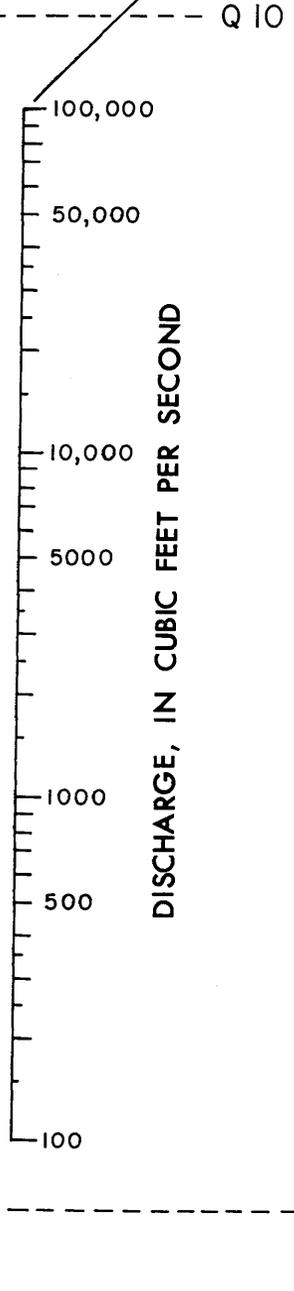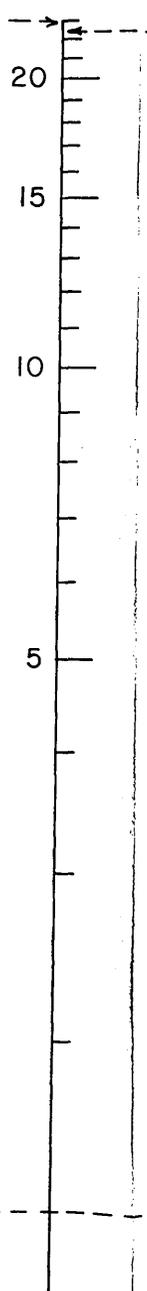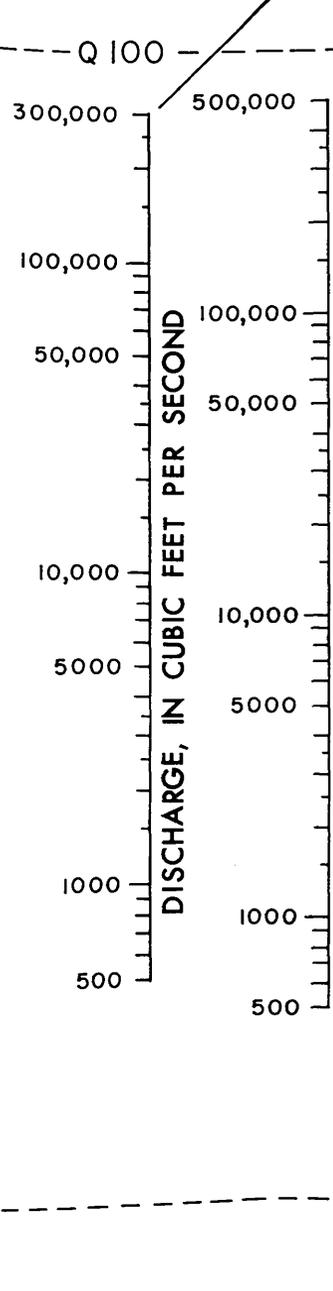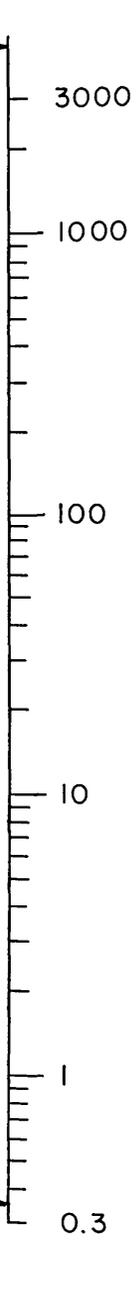contributing surface flows above the site as outlined along the drainage divide on the best available topographic maps. Slope (S), in feet per mile, is the average slope of the streambed between points 10 and 85 percent of the distance along the main-stream channel from the site to the basin divide. The main channel above stream junctions is the one draining the largest area. Elevation differences between the 10- and 85-percent points are divided by the distance between the points to determine the slope. Mean annual precipitation (P), in inches, if needed, is determined from figure 2. In the equations and nomographs for region 6, mean annual precipitation minus 7 inches (P-7) is used to reduce the range of values to more nearly represent precipitation related to flood runoff without introducing values of zero or less.

### Flood-Frequency Region 1

| Regression equation | Standard error of estimate (percent) |
|---|---|
| $Q_2 = 89.9A^{.629}S^{.130}$ ft$^3$/s | 27.4 |
| $Q_5 = 117A^{.685}S^{.254}$ ft$^3$/s | 25.0 |
| $Q_{10} = 131A^{.714}S^{.317}$ ft$^3$/s | 29.7 |
| $Q_{25} = 144A^{.747}S^{.386}$ ft$^3$/s | 36.8 |
| $Q_{50} = 152A^{.769}S^{.431}$ ft$^3$/s | 43.5 |
| $Q_{100} = 157A^{.788}S^{.469}$ ft$^3$/s | 46.8 |

### Flood-Frequency Region 2

| Regression equation | Standard error of estimate (percent) |
|---|---|
| $Q_2 = 216A^{.574}S^{.125}$ ft$^3$/s | 54.6 |
| $Q_5 = 322A^{.620}S^{.184}$ ft$^3$/s | 43.0 |
| $Q_{10} = 389A^{.646}S^{.214}$ ft$^3$/s | 40.3 |
| $Q_{25} = 485A^{.668}S^{.236}$ ft$^3$/s | 40.0 |
| $Q_{50} = 555A^{.682}S^{.250}$ ft$^3$/s | 41.4 |
| $Q_{100} = 628A^{.694}S^{.261}$ ft$^3$/s | 43.7 |

## Flood-Frequency Region 3

| Regression equation | Standard error of estimate (percent) |
|---|---|
| $Q_2$ = $175A^{.540}$ ft$^3$/s | 41.2 |
| $Q_5$ = $363A^{.580}$ ft$^3$/s | 40.7 |
| $Q_{10}$ = $521A^{.599}$ ft$^3$/s | 43.6 |
| $Q_{25}$ = $759A^{.616}$ ft$^3$/s | 47.5 |
| $Q_{50}$ = $957A^{.627}$ ft$^3$/s | 50.7 |
| $Q_{100}$ = $1175A^{.638}$ ft$^3$/s | 54.2 |

## Flood-Frequency Region 4

| Regression equation | Standard error of estimate (percent) |
|---|---|
| $Q_2$ = $13.3A^{.676}S^{.694}$ ft$^3$/s | 50.3 |
| $Q_5$ = $42.7A^{.630}S^{.641}$ ft$^3$/s | 40.9 |
| $Q_{10}$ = $80.7A^{.604}S^{.596}$ ft$^3$/s | 39.2 |
| $Q_{25}$ = $163A^{.576}S^{.535}$ ft$^3$/s | 40.5 |
| $Q_{50}$ = $248A^{.562}S^{.497}$ ft$^3$/s | 42.8 |
| $Q_{100}$ = $397A^{.540}S^{.442}$ ft$^3$/s | 46.5 |

## Flood-Frequency Region 5

| Regression equation | Standard error of estimate (percent) |
|---|---|
| $Q_2$ = $4.82A^{.799}S^{.966}$ ft$^3$/s | 62.1 |
| $Q_5$ = $36.4A^{.776}S^{.706}$ ft$^3$/s | 46.6 |
| $Q_{10}$ = $82.6A^{.776}S^{.622}$ ft$^3$/s | 42.6 |
| $Q_{25}$ = $180A^{.776}S^{.554}$ ft$^3$/s | 41.3 |
| $Q_{50}$ = $278A^{.778}S^{.522}$ ft$^3$/s | 42.0 |
| $Q_{100}$ = $399A^{.782}S^{.497}$ ft$^3$/s | 44.1 |

| Regression equation | Standard error of estimate (percent) |
|---|---|
| $Q_2 = 49.8A^{.602}(P-7)^{.447}$ ft$^3$/s | 46.7 |
| $Q_5 = 84.5A^{.643}(P-7)^{.533}$ ft$^3$/s | 27.9 |
| $Q_{10} = 111A^{.666}(P-7)^{.573}$ ft$^3$/s | 27.9 |
| $Q_{25} = 150A^{.692}(P-7)^{.608}$ ft$^3$/s | 34.3 |
| $Q_{50} = 182A^{.709}(P-7)^{.630}$ ft$^3$/s | 40.2 |
| $Q_{100} = 216A^{.725}(P-7)^{.647}$ ft$^3$/s | 46.1 |

## RANGE OF APPLICATION OF EQUATIONS

The flood-frequency equations presented in this report may be used to estimate the magnitude and frequency of floods for most natural, rural streams in Texas. The equations do not apply to urban streams or to streams that are regulated by manmade structures. The streams on part of the Southern High Plains are also excluded because internal drainage into the playa lakes results in varying amounts of noncontributing drainage areas. Data were not sufficient to develop relationships in south Texas or for the Nueces River downstream from the Balcones Fault Zone. In flood-frequency region 6, the equations do not apply to areas above an elevation of 4,000 feet above mean sea level, because no data were available.

The following table shows the range of drainage area and slope within which the equations were developed for each flood-frequency region.

| Flood-frequency region | Drainage area (square miles) | Slope (feet/mile) |
|---|---|---|
| 1 | 0.39 - 4,839 | 0.85 - 206.2 |
| 2 | .33 - 4,233 | 1.16 - 108.1 |
| 3 | 2.38 - 4,097 | -- |
| 4 | 1.09 - 3,988 | 2.33 - 74.8 |
| 5 | 1.08 - 1,947 | 9.15 - 76.8 |
| 6 | .32 - 2,730 | -- |

The equations presented in this report should provide the basis for the most reliable estimates available of the frequency and magnitude of floods on ungaged, unregulated rural streams in Texas, within the range of drainage areas and slope given in the preceding table. The equations were defined by using the most recently developed analytical techniques and by using all applicable floodflow data collected in Texas through September 30, 1974, for floods with recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Because of the refinement of analytical techniques and because of the volume of data used, these equations supersede all equations designed for unregulated rural streams in Texas previously published by the Geological Survey.

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