Chapter 11
Simplified Techniques

11-1. Introduction

a. Simplified techniques include numerous approaches for determining the approximate magnitude of the peak flow expected for events of varying frequency. These approaches are useful for an approximate answer with a minimum of effort. They are often used in ungauged drainage areas.

b. This chapter describes the role of simplified techniques for flood-runoff analysis. Various methods for estimating the peak flow associated with varying frequencies will be discussed including the rational method, regression techniques, SCS methods, and maximum expected envelop curves.

11-2. Rational Method

a. The so-called rational method is a popular, easy-to-use technique for estimating peak flow in any small drainage basin having mixed land use. It generally should not be used in basins larger than 1 square mile. The peak flow can be calculated by the following equation:

$$Q = CIA \tag{11-1}$$

where:

Q = peak flow, in cubic feet per second

C = runoff coefficient

I = rainfall intensity, in inches per hour

A = drainage area, in acres

b. The coefficient is the proportion of rainfall that contributes to runoff. Table 11-1 is an example of the relationship between this coefficient and land use. In basins having a significant nonhomogeneity of land use, an average coefficient can easily be determined by multiplying the percentage of each land use in the basin by its appropriate coefficient from Table 11-1.

c. The rainfall intensity is specifically defined for an event or the frequency of interest and for a duration equal to or greater than the time of concentration of the watershed. Time of concentration (T_c) is defined as the time for runoff to travel from the most distant point of the watershed to the watershed outlet. T_c influences the shape and peak of the runoff hydrograph and is a parameter used in many simplified techniques. Numerous methods exist in the literature for estimating T_c. The SCS has developed a method that takes a physically based approach to calculating T_c, which can be found in Chapter 2 of SCS (1986).

d. Use of the rational method for large drainage areas should be discouraged because of the greater complexity of land use and drainage pattern and the unlikelihood of having uniform rainfall intensity for a duration equal to the time of concentration. The method assumes that the peak flow occurs from uniform rainfall intensity over the entire area once every portion of the basin is contributing to runoff at the outlet.

11-3. Regional Frequency Analysis

a. Regional frequency analysis usually involves regression analysis of gauged watersheds within the general region. Through this very powerful technique, sufficiently reliable equations can often be derived for peak flow of varying frequency given quantifiable physical basin characteristics and rainfall intensity for a specific duration. Once these equations are developed, they can then be applied to ungauged basins within the same region.

b. A regional analysis usually consists of the following steps:

(1) Select components of interest, such as mean and peak discharge.

(2) Select definable basin characteristics of gauged watershed: drainage area, slope, etc.

(3) Derive prediction equations with single- or multiple-linear regression analysis.

(4) Map and explain the residuals (differences between computed and observed values) that constitute "unexplained variances" in the statistical analysis on a regional basis.

c. This procedure for development of the regression equation from gauged basin data is illustrated in Figure 11-1. The equation can then be used in ungauged areas within the same region and for data of similar magnitude to that used in the development process. Much

Table 11-1
Typical C Coefficients (for 5- to 10-year Frequency Design)

DESCRIPTION OF AREA	RUNOFF COEFFICIENT
Business	
Downtown areas	0.70 - 0.95
Neighborhood area	0.50 - 0.70
Residential	
Single-family areas	0.30 - 0.50
Multiunits, detached	0.40 - 0.60
Multiunits, attached	0.60 - 0.75
Residential (suburban)	0.25 - 0.40
Apartment dwelling areas	0.50 - 0.70
Industrial	
Light areas	0.50 - 0.80
Heavy areas	0.60 - 0.90
Parks, cemeteries	0.10 - 0.25
Playgrounds	0.20 - 0.35
Railroad yard areas	0.20 - 0.40
Unimproved areas	0.10 - 0.30
Streets	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs	0.75 - 0.95
Lawns, Sandy soil	
Flat, 2%	0.05 - 0.10
Average, 2-7%	0.10 - 0.15
Steep, 7%	0.15 - 0.20
Lawns, Heavy soil	
Flat, 2%	0.13 - 0.17
Average, 2-7%	0.18 - 0.22
Steep, 7%	0.25 - 0.35

(from Viessman et al. 1977)

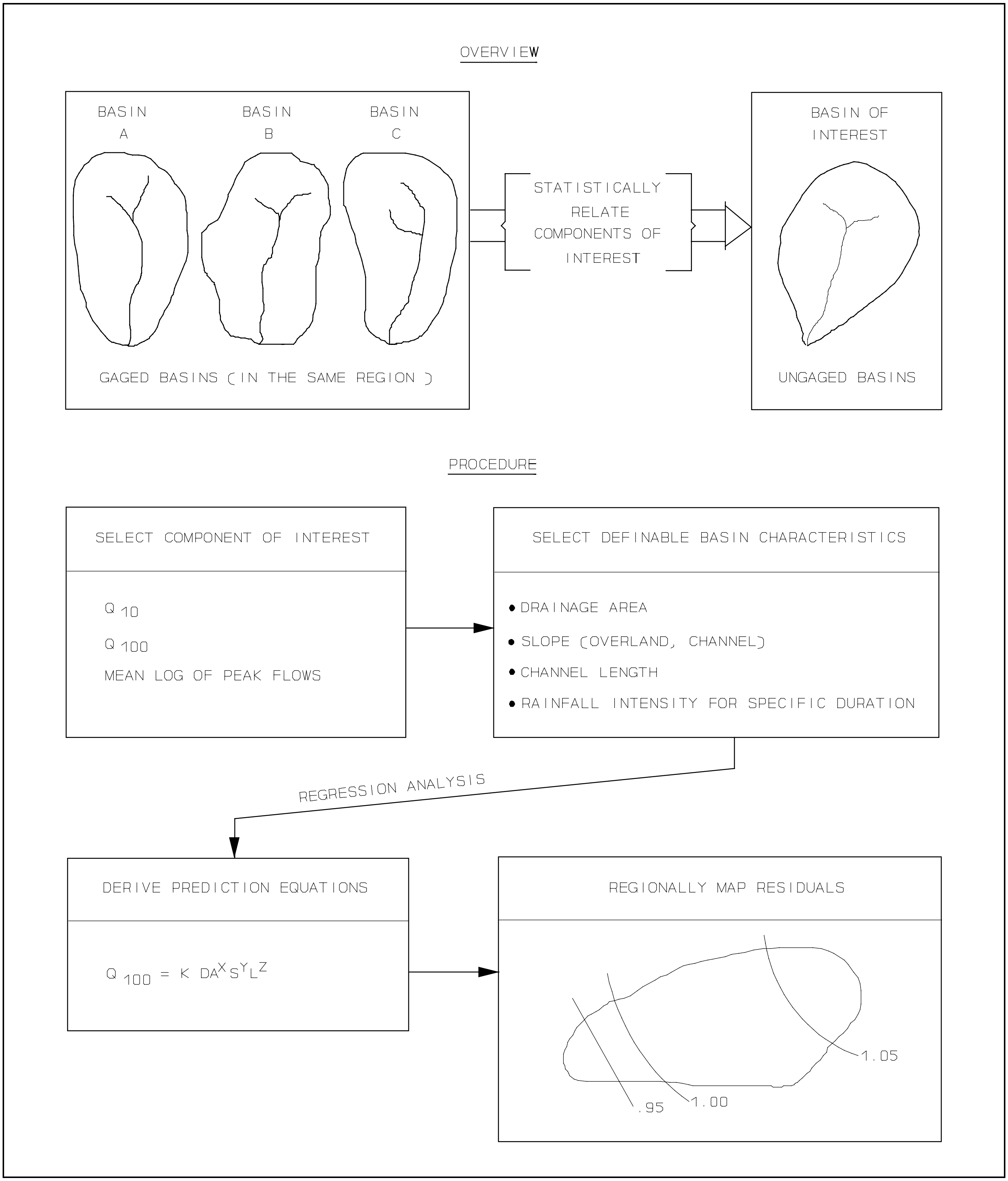

Figure 11-1. Regional analysis

more detail on regression and regional frequency analysis is available in EM 1110-2-1415, Hydrologic Frequency Analysis.

d. Regional equations have already been developed by the U.S. Geological Survey (USGS) and published for the various areas of the United States. An example of this type of equation is the following:

$$Q_{100} = 19.7\ A^{0.88}\ P^{0.84}\ H^{-0.33} \tag{11-2}$$

where

Q_{100} = the 1 percent chance flood peak, in cubic feet per second

A = drainage area, in square miles

P = mean annual precipitation, in inches

H = average main channel elevation at 10 and 85 percent points along the main channel length, in 1,000 ft

e. Table 11-2 illustrates various examples of regional equations for the entire state of California. These equations make no assumptions regarding statistical distribution or skew. Both characteristics are inherent in the data used to develop the regression equations. These predeveloped USGS regional equations may or may not be as good as ones developed specifically for the region of interest; but they are already available, and development of regional equations is an expensive approach.

f. In contrast to the USGS regional equations shown above, the USACE usually develops regional frequency equations as documented in EM 1110-2-1415. The USACE type equations are of the following form:

$$Q = \overline{X} + kS \tag{11-3}$$

$$\overline{X} = aA^{b}L^{c}(1+I)^{d} \tag{11-4}$$

$$S = eA^{f}G^{g}L^{h} \tag{11-5}$$

where

Q = flood peak for varying frequency, in cubic feet per second

$\overline{X}$ = mean of the logarithms of annual series peak flood events, in cubic feet per second

k = log Pearson type II deviates

S = standard deviation of the logarithms annual series peak flood events, in cubic feet per second

$A,L,I\&G$ = various (some are logarithmic) quantifiable physical basin characteristics

$a\&e$ = represent regression constants

$b,c,d,f,g\&h$ = represent regression coefficients

g. The USACE methods assume a log Pearson type III distribution for “k” values and a weighted skew coefficient for peak flood events. The equation provides a peak flow for various frequency levels associated with the value of “k.” Values of “k” are found in various USACE literature such as the EM 1110-2-1415.

h. Other governmental agencies (i.e., city and county) have developed regional frequency equations, but they may be difficult to locate.

i. Regardless of the source of the equations, the user must identify the standard error of estimate (SE) associated with the equation. The SE of estimate defines the possible range of error in the value of flow predicted by the regression equation. Assuming the error is log normally distributed, there is a 68 percent chance that the “true value” of flow is within ± 1 SE and a 95 percent chance that it is within ± 2 SE.

j. For the example of the USGS equation for Q_{100} (the Central Coast region of California), the standard error is 0.41 log units. The true value of Q_{100} is within ± antilog of $(0.41 + \log Q_{100})$. It can then be stated with 68 percent confidence that for the example above where the equation predicted the Q_{100} to be 1,000 cfs, the true value is between 2,570 and 389 cfs. Since the calculated flows (Q_{100}) for this data set vary from 159 cfs to 30,682 cfs, the example of Q_{100} at 1,000 cfs is not an unlikely case. This large range in confidence limits is not unusual for a regression approach. Often this approach is the best available technique to estimate the flow frequency at ungauged locations.

k. Again, it bears repeating that when using regression equations from any source, make sure the equations were developed within the region of interest, the basin characteristics for the watershed of interest are within the range of those used to derive the equations, and the

Table 11-2
Regional Flood-Frequency Equations for California

NORTH COAST REGION[1]		NORTH EAST REGION[2]	
$Q_2 = 3.52\ A^{.90}\ P^{.89}\ H^{-.47}$	(1)	$Q_2 = 22\ A^{.40}$	(7)
$Q_5 = 5.04\ A^{.89}\ P^{.91}\ H^{-.35}$	(2)	$Q_5 = 46\ A^{.45}$	(8)
$Q_{10} = 6.21\ A^{.88}\ P^{.93}\ H^{-.27}$	(3)	$Q_{10} = 61\ A^{.49}$	(9)
$Q_{25} = 7.64\ A^{.87}\ P^{.94}\ H^{-.17}$	(4)	$Q_{25} = 84\ A^{.54}$	(10)
$Q_{50} = 8.57\ A^{.87}\ P^{.96}\ H^{-.08}$	(5)	$Q_{50} = 103\ A^{.57}$	(11)
$Q_{100} = 9.23\ A^{.87}\ P^{.97}$	(6)	$Q_{100} = 125\ A^{.59}$	(12)

SIERRA REGION		CENTRAL COAST REGION	
$Q_2 = 0.24\ A^{.88}\ P^{1.58}\ H^{-.80}$	(13)	$Q_2 = 0.0061\ A^{.92}\ P^{2.54}\ H^{-1.10}$	(19)
$Q_5 = 1.20\ A^{.82}\ P^{1.37}\ H^{-.64}$	(14)	$Q_5 = 0.118\ A^{.91}\ P^{1.95}\ H^{-.79}$	(20)
$Q_{10} = 2.63\ A^{.80}\ P^{1.25}\ H^{-.58}$	(15)	$Q_{10} = 0.583\ A^{.90}\ P^{1.61}\ H^{-.64}$	(21)
$Q_{25} = 6.55\ A^{.79}\ P^{1.12}\ H^{-.52}$	(16)	$Q_{25} = 2.91\ A^{.89}\ P^{1.26}\ H^{-.50}$	(22)
$Q_{50} = 10.4\ A^{.78}\ P^{1.06}\ H^{-.48}$	(17)	$Q_{50} = 8.20\ A^{.89}\ P^{1.03}\ H^{-}.41$	(23)
$Q_{100} = 15.7\ A^{.77}\ P^{1.02}\ H^{-.43}$	(18)	$Q_{100} = 19.7\ A^{.88}\ P^{0.84}\ H^{-.33}$	(24)

SOUTH COAST REGION REGION[2]		SOUTH - COLORADO DESERT	
$Q_2 = 0.41\ A^{.72}\ P^{1.62}$	(25)	$Q_2 = 7.3\ A^{.30}$	(31)
$Q_5 = 0.40\ A^{.77}\ P^{1.69}$	(26)	$Q_5 = 53\ A^{.44}$	(32)
$Q_{10} = 0.63\ A^{.79}\ P^{1.75}$	(27)	$Q_{10} = 150\ A^{.53}$	(33)
$Q_{25} = 1.10\ A^{.81}\ P^{1.81}$	(28)	$Q_{25} = 410\ A^{.63}$	(34)
$Q_{50} = 1.50\ A^{.82}\ P^{1.85}$	(29)	$Q_{50} = 700\ A^{.68}$	(35)
$Q_{100} = 1.95\ A^{.83}\ P^{1.87}$	(30)	$Q_{100} = 1080\ A^{.71}$	(36)

where:

Q = Peak discharge, in cubic feet per second

A = Drainage area, in square miles

P = Mean annual precipitation, in inches

H = Altitude index, in thousands of feet

Notes:
[1] In the north coast region, use a minimum value of 1.0 for altitude index (H).
[2] These equations are defined only for basins of 25 square miles or less.

confidence of the predicted peak flow value is evaluated by assessing the magnitude of ± 1 SE.

11-4. Envelope Curves

a. The maximum "credible" peak discharge at any site (usually ungauged) can be estimated by using envelope curves. Although the result has no frequency associated with it, the maximum peak discharge may be useful for comparison with a family of peak discharges at various frequencies obtained by techniques discussed in previous paragraphs 11-2 and 11-3 of this manual.

b. Figure 11-2 is first used to determine the region number for the geographical area of interest. Select the appropriate envelope curve for the region of interest. An example regional envelope curve is shown in Figure 11-3. With the known drainage area, determine the maximum peak discharge.

c. More extensive discussion regarding envelope curves can be found in USGS Water Supply Papers 1887 (Crippen and Bue 1977) and 1850-B (Matthai 1969); Water Resources Investigations 77-21 (Waananen and

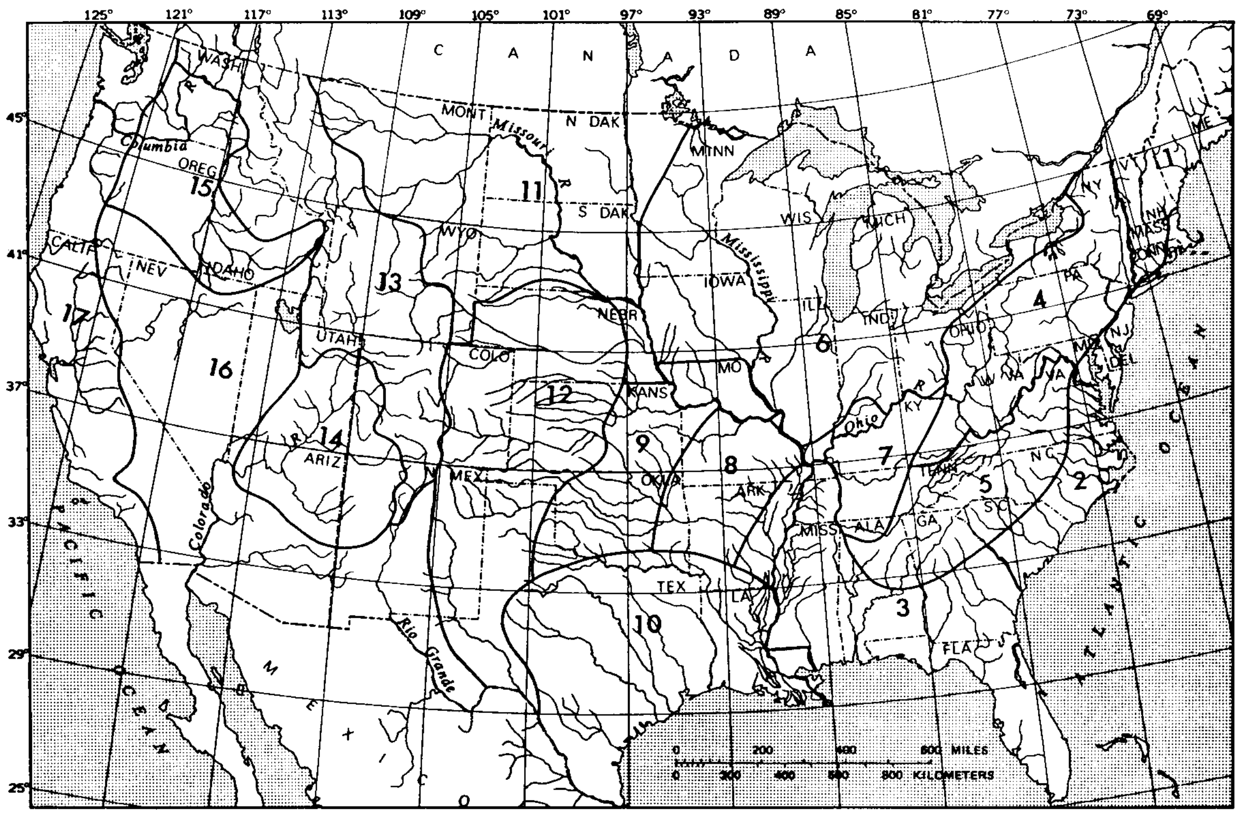

Figure 11-2. Map of the conterminous United States showing flood-region boundaries

Crippen 1977); and the American Society of Civil Engineers, *Hydraulic Journal* (Crippen 1982).

11-5. Rainfall Data Sources

This section lists the most current 24-hour rainfall data published by the National Weather Service (NWS) for various parts of the country. For the area generally west of the 105th meridian, TP-40 has been superseded by the (NOAA) Atlas 2, "Precipitation-Frequency Atlas of the Western United States," published by the NOAA.

a. East of 105th Meridian (Hershfield 1961). "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 40, Washington, DC. For durations of 1 hour and less, TP40 has been superseded by Hydrometeorological Report No. 35, U.S. Department of Commerce, National Weather Service, Silver Springs, MD.

b. West of 105th Meridian (Miller, Frederick, and Tracey 1973). "Precipitation-Frequency Atlas of the Western United States, Volume I, Montana; Volume II, Wyoming; Volume III, Colorado; Volume IV, New Mexico; Volume V, Idaho; Volume VI, Utah; Volume VII, Nevada; Volume VIII, Arizona; Volume IX, Washington; Volume X, Oregon; Volume XI, California," U.S. Department of Commerce, National Weather Service, NOAA Atlas 2, Silver Springs, MD.

c. Alaska (Miller 1963). "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska for Areas to 400 Square Miles, Durations to 24 Hours and Return Periods From 1 to 100 Years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 47, Washington, DC.

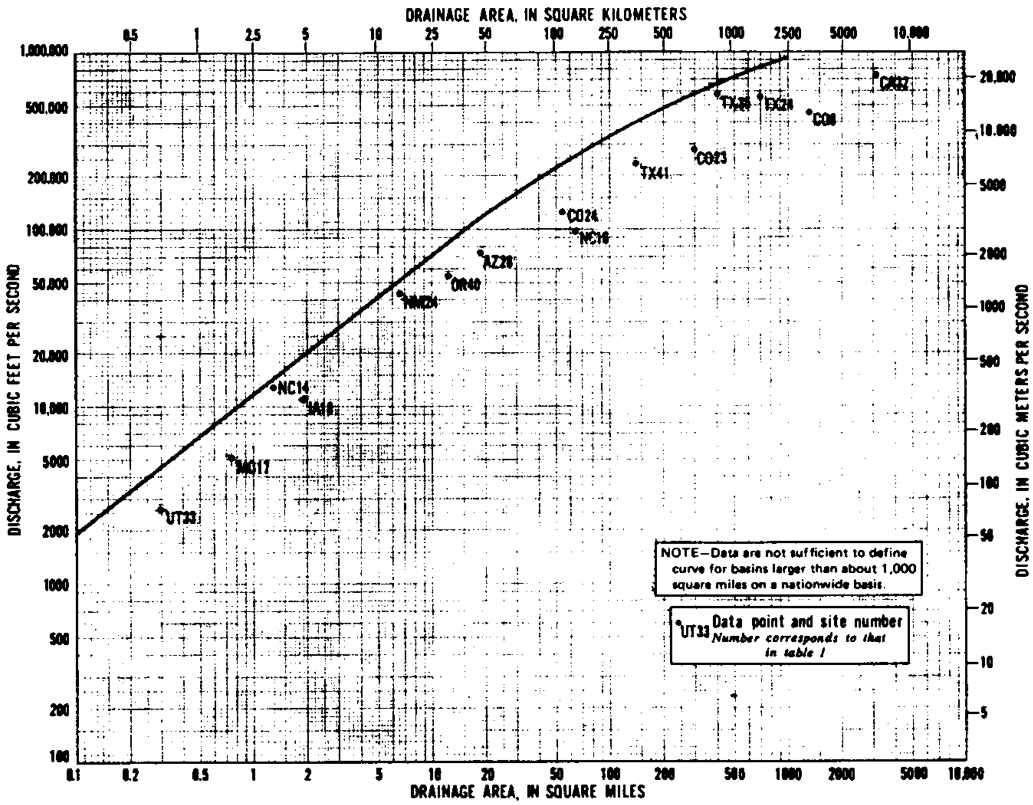

Figure 11-3. Peak discharge versus drainage area, and envelope curve for Region 1

d. Hawaii (U.S. Department of Commerce 1962). "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Duration to 24 Hours and Return Periods From 1 to 100 Years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 43, Washington, DC.

e. Puerto Rico and Virgin Islands (U.S. Department of Commerce 1961). "Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands for Areas to 400 Square Miles, Durations to 24 Hours, and Return Periods From 1 to 100 years," U.S. Department of Commerce, Weather Bureau, Technical Paper No. 42, Washington, DC.