Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 1993

Compiled By M.E. Jennings, W.O. Thomas, Jr., and H.C. Riggs

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 94-4002

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U.S. DEPARTMENT OF THE INTERIOR

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DISKETTE

(Diskette is in pocket)

National Flood Frequency (NFF) Program diskette

FIGURES

Each State summary includes up to five figures. If the State has been divided into flood-frequency regions, the first figure will be a flood-frequency region map for that State. The other figures differ from State to State depending on the explanatory variables needed in the statewide regression equations.

Errata Sheet for U.S. Geological Survey Water-Resources Investigations Report 94-4002

The following errors or omissions were noted in U.S. Geological Survey Water-Resources Investigations Report 94-4002 after is was printed. This errata sheet corrects those errors or omissions.

Page 20 - #7 - The National Flood Frequency (NFF) program allows the weighting of the **logarithms** of the estimated and observed peak discharges using the **equivalent years of record** of the regression estimate and the number of **years of observed record** as the weighting factors. When equivalent years of record are available for the regression equations, the user is prompted to enter the number of years of observed record and the observed peak discharges. NFF was changed to allow the user to enter observed values of the 500-year flood and to compute a weighted estimate of the 500-year flood even if the 500-year regression equation is not available for a given State. The equivalent years of record of the 100-year regression equation and the extrapolated 500-year flood are used in this calculation.

Page 124 - North Dakota - The regression constant for Q2 for Region C should be 4.08, not 7.08.

Page 127 - Ohio - The exponents for (13-BDF) in the statewide urban equations are incorrect. For completeness, the correct equations are given below:

$$UQ2 = 155\ A^{0.68}\ (P\text{-}30)^{0.50}\ (13\text{-}BDF)^{-0.50}$$
$$UQ5 = 200\ A^{0.71}\ (P\text{-}30)^{0.63}\ (13\text{-}BDF)^{-0.44}$$
$$UQ10 = 228\ A^{0.74}\ (P\text{-}30)^{0.68}\ (13\text{-}BDF)^{-0.41}$$
$$UQ25 = 265\ A^{0.76}\ (P\text{-}30)^{0.72}\ (13\text{-}BDF)^{-0.37}$$
$$UQ50 = 293\ A^{0.78}\ (P\text{-}30)^{0.74}\ (13\text{-}BDF)^{-0.35}$$
$$UQ100 = 321\ A^{0.79}\ (P\text{-}30)^{0.76}\ (13\text{-}BDF)^{-0.33}$$

Figure 2 showing the average (mean) annual precipitation for Ohio was inadvertently omitted from the documentation. The necessary figure is given on the back of this page (Sherwood, 1993).

Page 176 - Wyoming - The Plains and High Desert Regions regression equations are shown correctly below (note that A is raised to a power of A):

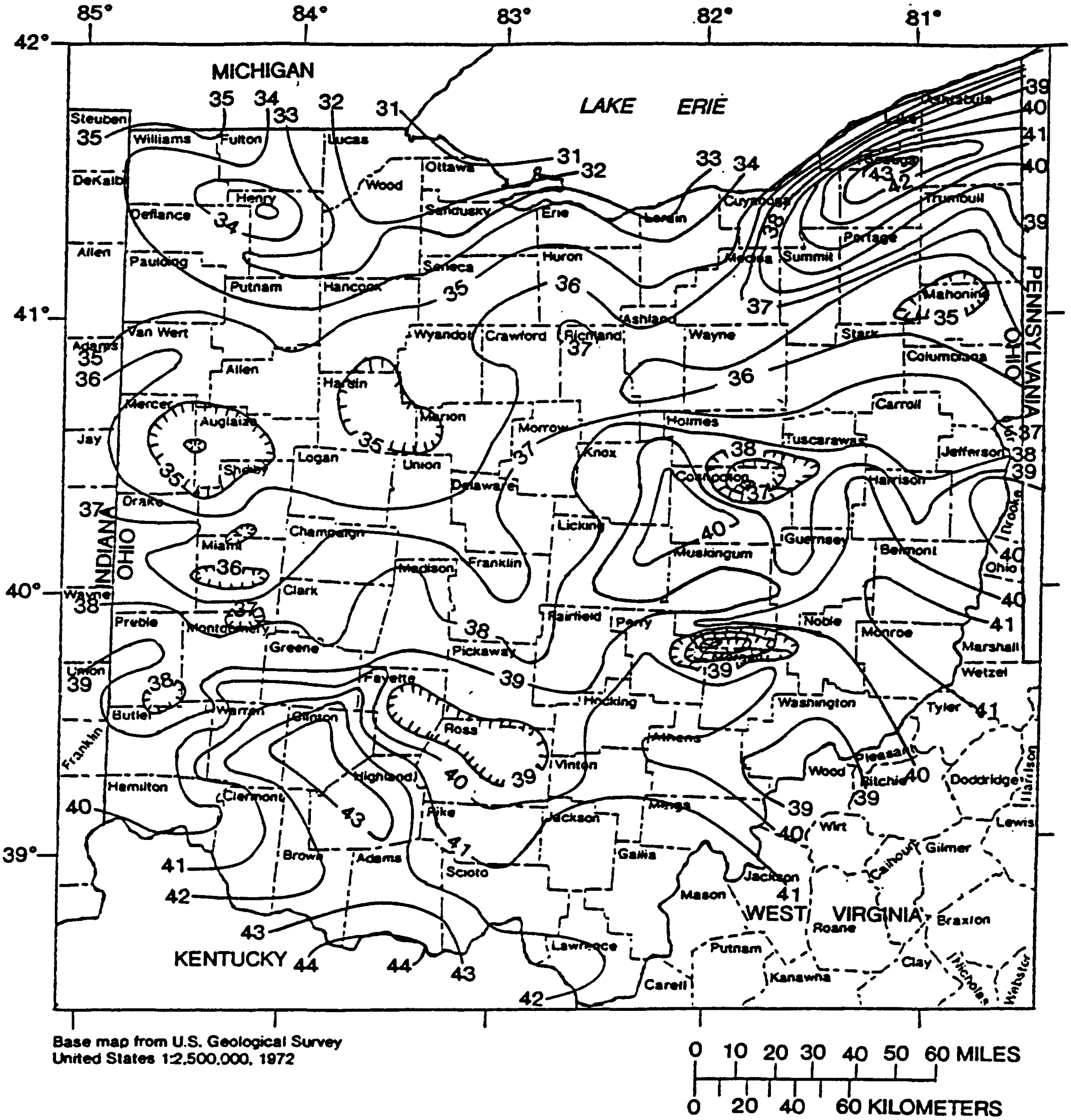
$$Q2 = 41.3A^{0.60A^{**}\text{-}0.05}\ Gf$$
$$Q5 = 63.7A^{0.60A^{**}\text{-}0.05}\ SB^{0.09}\ Gf$$
$$Q10 = 76.9A^{0.59A^{**}\text{-}0.05}\ SB^{0.14}\ Gf$$
$$Q25 = 94.2A^{0.59A^{**}\text{-}0.05}\ SB^{0.19}\ Gf$$
$$Q50 = 112\ A^{0.58A^{**}\text{-}0.05}\ SB^{0.23}\ Gf$$
$$Q100 = 130\ A^{0.58A^{**}\text{-}0.05}\ SB^{0.25}\ Gf$$
$$Q200 = 182\ A^{0.57A^{**}\text{-}0.05}\ SB^{0.26}\ Gf$$
$$Q500 = 245\ A^{0.57A^{**}\text{-}0.05}\ SB^{0.27}\ Gf$$

$$Q2 = 6.66A^{0.59\ A^{**}\text{-}0.03}\ PR^{0.60}\ Gf$$
$$Q5 = 10.6\ A^{0.56\ A^{**}\text{-}0.03}\ PR^{0.81}\ Gf$$
$$Q10 = 13.8\ A^{0.55\ A^{**}\text{-}0.03}\ PR^{0.90}\ Gf$$
$$Q25 = 19.4\ A^{0.53\ A^{**}\text{-}0.03}\ PR^{0.98}\ Gf$$
$$Q50 = 24.2\ A^{0.52\ A^{**}\text{-}0.03}\ PR^{1.02}\ Gf$$
$$Q100 = 30.1\ A^{0.51\ A^{**}\text{-}0.03}\ PR^{1.05}\ Gf$$
$$Q200 = 36.0\ A^{0.51\ A^{**}\text{-}0.03}\ PR^{1.07}\ Gf$$
$$Q500 = 47.1\ A^{0.50\ A^{**}\text{-}0.03}\ PR^{1.09}\ Gf$$

Page 190 - The format of the output file for the flood-frequency curve ordinates was modified to appear as follows:

```
--------------------------------------National Flood Frequency Program--------------------------------------
Flood Peak Discharge, in cubic feet per second
Date: 09/21/1994 10:30
Basin: Hypothetical River near Example
Consult the log file for the input data.

Recurrence Interval, years       2        5       10       25       50      100      500
                          -------- -------- -------- -------- -------- -------- --------
Rural                         8120    13200    17400    22100    26700    29800    39900
National Urban               24000    32000    35000    40000    44000    47500    59800
Statewide Urban              19000    25100    29200    34500    38500    42100    55000
```



EXPLANATION

—34 LINE OF EQUAL AVERAGE ANNUAL PRECIPITATION—Hachured lines enclose areas of lesser precipitation. Interval is one-inch

Figure 2.- Average annual precipitation for Ohio for 1931-1980.

Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 1993

Compiled by M.E. Jennings, W.O. Thomas, Jr., *and* H.C. Riggs

Abstract

For many years, the U.S. Geological Survey (USGS) has been involved in the development of regional regression equations for estimating flood magnitude and frequency at ungaged sites. These regression equations are used to transfer flood characteristics from gaged to ungaged sites through the use of watershed and climatic characteristics as explanatory or predictor variables. Generally these equations have been developed on a statewide or metropolitan area basis as part of cooperative study programs with specific State Departments of Transportation or specific cities.

The USGS, in cooperation with the Federal Highway Administration and the Federal Emergency Management Agency, has compiled all the current (as of September 1993) statewide and metropolitan area regression equations into a microcomputer program titled the National Flood Frequency Program. This program includes regression equations for estimating flood-peak discharges and techniques for estimating a typical flood hydrograph for a given recurrence interval peak discharge for unregulated rural and urban watersheds. These techniques should be useful to engineers and hydrologists for planning and design applications. This report summarizes the statewide regression equations for rural watersheds in each State, summarizes the applicable metropolitan area or statewide regression equations for urban watersheds, describes the National Flood Frequency Program for making these computations, and provides much of the reference information on the extrapolation variables needed to run the program.

INTRODUCTION

By W.O. Thomas, Jr., *and* M.E. Jennings

Estimates of the magnitude and frequency of flood-peak discharges and flood hydrographs are used for a variety of purposes, such as the design of bridges and culverts, flood-control structures, and flood-plain management. These estimates are often needed at ungaged sites where no observed flood data are available for frequency analysis. Basically, two approaches are used for estimating the frequency of flood-peak discharges and flood hydrographs at ungaged sites--those methods based on the statistical (regression) analysis of data collected at gaging stations and those methods based on rainfall characteristics and a deterministic watershed model that uses equations and algorithms to convert rainfall excess to flood runoff. This report describes a microcomputer program, the National Flood Frequency (NFF) Program, that provides estimates of flood frequency based on the statistical approach. A disk of the program is included at the back of this report.

Support and justification for the applicability of regression equations developed by the USGS for estimating flood-peak discharges for rural watersheds is given by the U.S. Water Resources Council (1981) and by Newton and Herrin (1982). These reports summarize a test of nine different procedures, statistical and deterministic, for estimating flood-peak discharges for rural watersheds. The results of this test indicate that USGS-developed regression equations are unbiased, reproducible, and easy to apply.

The USGS has traditionally been involved in the development of statistical methods for estimating the magnitude and frequency of floods at ungaged sites; specifically, methods that relate flood characteristics at gaging stations to watershed and climatic characteristics through the use of regression analysis. These methods enable the transfer of flood characteristics from gaging stations to ungaged sites simply by determining the needed watershed and climatic characteristics for the ungaged site. Since 1973, regression equations for estimating flood-peak discharges for rural, unregulated watersheds have been published, at least once, for every State and the Commonwealth of Puerto Rico. For some areas of the Nation, however, data are still inadequate to define flood-frequency characteristics. Regression equations for estimating urban flood-peak discharges for several metropolitan areas in at least 13 States are also available. Typical flood hydrographs corresponding to a given rural and (or) urban peak discharge can also be estimated by procedures described in this report. The statewide flood-frequency reports were prepared by the USGS, generally in cooperation with a given State Department of Transportation, and were published either by the USGS or the State Department of Transportation. The USGS, in cooperation with the Federal Highway Administration and the Federal Management Emergency Agency, has compiled all the current (September 1993) statewide or metropolitan area regression equations in the NFF Program.

Purpose

The purpose of this report is to document and describe the flood-frequency regression equations and procedures in the NFF computer program, a program that provides engineers and hydrologists easy-to-use methods for estimating flood-peak discharges and flood hydrographs for planning and design applications. This report summarizes the current statewide regression equations that have been approved for publication as of September 30, 1993. The compilation of all USGS-developed regression equations into a single report and computer program, and the compilation of figures and other needed input allows the analyst to quickly and easily estimate flood-frequency characteristics for ungaged stream sites throughout the United States. It is anticipated that this report and the NFF program will be updated every couple of years as new statewide regression equations become available.

Report Format

This report is divided into two major parts. The front sections give an overview of flood regionalization methods, summarize the characteristics of the estimating techniques, and describe their applicability and limitations. The latter sections summarize flood-estimation methods in each State and provide references to the applicable statewide or metropolitan area flood-frequency reports. Many persons contributed to the development of the computer program and this associated documentation. Persons responsible for preparing each section of this report are so noted.

Most maps or figures needed to make flood estimates, such as maps delineating flood regions or maps of climatic variables characteristics, are reproduced in this report. However, the user will occasionally be required to refer to the appropriate State reports to obtain the input needed for the application of the regression equations. Watershed characteristics needed in application of the regression equations must be measured from the best-available topographic maps obtained by the user.

Information on computer specifications and the computer program are given in appendixes. Instructions for installing NFF on your own personal computer are given in Appendix A. A description of the NFF program and the associated data base of regression statistics is given in Appendix B.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of Eugene Cookmeyer, a former employee of the USGS, who wrote the original version of the NFF program and compiled the initial state-by-state data base of regression coefficients. We also wish to acknowledge the contributions of Dr. William Rogers, Assistant Professor, Department of Electrical and Computer Engineering, University of Texas, Austin, Texas, for making revisions and improvements in the original program and for revising the state-by-state data base of regression coefficients. Dr. Rogers also revised the program so that it would run on a greater variety of personal computers.

HISTORY AND OVERVIEW OF FLOOD REGIONALIZATION METHODS

By W.O. Thomas, Jr.

INTRODUCTION

The USGS has been involved in the development of flood-regionalization procedures for over 40 years. These regionalization procedures are used to transfer flood characteristics, such as the 100-year flood-peak discharge, from gaged to ungaged sites. The USGS has traditionally used regionalization procedures that relate flood characteristics to watershed and climatic characteristics through the use of correlation or regression techniques. Herein, flood characteristics are defined as flood-peak discharges for a selected T-year recurrence interval (such as the 100-year flood). Because these flood characteristics may vary substantially between regions due to differences in climate, topography, and geology, tests of regional homogeneity form an integral part of flood regionalization procedures.

The evolution of flood-peak discharge regionalization procedures within USGS is described by discussing the following three procedures: (1) index-flood procedure used from the late 1940's to the 1960's, (2) ordinary-least-squares regression procedure used in the 1970's and 1980's and (3) generalized-least-squares regression procedure that is being used today (1990's).

Index-Flood Procedures

Dalrymple (1949) states "The method of computing flood frequencies that is presented in this paper reflects the latest developments based on a continuing study of the subject by engineers of the Water Resources Division of the United States Geological Survey. The method has been revised several times in the last few years and probably will be again in the future." This statement indicates that the index-flood procedure was being used by the USGS in the 1940's.

The index-flood procedure consisted of two major parts. The first was the development of basic, dimensionless frequency curves representing the ratio of flood discharges at selected recurrence intervals to an index flood (mean annual flood). The second part was the development of a relation between watershed and climatic characteristics and the mean annual flood, to enable the mean annual flood to be predicted at any point in the region. The combination of the mean annual flood with the basic frequency curve, expressed as a ratio of the mean annual flood, provided a frequency curve for any location (Dalrymple, 1960).

The determination of the dimensionless frequency curve involved: (1) graphical determination of the frequency curve for each station using the Weibull plotting position, (2) determination of homogeneous regions using a homogeneity test on the slopes of the frequency curves, and (3) computation of the regional dimensionless frequency curve based on the median flood ratios for each recurrence interval for each station in the region. The homogeneity test used the ratio of the 10-year flood to the mean annual flood to determine whether the differences in slopes of frequency curves for all stations in a given region are greater than those attributed to chance. The 10-year flood discharge was first estimated from the regional dimensionless frequency curve. The 95-percent confidence interval for the recurrence interval of this discharge, as determined from the individual station frequency curves, was then determined as a function of record length. If the recurrence interval for a given station was within the 95-percent confidence bands, then this station was considered part of the homogeneous region. Otherwise, the station was assumed to be in another region.

The mean annual flood, as used in the index-flood procedure, was determined from the graphical frequency curve to have a recurrence interval of 2.33 years. The mean annual flood for an ungaged location was estimated from a relation that was determined by relating the mean annual flood at gaging stations to measurable watershed characteristics such as drainage area, area of lakes and swamps, and mean altitude.

The index-flood procedure described above was used to develop a nationwide series of flood-frequency reports entitled "Magnitude and Frequency of Floods in the United States." Each report provided techniques for estimating flood magnitude and frequency for a major drainage basin or subbasin, such as the Lower Mississippi River Basin. These reports were published as USGS Water-Supply Papers 1671-1689 during the period 1964-68. In three States, Alaska, Idaho, and Rhode Island, the index-flood procedure (documented in reports published since 1973) is still used to estimate flood frequency.

Ordinary-Least-Squares Regression

Studies by Benson (1962a, 1962b, 1964) suggested that T-year flood-peak discharges could be estimated directly using watershed and climatic characteristics based on multiple regression techniques. As noted by Benson (1962a), the direct estimation of T-year floodpeak discharges avoided the following deficiencies in the index-flood procedure: (1) the flood ratios for comparable streams may differ because of large differences in the index flood, (2) homogeneity of frequency curve slope can be established at the 10-year level, but individual frequency curves commonly show wide and sometimes systematic differences at the higher recurrence levels, and (3) the slopes of the frequency curves generally vary inversely with drainage area. Benson (1962b and 1964) has also shown that the flood ratios vary not only with drainage area but with main-channel slope and climatic characteristics as well. On the basis of this early work of Benson and later work by Thomas and Benson (1970), direct regression on the T-year flood became the standard approach of the USGS for regionalizing flood characteristics in the 1970's.

The T-year flood-peak discharges for each gaging station were estimated by fitting the Pearson Type III distribution to the logarithms of the annual peak discharges using guidelines in Bulletin 15 (U.S. Water Resources Council, 1967) or some version of Bulletin 17 (U.S. Water Resources Council, 1976, 1977, 1981; Interagency Advisory Committee on Water Data (IACWD), 1982). The regression equations that related the T-year flood-peak discharges to watershed and climatic characteristics were computed using ordinary-least-squares techniques. In ordinary-least-squares regression, equal weight is given to all stations in the analysis regardless of record length and the possible correlation of flood estimates among stations.

In most statewide flood-frequency reports, the analysts divided their States into separate hydrologic regions. Regions of homogeneous flood characteristics were generally defined on the basis of major watershed boundaries and an analysis of the areal distribution of regression residuals to identify regions of residuals whose size and algebraic sign were similar within and dissimilar between regions. In several instances, the hydrologic regions were also defined on the basis of the mean elevation of the watershed. Although this procedure may improve the accuracy of the estimating technique, it is somewhat subjective. More objective procedures are now being used for defining hydrologic regions.

Generalized-Least-Squares Regression

Recent developments in the regionalization of flood characteristics have centered on accounting for the deficiencies in the assumptions of ordinary-least-squares regression and on more accurate and objective tests of regional homogeneity. Ordinary-least-squares regression procedures do not account for variable errors in flood characteristics that exist due to unequal record lengths at gaging stations. Tasker (1980) proposed the use of weighted-least-squares regression for flood characteristics where the variance of the observed flood characteristics was estimated as an inverse function of record length. Tasker and Stedinger (1986) used weighted-least-squares regression to estimate regional skew of annual peak discharges, and showed greater accuracy in results as compared to using ordinary-least-squares regression. Both ordinary-least-squares and weighted-least-squares regression do not account for the possible correlation of concurrent annual peak flow records between sites. This problem may be particularly significant where gages are located on the same stream, on similar and adjacent watersheds or where flood-frequency estimates have been determined from a rainfall-runoff model using the same long-term rainfall record.

A new procedure, generalized-least-squares regression, was proposed by Stedinger and Tasker (1985, 1986). This procedure accounted for both the unequal reliability and the correlation of flood characteristics between sites. Stedinger and Tasker (1985) showed, in a Monte Carlo simulation, that generalized-least-squares regression procedures provided more accurate estimates of regression coefficients, better estimates of the accuracy of the regression coefficients, and better estimates of the model error than did ordinary-least-squares procedures. Also, Tasker and others (1986) showed that generalized-least-squares procedures provided a smaller average variance of prediction than ordinary-least-squares procedures for the regional 100-year flood for streams in Pima County, Arizona. Several of the State reports described in this documentation are based on generalized or weighted-least-squares regression. The estimation of T-year flood-peak discharges at gaging stations is still accomplished through the use of Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982).

RURAL FLOOD-FREQUENCY ESTIMATING TECHNIQUES

By W.O. Thomas, Jr.

INTRODUCTION

The National Flood Frequency (NFF) Program provides equations for estimating the magnitude and frequency of flood characteristics for rural, unregulated watersheds in the 50 States and the Commonwealth of Puerto Rico. The most current regression equations for each State are included in NFF. These equations are taken from reports that were published between 1973 and September 1993. The purpose of this section is to provide a brief overview of the rural regression equations that are presented in NFF. The regression equations for each State are documented later in the report in the State summary section.

Watershed and Climatic Characteristics

The rural equations in NFF are based on watershed and climatic characteristics that can be obtained from topographic maps or rainfall reports and atlases. The USGS has published regression equations in many States based on channel-geometry characteristics, such as channel width, but these equations are not provided in NFF because a site visit is required to obtain the explanatory variables. The most frequently used watershed and climatic characteristics are drainage area, main-channel slope, and mean annual precipitation. The regression equations are generally reported in the following form:

$$RQ_T = a\, A^b\, S^c\, P^d$$

where

RQ_T is the T-year rural flood-peak discharge,

A is the drainage area,

S is the channel slope,

P is the mean annual precipitation, and

a,b,c,d are regression coefficients.

The regression coefficients are normally computed by taking the logarithms of the above variables and using linear multiple regression techniques. In instances where a variable could equal zero (such as percentage of drainage area covered by lakes and ponds), a constant is added to the variable prior to taking the logarithms. The frequency of use of the various watershed/climatic characteristics in the rural regression equations given in NFF is summarized below. The table below does not summarize the use of watershed/climatic characteristics for regional studies, such as the one by Thomas and others (1993).

Watershed or climatic characteristic	Number of States (including Puerto Rico)
Drainage area (square miles)	51
Main-channel slope (feet per mile)	27
Mean annual precipitation (inches)	19
Storage/area of lakes and ponds (percent)	16
Rainfall amount for a given duration (inches)	14
Elevation of watershed (feet)	13
Forest cover (percent)	8
Channel length (miles)	6
Minimum mean January temperature (degrees F)	4
Basin shape ((length)^2 per drainage area)	4
Soils characteristics	3
Mean basin slope (feet per foot or feet per mile)	2
Mean annual snowfall	2
Area of stratified drift (percent)	1
High elevation index (percent basin above 6000 feet)	1
Relative relief (feet per mile)	1
Drainage frequency (number of first order streams per square mile)	1

There were 6 States in which drainage area was the only explanatory variable in the regression equations. In many States, 3 to 4 explanatory variables were used in the equations.

Hydrologic Flood Regions

In most statewide flood-frequency reports, the analysts divided their States into separate hydrologic regions. Regions of homogeneous flood characteristics were generally determined by using major watershed boundaries and an analysis of the areal distribution of the regression residuals (differences between regression and station (observed) T-year estimates). In some instances, the hydrologic regions were also defined by the mean elevation of the watershed or by statistical tests such as the Wilcoxon signed-rank test. Regression equations are defined for 210 hydrologic regions throughout the Nation, indicating that, on average, there are about four regions per State. Some areas of the Nation, however, have inadequate data to define flood-frequency regions. For example, there are regions of undefined flood frequency in Florida, Georgia, Texas, and Nevada. For the State of Hawaii, regression equations are only provided for the Island of Oahu. Regression equations for estimating flood-peak discharges for the other islands were computed as part of a nationwide network analysis (Yamanaga, 1972) but are not included in NFF since that study was not specifically oriented to flood-frequency analysis.

Measures of Accuracy

Every USGS regional flood report provides some measure of accuracy of the regression equations. The most frequently used measure of accuracy is the standard error of estimate, usually reported in percent. This standard error is a measure of the variation between the regression estimates and the station data for those stations used in deriving the regression equations. More recently, analysts have begun reporting the standard error of prediction, which is a measure of the accuracy of the regression equations when predicting values for watersheds not used in the analysis. The standard error of prediction is generally slightly larger than the standard error of estimate. The standard error reported in the individual statewide report is the standard error given in NFF because that is the only estimate of error that was available. Often, the standard errors of estimate or prediction are converted to equivalent years of record. The equivalent years of record are defined as the number of years of actual streamflow record needed to achieve the same accuracy as the regional regression equations.

The standard errors of estimate or prediction generally range from 30-60 percent, with 21 States and the Commonwealth of Puerto Rico having standard errors in this range. There are 14 States where there is at least one hydrologic region within the State with a standard error less than 30 percent. The remaining 15 States have at least one hydrologic region where the standard error is in excess of 60 percent. The largest standard errors generally are for equations developed for the western portion of the Nation where the at-site variability of the flood records is greater, where the network of unregulated gaging stations is less dense and there are more difficulties in regionalizing flood characteristics, and the flood records are generally shorter. The smallest standard errors are generally for equations developed for the eastern portion of the Nation where the converse of the above conditions are generally true.

URBAN FLOOD-FREQUENCY ESTIMATING TECHNIQUES

By V.B. Sauer

INTRODUCTION

The National Flood Frequency (NFF) Program provides equations for estimating the magnitude and recurrence intervals for floods in urbanized areas throughout the conterminous United States and Hawaii. The seven-parameter nationwide equations described in USGS Water-Supply Paper (WSP) 2207, by Sauer and others (1983), are based on urban runoff data from 199 basins in 56 cities and 31 States. These equations have been thoroughly tested and proven to give reasonable estimates for floods having recurrence intervals between 2 and 500 years. A later study by Sauer (1985) of urban data at 78 additional sites in the southeastern United States verified the seven-parameter equations as unbiased and having standard errors equal to or better than those reported in WSP 2207.

Additional equations for some urban areas in a few States have been included in the NFF program as optional methods to estimate and compare urban flood frequency. These equations were developed for local use within their designated urban area and should not be used for other urban areas.

Nationwide Urban Equations

The following seven-parameter equations and definitions are excerpted from Sauer and others (1983). The equations are based on multiple regression analysis of urban flood frequency data from 199 urbanized basins.

$$UQ2 = 2.35\,A^{.41}\,SL^{.17}\,(RI2+3)^{2.04}\,(ST+8)^{-.65}\,(13-BDF)^{-.32}\,IA^{.15}\,RQ2^{.47}$$

standard error of estimate is 38 percent

$$UQ5 = 2.70\,A^{.35}\,SL^{.16}\,(RI2+3)^{1.86}\,(ST+8)^{-.59}\,(13-BDF)^{-.31}\,IA^{.11}\,RQ5^{.54}$$

standard error of estimate is 37 percent

$$UQ10 = 2.99\,A^{.32}\,SL^{.15}\,(RI2+3)^{1.75}\,(ST+8)^{-.57}\,(13-BDF)^{-.30}\,IA^{.09}\,RQ10^{.58}$$

standard error of estimate is 38 percent

$$UQ25 = 2.78\,A^{.31}\,SL^{.15}\,(RI2+3)^{1.76}\,(ST+8)^{-.55}\,(13-BDF)^{-.29}\,IA^{.07}\,RQ25^{.60}$$

standard error of estimate is 40 percent

$$UQ50 = 2.67\,A^{.29}\,SL^{.15}\,(RI2+3)^{1.74}\,(ST+8)^{-.53}\,(13-BDF)^{-.28}\,IA^{.06}\,RQ50^{.62}$$

standard error of estimate is 42 percent

$$UQ100 = 2.50\,A^{.29}\,SL^{.15}\,(RI2+3)^{1.76}\,(ST+8)^{-.52}\,(13-BDF)^{-.28}\,IA^{.06}\,RQ100^{.63}$$

standard error of estimate is 44 percent

$$UQ500 = 2.27\,A^{.29}\,SL^{.16}\,(RI2+3)^{1.86}\,(ST+8)^{-.54}\,(13-BDF)^{-.27}\,IA^{.05}\,RQ500^{.63}$$

standard error of estimate is 49 percent

where

Q2, UQ5,... UQ500 are the urban peak discharges, in cubic feet per second (ft^3/s), for the 2-, 5-, ... 500-year recurrence intervals;

A is the contributing drainage area, in square miles, as determined from the best available topographic maps; in urban areas, drainage systems sometimes cross topographic divides. Such drainage changes should be accounted for when computing A;

SL is the main channel slope, in feet per mile (ft/mi), measured between points which are 10 percent and 85 percent of the main channel length upstream from the study site (for sites where SL is greater than 70 ft/mi, 70 ft/mi is used in the equations);

RI2 is the rainfall, in inches (in) for the 2-hour, 2-year recurrence interval, determined from U.S. Weather Bureau (USWB) Technical Paper 40 (1961) (eastern USA), or from NOAA Atlas 2 (Miller and others, 1973) (western USA);

ST is basin storage, the percentage of the drainage basin occupied by lakes, reservoirs, swamps, and wetlands; in-channel storage of a temporary nature, resulting from detention ponds or roadway embankments, should not be included in the computation of ST;

BDF is the basin development factor, an index of the prevalence of the urban drainage improvements;

IA is the percentage of the drainage basin occupied by impervious surfaces, such as houses, buildings, streets, and parking lots; and

RQT, are the peak discharges, in cubic feet per second, for an equivalent rural drainage basin in the same hydrologic area as the urban basin, for a recurrence interval of **T** years; equivalent rural peak discharges are computed from the rural equations for the appropriate State, in the NFF program, and are automatically transferred to the urban computations.

The basin development factor (**BDF**) is a highly significant variable in the equations, and provides a measure of the efficiency of the drainage basin. It can be easily determined from drainage maps and field inspections of the drainage basin. The basin is first divided into upper, middle, and lower thirds on a drainage map, as shown (fig. 1a-c). Each third should contain about one-third of the contributing drainage area, and stream lengths of two or more streams should be approximately the same in each third. However, stream lengths of different thirds can be different. For instance, (fig. 1c), the stream distances of the lower third are all about equal, but are longer than those in the middle third. Precise definition of the basin thirds is not considered necessary because it will not have much effect on the final value of BDF. Therefore, the boundaries between basin thirds can be drawn by eye without precise measurements.

Within each third of the basin, four characteristics of the drainage system must be evaluated and assigned a code of 0 or 1. Summation of the 12 codes (four codes in each third of the basin) yields the BDF. The following guidelines should not be considered as requiring precise measurements. A certain amount of subjectivity will necessarily be involved, and field checking should be performed to obtain the best estimates.

1. Channel improvements.--If channel improvements such as straightening, enlarging, deepening, and clearing are prevalent for the main drainage channels and principal tributaries (those that drain directly into the main channel), then a code of 1 is assigned. To be considered prevalent, at least 50 percent of the main drainage channels and principal tributaries must be improved to some degree over natural conditions. If channel improvements are not prevalent, then a code of zero is assigned.

2. Channel linings.--If more than 50 percent of the length of the main channels and principal tributaries has been lined with an impervious surface, such as concrete, then a code of 1 is assigned to this characteristic. Otherwise, a code of zero is assigned. The presence of channel linings would obviously indicate the presence of channel improvements as well. Therefore, this is an added factor and indicates a more highly developed drainage system.

3. Storm drains or storm sewers.--Storm drains are defined as those enclosed drainage structures (usually pipes), frequently used on the secondary tributaries where the drainage is received directly from streets or parking lots. Many of these drains empty into open channels; however, in some basins they empty into channels enclosed as box and pipe culverts. When more than 50 percent of the secondary tributaries within a subarea (third) consists of storm drains, then a code of 1 is assigned to this aspect, otherwise a code of zero is assigned.

4. Curb-and-gutter streets.--If more than 50 percent of the subarea (third) is urbanized (covered with residential, commercial, and/or industrial development), and if more than 50 percent of the streets and highways in the subarea are constructed with curbs and gutters, then a code of 1 would be assigned to this aspect. Otherwise, a code of zero is assigned. Drainage from curb-and-gutter streets frequently empties into storm drains.

Estimates of urban flood frequency values should not be made with the seven-variable equations under certain conditions. For instance, the equations should not be used for basins where flow is controlled by reservoirs, or where detention storage is used to reduce flood peaks. The equations should not be used if any of the values of the seven variables are outside the range of values used in the original regression study (except for SL which is limited to 70 ft/mi). These ranges are provided in the NFF program, and the user is warned anytime a variable value exceeds the range. The program will compute urban estimates even though a parameter may be outside the range; however, the standard error of estimate may be greater than the value given for each equation.

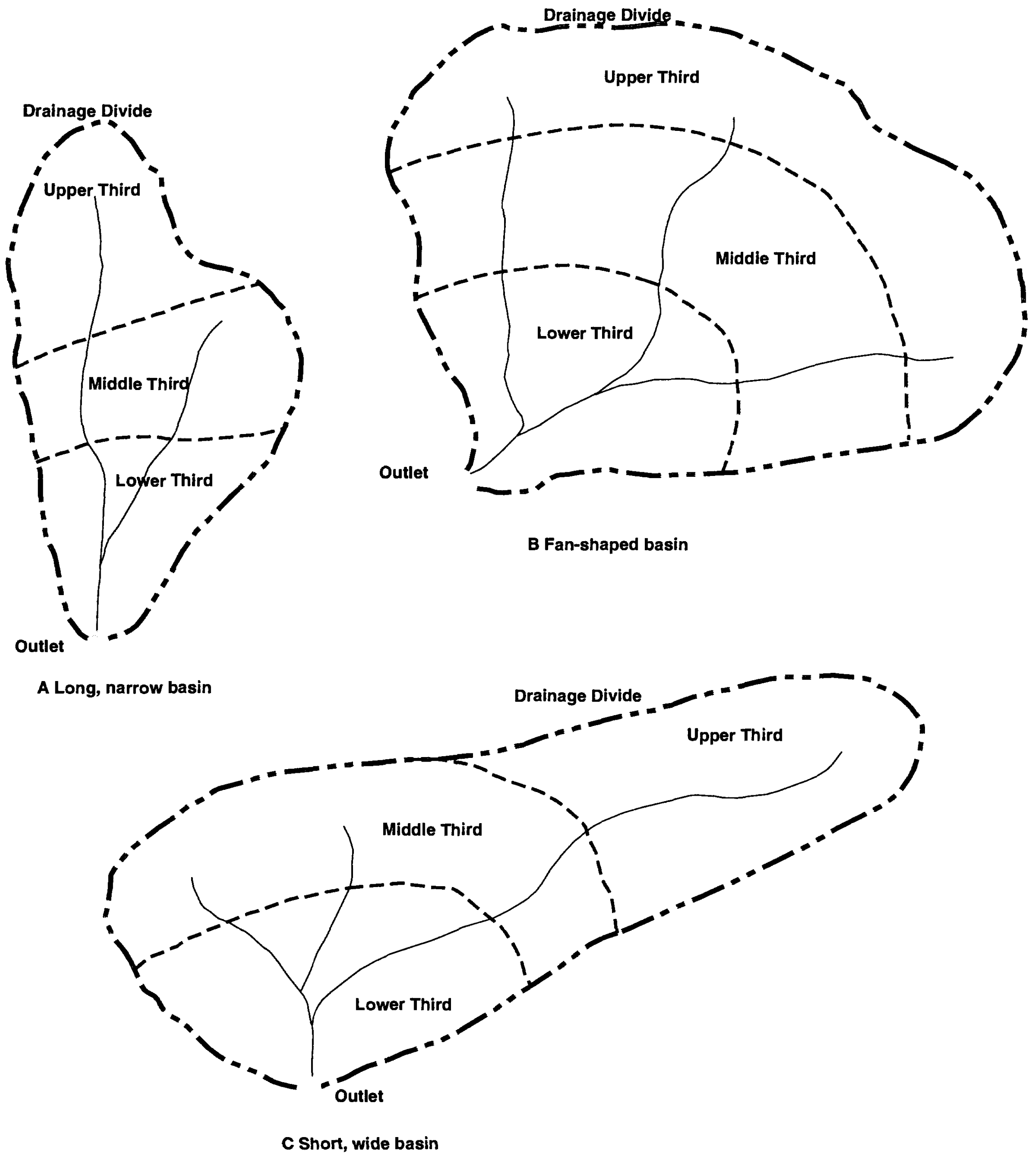


Figure 1. Schematic of typical drainage basin shapes and subdivision into basin thirds. (From Sauer and others, 1983.)

Local Urban Equations

The NFF program includes additional equations for some cities and metropolitan areas that were developed for local use in those designated areas only. These local urban equations can be used in lieu of the nationwide urban equations, or they can be used for comparative purposes. It would be highly coincidental for the local equations and the nationwide equations to give identical results. Therefore, the user is advised to compare results of the two (or more) sets of urban equations, and to also compare the urban results to the equivalent rural results. Ultimately, it is the user's decision as to which urban results to use.

A brief description of the local urban equations is given in the section of this report which describes the individual State equations. Local urban equations are available in NFF for the following cities, metropolitan areas, or States:

Alabama	Statewide Urban
Florida	Tampa Urban
	Leon County Urban
Georgia	Statewide Urban
Missouri	Statewide Urban
North Carolina	Piedmont Province Urban
Ohio	Statewide Urban
Oregon	Portland-Vancouver, Washington Urban
Tennessee	Memphis Urban
	Statewide Urban
Texas	Austin Urban
	Dallas-Ft. Worth Urban
	Houston Urban
Wisconsin	Statewide Urban

In addition, some of the rural reports contain estimation techniques for urban watersheds. Several of the rural reports suggest the use of the nationwide equations given by Sauer and others (1983) and described above.

FLOOD HYDROGRAPH ESTIMATION

By V.B. Sauer

The NFF Program contains a procedure for computing a typical hydrograph that represents average runoff for a specified peak discharge. It is emphasized that this is an average hydrograph, and is not necessarily representative of any particular rainfall distribution. The average, or typical, hydrograph could be considered a design hydrograph for some applications.

The procedure used in NFF to compute the average hydrograph is known as the dimensionless hydrograph method. Stricker and Sauer (1982) developed the method for urban basins using theoretical techniques. Later, Inman (1987) used actual streamflow data for both urban and rural streams in Georgia, and confirmed the theoretical dimensionless hydrograph developed by Stricker and Sauer. Other investigators have since developed similar dimensionless hydrographs for numerous other States (Sauer, 1989). Except in some relatively flat-topography, slow-runoff areas, the same dimensionless hydrograph seems to apply with reasonable accuracy. The dimensionless hydrograph approach, however, is not applicable to snowmelt runoff or for estimating more complex double-peaked hydrographs.

The dimensionless hydrograph method has three essential parts: (1) the peak discharge for which a hydrograph is desired, (2) the basin lagtime, and (3) the dimensionless hydrograph ordinates. In order to compute the average, or design hydrograph using the NFF procedures, the user selects the peak discharge from the NFF frequency output. The user must also provide an estimate of the basin lagtime. The NFF program then computes the hydrograph using the dimensionless ordinates of the hydrograph developed by Inman (1987) which are stored in the program.

Basin lagtime (LT) is defined as the elapsed time, in hours, from the center of mass of rainfall excess to the center of mass of the resultant runoff hydrograph. This is the most difficult estimate to make for the hydrograph computations. For rural basins, the user must make an estimate of lagtime, independent of the NFF program, because there are no lagtime equations currently available in NFF for rural watersheds. However, Sauer (1989) has summarized basin lagtime equations that have been developed for rural and urban watersheds in several States. The following statewide equations computed for rural Georgia streams by Inman (1987) are an example:

$$LT = 4.64\ A^{.49}\ SL^{-.21} \quad \text{(North of fall line)}$$

$$LT = 13.6\ A^{.43} SL^{-.31} \quad \text{(South of fall line)}$$

where

A is drainage area, in square miles, and

SL is channel slope, in feet per mile, as defined earlier.

Appendix C includes a summary of equations for estimating basin lagtime as given by Sauer (1989) plus a few other known studies.

On the other hand, the following generalized equation was developed by Sauer and others (1983) for urban basins for use on a nationwide basis:

$$LT = 0.003L^{.71}\ (13\text{-}BDF)^{.34}\ (ST+10)^{2.53}\ RI2^{-.44}\ IA^{-.20}\ SL^{-.14}$$

where

LT is basin lagtime, in hours,

L is the length, in miles, of the main channel from the point of interest to the extension of the main channel to the basin divide, and

BDF, ST, RI2, IA, and SL, are described in the section "Urban Flood Frequency."

The standard error for the above lagtime equation is +/- 61 percent, based on regression analysis for 170 stations on a nationwide basis. For urban basins, the user has a choice of using the nationwide lagtime equation given above, or of inputting an independent estimate of lagtime.

ESTIMATION OF EXTREME FLOODS

By W.O. Thomas, Jr. *and* W.H. Kirby

Measures of Extreme Floods

Very large or extreme floods can be characterized in several ways. Some examples are the Probable Maximum Flood (PMF), envelope curve values based on maximum observed floods (Crippen and Bue, 1977; Crippen, 1982), and probabilistic floods, such as the 500-year flood, which has only a 0.2 percent chance of being exceeded in any given year.

The PMF is defined as the most severe flood that is considered reasonably possible at a site as a result of hydrologic and meteorologic conditions (Cudworth, 1989; Hansen and others, 1982). The estimation of the PMF involves three steps: (1) determination of the Probable Maximum Precipitation (PMP) from reports published by the National Weather Service (e.g., Hansen and others, 1982), (2) determination of infiltration and other losses, and (3) the conversion of the excess precipitation to runoff. In step (2), it is general practice to assume that an antecedent storm of sufficient magnitude has reduced water losses such as interception, evaporation, and surface depression storage to negligible levels. In step (3), the conversion of precipitation excess to runoff is accomplished by one of a number of techniques or models ranging from detailed watershed models to a less detailed unit hydrograph approach. Most Federal construction and regulatory agencies use the less detailed unit hydrograph approach that is based on the principle of linear superposition of hydrographs as originally described by Sherman (1932).

The words "probable" and "likely" in the definition of the PMF and PMP do not refer to any specific quantitative measures of probability or likelihood of occurrence. Moreover, a recent interagency work group of the Hydrology Subcommittee of the IACWD decided "It is not within the state of the art to calculate the probability of PMF-scale floods within definable confidence or error bounds" (Interagency Advisory Committee on Water Data, 1986).

The definition of another type of large or extreme flood is based on the maximum observed flood for a given size watershed. Crippen and Bue (1977) and Crippen (1982) developed flood-envelope curves by plotting the maximum known flood discharges against drainage area for 17 flood regions of the conterminous United States. These flood-envelope curves approximate the maximum flood-peak discharge that has been regionally experienced for a given size watershed. Like the PMF, these flood-envelope values do not have an associated probability of exceedance.

In general, the largest flood having a defined probability of exceedance that is used for planning, management, and design is the 500-year flood. This flood discharge has a 0.2 percent chance of being exceeded in any given year or, stated another way, will be exceeded at intervals of time averaging 500 years in length. The 500-year flood is the most extreme flood discharge computed in flood-frequency programs of the U.S. Geological Survey (Kirby, 1981) and the U.S. Army Corps of Engineers (U.S. Army Corps of Engineers, 1982) that implement Federal Interagency Bulletin 17B guidelines for flood frequency (Interagency Advisory Committee on Water Data, 1982). These two computer programs are the ones most frequently used by the hydrologic community.

Estimates of 500-year flood discharges are used in defining floodplains for the flood insurance studies of the Federal Emergency Management Agency (FEMA) as well as by the National Park Service for defining floodplains in National Parks. Flood-plain boundaries based on the 500-year flood are used mostly for planning purposes to identify areas that would be inundated by an extreme flood. Recent bridge failures resulting from excessive scour have prompted the Federal Highway Administration (FHWA) to develop procedures for evaluating scour at bridges. As part of this program, the FHWA advised the State Departments of Transportation nationwide to evaluate the risk of their bridges being subjected to scour damage during floods on the order of a 100- to 500-year or greater average return periods. Therefore, there is a defined need for estimates of flood discharges having return periods on the order of 500 years.

Extrapolation for the 500-Year Flood

Only recently has the USGS begun to publish at-site estimates of the 500-year flood or to publish regional regression equations for estimating the 500-year flood at ungaged sites. Therefore, most of the USGS statewide reports do not contain regression equations or at-site estimates for the 500-year flood. A procedure is given in the NFF program for extrapolating the regional regression equations in any State to the 500-year flood. The extrapolation procedure basically consists of fitting a log-Pearson Type III curve to the 2- to 100-year flood discharges given by NFF and extrapolating this curve to the 500-year flood discharge. The procedure consists of the following steps for a given watershed:

1. Determine the flood-peak discharges for selected return periods from the appropriate regional regression equations given in NFF. At least three points are needed to define the skew coefficient required in a subsequent step. Use of additional points improves the definition of the frequency curve that is defined by the regional equations and helps to average out any minor irregularities that may exist in the relations among the regional equations. The NFF program uses all available regional equations for selected return periods to define the frequency curve.

2. Fit a quadratic curve to the selected points on log-probability paper using least squares regression computations. The variables used in the regression computations are the logarithms of the selected discharges and the standard normal deviates associated with the corresponding probabilities. The purpose of this quadratic curve is to obtain a smooth curve through the selected flood-peak discharges from step 1 above. The quadratic curve is an approximation of the log-Pearson Type III curve that will be computed.

3. Determine the skew coefficient of the log-Pearson Type III frequency curve that passes through the 2-, 10-, and 100-year floods defined by the quadratic curve. The skew coefficient is defined approximately by the formula (Interagency Advisory Committee on Water Data, 1982)
   $G = -2.50 + 3.12 \log (Q_{100}/Q_{10}) / \log (Q_{10}/Q_2)$.

4. Replot (conceptually) the selected discharges and return periods using a Pearson Type III probability scale defined such that a frequency curve with the computed skew plots as a straight line. This scale is defined by plotting probability values p at positions x on the probability axis, where x is defined by the standardized Pearson Type III deviate (K values) for the given skew and probability. A Wilson-Hilferty approximation (Kirby, 1972) is used to compute the K value.

5. Fit a straight line by least-squares regression to the points plotted in step 4, and extrapolate this line to the 500-year flood-peak discharge. The variables used in the least squares computation are the logarithms of the selected discharges and the Pearson Type III K values associated with the corresponding probabilities.

Figure 2 is an example of a flood-frequency curve computed by this procedure for the Fenholloway River near Foley, Florida. The solid triangles (fig. 2) are the regional flood-frequency values as estimated by the equations given by Bridges (1982), which are incorporated in the NFF program. The 500-year value shown as a solid circle (fig. 2) (12,800 cubic feet per second) is estimated using the extrapolation procedure described above. Note that the extrapolated 500-year value is a reasonable extension (see dotted line) of the regional frequency curve.

The solid triangle (fig. 2) (11,500 cubic feet per second) for the 500-year value is the regional value as obtained directly from the 500-year equation given in Bridges (1982). The 500-year flood for the Fenholloway River can be estimated without extrapolation since Florida is one of the few States for which 500-year regression equations have been published. The difference between the two 500-year values is 11.3 percent. This is typical of several comparisons of extrapolated 500-year floods to published regional equations that has indicated most results agree within plus or minus 15 percent. Details of these comparisons are given in a later section.

For comparison and evaluation, the NFF program compares each extrapolated 500-year flood-peak discharge with the maximum flood-envelope curves given by Crippen and Bue (1977) and Crippen (1982). Because there is no frequency of occurrence associated with the envelope-curve estimates, the comparison of these values to the extrapolated 500-year flood is merely a qualitative evaluation. In general, one would expect the extrapolated 500-year flood-peak discharge to be less than the envelope-curve values, assuming that several watersheds in a given region have experienced at least one flood exceeding the 500-year value during the period of data collection. For the Fenholloway River near Foley, Florida, estimates of the 500-year flood range from 11,500 to 12,800 cubic feet per second. The envelope-curve value from Crippen and Bue (1977) and Crippen (1982) is 101,000 cubic feet per second given that the watershed is in region 3 as defined by Crippen and Bue (1977) and Crippen (1982). Figure 3, from Crippen and Bue (1977), is provided in this report so the analyst can determine the appropriate flood region for a site of interest.

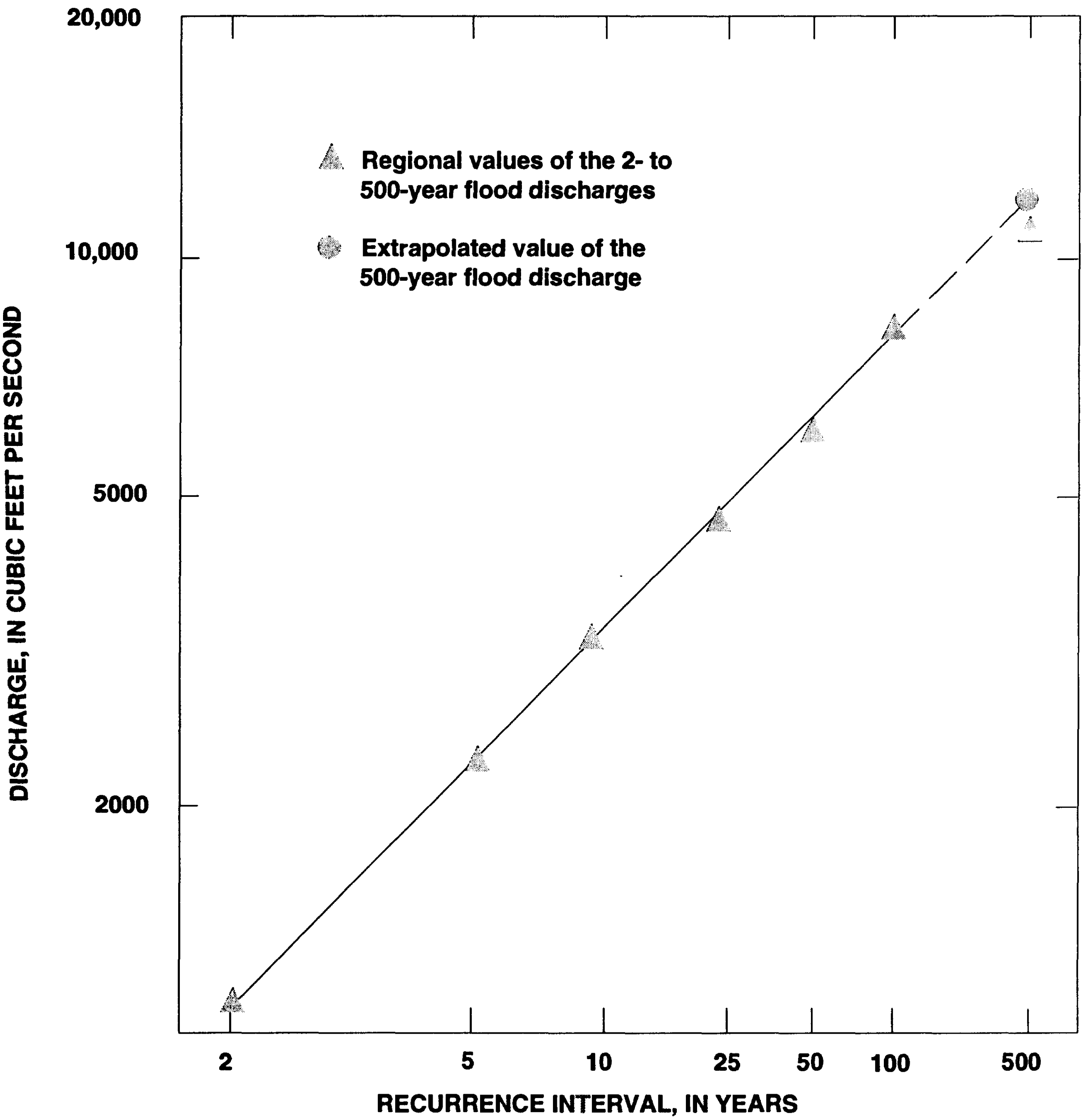


Figure 2. Regional flood-frequency curve for the Fenholloway River near Foley, Florida.

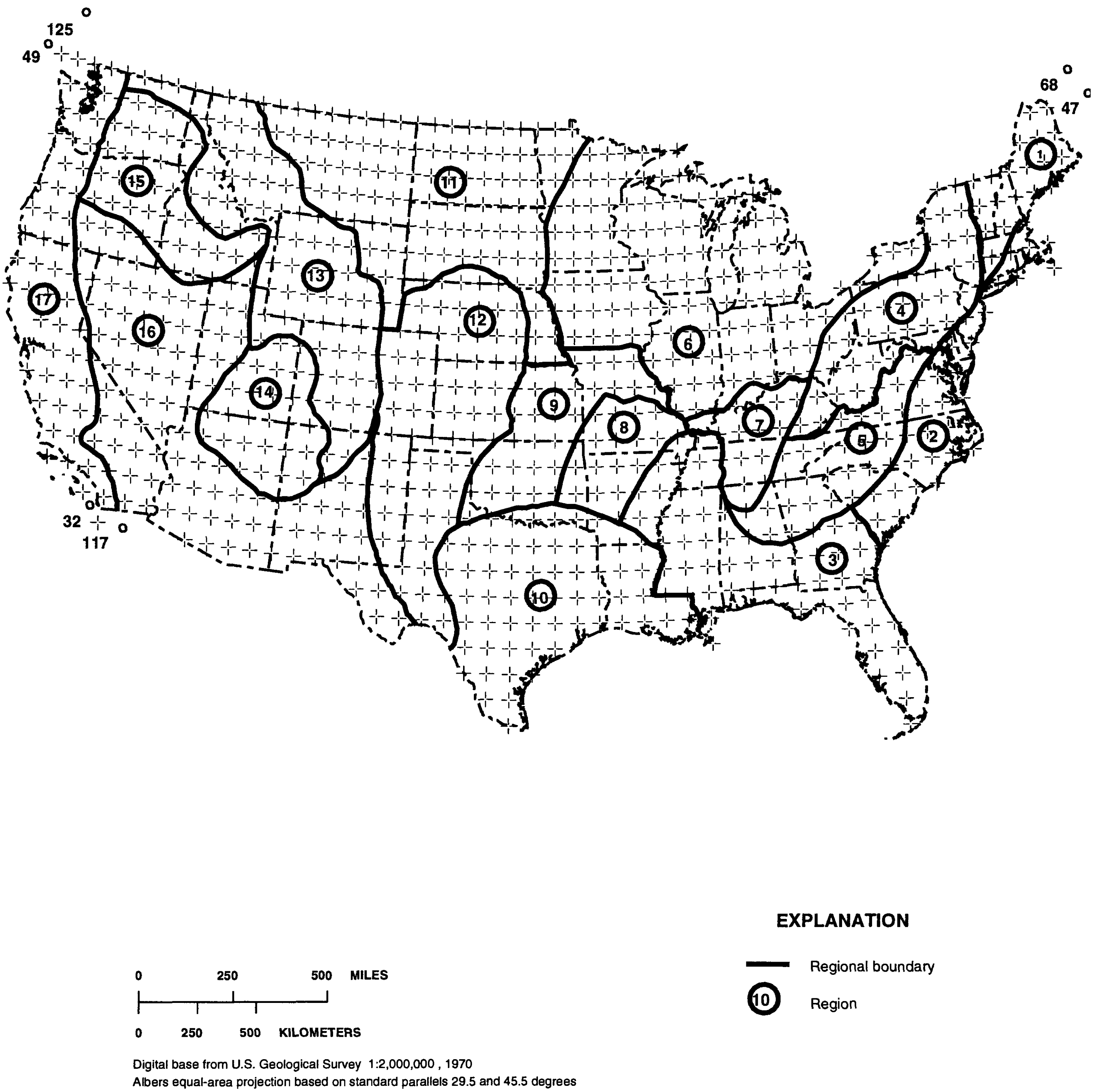


Figure 3. Map of the conterminous United States showing flood-region boundaries. (From Crippen and Bue, 1977.)

TESTING AND VALIDATION OF TECHNIQUES

By J.B. Atkins

INTRODUCTION

Three to five sites from each hydrologic region in each State were selected to use for the testing of National Flood Frequency (NFF) Program, using watershed and climatic data obtained from published flood-frequency reports or provided by local USGS District offices. The sites represented a range of the independent variables required by the region's respective flood-frequency equations. Of particular interest was the accuracy of the 500-year extrapolation procedure described in an earlier section of this report. Published 500-year peak prediction equations for eight States (Arizona, Colorado, Florida, Illinois, Oklahoma, Utah, West Virginia, and Wyoming) provided the basis for evaluating the 500-year extrapolation procedure in NFF. Since these tests were completed, regression equations have been updated for six more States (Mississippi, New York, South Carolina, Montana, North Dakota and Tennessee) that have 500-year equations. These latter States were not used in the tests.

Testing and evaluation of NFF was performed by comparing values from State 500-year equations with extrapolated 500-year values for the eight States noted above. Certain ratios were also computed such as the ratios of the 500-year peak discharge to the 100-year peak discharge from NFF which was subtracted from 1 so that extreme values would be easier to recognize. The ratio of the 500-year peak discharge to the Crippen and Bue maximum flood-envelope value was also computed.

Evaluation of NFF also examined how well the frequency curve from NFF at each site conformed to a smooth log-Pearson Type III distribution frequency curve. Conformity to a smooth curve was measured by computing the Root-Mean-Square (RMS) deviation of log residuals of the T-year peak discharges of the estimated State equation from a fitted log-Pearson Type III frequency curve through those T-year values. This statistic was used to examine how the frequency curve computed by the regression equations compared to a smooth fitted log-Pearson type III frequency curve.

Next, a site-specific skew coefficient computed by NFF for the smooth fitted log-Pearson type III curve was compared with a generalized skew coefficient from Plate I of Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). This comparison was made in the form of a standardized skew residual statistic, which was computed by subtracting the generalized skew coefficient from the site-specific skew coefficient and dividing the difference by 0.55 ((site skew - generalized skew)/0.55), which is the nationwide standard deviation of station values of skew coefficient about the skew contour lines of Plate I in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). In addition to the fitted-curve skew, the fitted-curve standard deviation was computed (in log10 units). This standard deviation was used to evaluate the slope of the smooth curve.

General Testing

The published 500-year peak discharge equations for the eight States noted earlier, were derived by linear regression techniques except for Utah, in which a 500-year peak discharge can be computed by multiplying the 100-year peak discharge by a factor. The 500-year peak discharge estimates computed from these equations were evaluated using the above mentioned procedures.

The extrapolated 500-year peak discharges differed from the 500-year estimates from the equation developed by regression analysis by as much as +35 percent and -68 percent with a mean difference of -0.83 percent. One minus the ratio of the 500-year peak discharges from the computed State equations to the 100-year peak discharges (1 - Q500/Q100) was 0.57. This same statistic, using extrapolated values, had a mean ratio of 0.58 indicating that extrapolated 500-year values are similar to those from the State equations developed by regression analysis.

The mean ratio of 500-year peak discharges from the State equations to the Crippen and Bue maximum envelope values was 0.22 while the same mean ratio using extrapolated 500-year peak discharge values was

0.23. Some sites in the testing had 500-year peak discharges which exceeded the maximum envelope values in Arizona, Oklahoma, and Utah. Consequently, the user must be aware that some T-year peak discharge estimates may exceed the maximum flood envelope value for that site. Careful attention should be given to determining in which maximum flood region a basin is located (Crippen, 1982).

The same procedures were used in comparing 500-year estimates to the Crippen and Bue maximum envelope value for States without 500-year equations. The mean ratio of extrapolated 500-year peak discharges to the Crippen and Bue maximum envelope values was 0.17. Some sites in the testing had 500-year peak discharges which exceeded the maximum envelope values in Arkansas, Connecticut, Kentucky, Nebraska, New Mexico, New York, South Dakota, Tennessee, and Texas. Again, the user must be aware that some T-year peak discharge estimates may exceed the computed maximum flood envelope value for that site.

The mean standardized skew residual for the sites with 500-year equations was 0.155 with values ranging from 6.46 to -1.93. The mean of the RMS deviations of the log residuals of the State equation T-year peaks from the smooth log-Pearson Type III curve was 0.00437 with values ranging from 0.0389 to 0.0001, while the mean of the smooth-curve RMS deviations was 0.3667 with a maximum of 0.97 and a minimum of 0.11.

The mean standardized skew residual for the sites without 500-year equations was 0.104 with values ranging from 10.1 to -2.57. The mean of the RMS deviations of the log residuals of the State equation T-year peaks from the smooth log-Pearson Type III curve was 0.00565 with values ranging from 0.0623 to -0.0099 while the mean of the smooth-curve RMS deviations was 0.33 with a maximum of 1.39 and a minimum of 0.06.

Results of the testing indicated that the frequency curves generally fit a log-Pearson Type III distribution by virtue of the small RMS deviations of the log residuals of State equation T-year peak discharges from the smooth fitted log-Pearson Type III curve. The low skew errors suggest that the skew coefficients, computed from the frequency curves by NFF, are very similar to the generalized skew coefficients computed for the United States (Interagency Advisory Committee on Water Data, 1982).

Extrapolation Testing for the 500-Year Flood

Estimates of 500-year peak discharges for 149 stations used in the testing were obtained from published flood-frequency reports or from USGS District offices. The extrapolated 500-year peak discharges were obtained by using station frequency curve values for 2-year through 100-year peak discharges and then extrapolating to the 500-year recurrence interval using the extrapolation procedures described earlier. These extrapolated 500-year peaks differed by an average of 0.04 percent when compared with the 500-year peak discharges from the station frequency curves which indicated that the extrapolated peaks were similar to, and on the average slightly higher than, the station 500-year floods.

Regional/State Boundary Testing

Currently, NFF allows computations of frequency curves for basins that span more that one hydrologic region within the same State. This is accomplished on the basis of percentage of drainage area in each region. The user should verify that the resultant curves reflect the flood characteristics of the regions by consulting the respective State flood-frequency report and by examining plots of the computed frequency curves.

Regional flood-frequency computations for watersheds that span State boundaries may give different results depending on which State's equations are used. Nine sites were evaluated using the previously described methods to examine the application of NFF to basins that cross State boundaries. Currently, NFF does not allow the user the option to compute a weighted frequency curve by drainage area for basins which cross State boundaries. Because of this limitation, the user must perform this procedure manually, which can be accomplished by applying NFF for each State using the basin's full drainage area. Next, the user must manually weight the frequency curve estimates based on the percentage of the basin's drainage area in each State. For example, two frequency curves were computed for the Sucarnoochee River at Livingston, Alabama; 320 square miles of the basin's total area of 606 square miles is in Mississippi, and 286 square miles of the basin is in Alabama. Table 1 shows the frequency curves computed using the full drainage area in the application of each State's equation and the weighted frequency curve.

Table 1. Frequency curves for Sucarnoochee River at Livingston, Alabama.

Recurrence interval (years)	Computed Peak Q in Mississippi (ft^3/s)	Computed Peak Q in Alabama (ft^3/s)	Weighted frequency estimates (ft^3/s)
2	16,000	9,680	13,000
5	27,900	15,700	22,100
10	36,100	20,300	28,600
25	47,400	27,100	37,800
50	58,200	32,600	46,100
100	63,800	38,700	52,000
500	85,700	55,200	71,300

The weighted frequency curve was obtained by using the following equation:

$$Q_w(T) = \frac{286}{606} Q_{AL}(T) + \frac{320}{606} Q_{MS}(T)$$

where

$Q_{AL}(T)$, $Q_{MS}(T)$ = computed T-year peak discharge, in cubic feet per second, using the Alabama and Mississippi regression equations, respectively;

$Q_w(T)$ = weighted T-year peak discharge, in cubic feet per second.

If the estimating equation for one state is used for the entire basin, the difference between T-year can be significant, depending on which state equation is used. For example, the 100-year flood discharge for the Sucarnoochee River would be about 64,000 cubic feet per second if the basin was entirely within Mississippi but only about 39,000 cubic feet per second if the basin was entirely within Alabama.

Summary

The use of gaging station data, such as watershed and climatic characteristics and station frequency curves, in the testing of NFF indicated that the curves used to compute the extrapolated 500-year peak discharges in NFF conformed to log-Pearson Type III distributions. When compared to observed station 500-year peak discharge estimates, the extrapolated peak discharges agreed closely, differing by an average of 0.04 percent. Comparison of skew coefficients from the at-site frequency curves, computed by NFF with generalized skew coefficients, indicated only minor differences. Manual procedures for computing frequency curves across State boundaries and their limitations were described. The testing process indicated that the extrapolation procedure for the 500-year flood was reasonable and gave estimates similar to those based on station data and regional equations developed by regression analysis.

APPLICABILITY AND LIMITATIONS

By J.B. Atkins

The regression equations in National Flood Frequency (NFF) Program are applicable and representative of data used to derive them. Because the user of NFF is responsible for the assessment and interpretation of the computed frequency results, the following limitations of NFF should be observed:

1. The rural equations in NFF should only be used for rural areas and should not be used in urban areas unless the effects of urbanization are insignificant.
2. NFF should not be used where dams, flood-detention structures, and other man-made works have a significant effect on peak discharges.
3. The user is cautioned that the magnitude of the standard errors can be larger than the reported errors if the equations in NFF are used to estimate flood magnitudes for streams with explanatory variables outside the ranges identified in NFF.
4. Drainage area must always be determined, as NFF requires a value. Although a hydrologic region might not include drainage area as a variable in the prediction equation to compute a frequency curve, NFF requires the use of a watershed's drainage area for other computations, such as determining the maximum flood envelope discharge from Crippen and Bue (1977) and (or) Crippen (1982), and weighting of flood-frequency curves for watersheds in more than one region.
5. Frequency curves for watersheds contained in more than one region cannot be computed if the regions involved do not have corresponding T-year equations. Failure to observe this limitation of NFF will lead to erroneous results. Frequency curves are weighted by the percentage of drainage area in each region within a given state. No provision is provided for weighting frequency curves for watersheds in two different States.
6. In some instances, the maximum flood envelope value might be less than some T-year computed peak discharges for a given watershed. The T-year peak discharge is that discharge that will be exceeded as an annual maximum peak discharge, on average, every T years. The user should carefully determine which maximum flood-region contains the watershed being analyzed (fig. 3) and is encouraged to consult Crippen and Bue (1977) and (or) Crippen (1982) for guidance and interpretation.
7. NFF allows the weighting of estimated and observed peak discharges for frequency curve calculations. However, because very few 500-year peak discharges estimates have been published, NFF does not allow the user to enter observed values for the 500-year peak discharge. The user should evaluate the weighted curve thoroughly; it is possible for the 500-year peak discharge to be less than some of the other less extreme T-year peak discharges.
8. The user should be cautioned that some hydrologic regions do not have prediction equations for peak discharges as large as the 100-year peak discharge. The user is responsible for the assessment and interpretation of any interpolated or any extrapolated T-year peak discharges. Examination of plots of the frequency curves computed by NFF is highly desirable.
9. Hydrographs of flood flows, computed by procedures in NFF, are not applicable to watersheds whose flood hydrographs are typically derived from snowmelt runoff, or watersheds that typically exhibit double-peaked hydrographs. Furthermore, the flood hydrograph estimation procedure might not be applicable to watersheds in the semiarid/arid regions of the Nation because the procedure is based on data from Georgia (Inman, 1987). Future versions of NFF will include flood hydrograph estimation procedures for different regions of the country.

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SUMMARY OF STATE FLOOD-FREQUENCY TECHNIQUES

By H.C. Riggs *and* W.O. Thomas, Jr.

The remainder of this report provides a summary of the applicable rural and urban flood-frequency reports on which the equations in National Flood Frequency (NFF) Program are based. For each State and metropolitan area, there is a summary of the data used in developing the regression equations and a reference to the applicable report. A description of the explanatory variables and a range of standard errors are provided for the regression equations for each State or metropolitan area. All figures and maps that could be easily digitized are also included in this report. In some cases, the user will need to consult the original report to obtain some of the input variables for the regression equations.

A few notes about designation of watershed characteristics are appropriate. In the State summaries that follow, different analysts used different symbols for the same variable. We have not tried to standardize notation here but have retained the notation used in the original reports. The most prominent example of this use of different notation (and terminology) is that for main-channel slope, also referred to as channel slope, or streambed slope, which is identified by a variety of symbols such as S, SL, Sc, Sb, and Sm. Unless otherwise noted, all these slopes are the slope between two points on the main channel, 85- and 10-percent of the channel length upstream from the gage or outlet of the watershed.

Percentages, such as the percentage of the watershed in forests or lakes and ponds, are generally determined by a grid-sampling method using 20-80 points in the watershed. A transparent grid is overlain the outline of the watershed on the most appropriate topographic map. The grid should have from 20-80 nodes within the respective watershed boundary, the number of nodes overlying green (forest) or blue (lakes and ponds) is determined, and the percentage of forest or lakes and ponds is computed as the number of node intersections (with green or blue) divided by the total nodes within the watershed. Mean basin elevation is also generally determined by the same grid-sampling method averaging elevations for 20-80 points in the watershed. Several maps of variables such as mean annual precipitation, the 2-year 24-hour rainfall, average annual snowfall and minimum mean January temperature are needed and provided for some States. The maps provided in this report are, in most cases, of smaller scale than the maps provided in the statewide flood-frequency report. In some instances, the user may want to refer to the more detailed maps provided in the statewide reports for a more accurate determination of the explanatory variables.

The regression equations are provided in the same format as in the original reports. In the application of these equations, it is often necessary to add a constant to an independent variable that might equal zero. These constants are not always shown in the equations. The user should enter the actual value of the variable and the necessary constants will be applied in the computer program.

Precipitation frequencies, such as the 2-year 24-hour precipitation or rainfall, are used as explanatory variables in many of the statewide regression equations. In some of the statewide reports, this variable is defined as the 24-hour 2-year precipitation or rainfall rather than the 2-year 24-hour value. For standardization in this report, we use the terminology 2-year 24-hour precipitation even if the original statewide report reversed the order of the adjectives.

A brief description of each variable used in the regression equations is provided in the individual statewide summaries. It is assumed that the user is knowledgeable with regard to determination of many of the routine watershed characteristics, such as drainage area and channel length, from topographic maps. The applicable range of all variables is given in the NFF program so the user will know if estimates are being made outside the range of data used in developing the regression equations. The user is cautioned NOT to extrapolate the flood estimates beyond the data used to develop the equations.

ALABAMA

STATEWIDE RURAL

Summary

Alabama is divided into six hydrologic areas (fig. 1). The regression equations developed for these hydrologic areas are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; and storage (ST), which is the percentage of the basin occupied by swamps, ponds, or reservoirs. For area 2, the constant of 1.0 is added to ST in the computer application of the equation and the user should enter the actual value of ST. Both of these variables can be measured from topographic maps. The regression equations were developed from peak-discharge records available as of 1981 for about 200 streams and are applicable to unregulated streams that drain nonurban areas less than 1,500 square miles, but excluding the Little River Basin (see fig. 1). Standard errors of estimate for the regression equations range from 20 to 36 percent, except for those in hydrologic area 4, which range from 34 to 46 percent. The report by Olin (1984) includes regression equations for estimating flood characteristics as a function of drainage area for 10 reaches of major streams.

Procedure

Topographic maps, the hydrologic area map (fig. 1) and the following regression equations are used to estimate the needed peak discharges, QT, in cubic feet per second, having selected recurrence intervals T.

	Hydrologic Areas	
	1 & 6	2
Q2	$182A^{0.706}$	$149A^{0.689}(ST+1.0)^{-.219}$
Q5	$291A^{0.711}$	$310A^{0.642}(ST+1.0)^{-.172}$
Q10	$372A^{0.714}$	$459A^{0.616}(ST+1.0)^{-.142}$
Q25	$483A^{0.717}$	$696A^{0.590}(ST+1.0)^{-.109}$
Q50	$571A^{0.720}$	$904A^{0.574}(ST+1.0)^{-.084}$
Q100	$664A^{0.722}$	$1,144A^{0.560}(ST+1.0)^{-.060}$

	Hydrologic Areas		
	3	4	5
Q2	$270A^{0.569}$	$292A^{0.631}$	$226A^{0.567}$
Q5	$419A^{0.566}$	$480A^{0.647}$	$376A^{0.577}$
Q10	$524A^{0.564}$	$630A^{0.653}$	$495A^{0.582}$
Q25	$675A^{0.559}$	$845A^{0.660}$	$668A^{0.587}$
Q50	$807A^{0.554}$	$1,024A^{0.665}$	$813A^{0.591}$
Q100	$937A^{0.550}$	$1,215A^{0.669}$	$972A^{0.595}$

Reference

Olin, D.A., 1984, Magnitude and frequency of floods in Alabama: U.S. Geological Survey Water-Resources Investigations Report 84-4191, 105 p.

STATEWIDE URBAN

Summary

The regression equations are for estimating urban peak discharges (Q(u)T) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; and the percentage of the basin underlain by impervious surface (IA). These variables can be measured from topographic maps; IA can also be measured from aerial photographs. The regression equations were developed from peak-discharge records at 23 gaging stations having drainage areas ranging from less than 1 to 83 square miles and impervious surface (IA) from 5 to 43 percent. The percentage of the basin underlain by impervious area ranges from 8.3 to 42.9. The equations are applicable statewide and have standard errors of estimate that range from 24 to 26 percent. The following equations are applicable to streams draining urban areas:

$$Q(u)2 = 150A^{0.70}\,IA^{0.36}$$
$$Q(u)5 = 210A^{0.70}\,IA^{0.39}$$
$$Q(u)10 = 266A^{0.69}\,IA^{0.39}$$
$$Q(u)25 = 337A^{0.69}\,IA^{0.39}$$
$$Q(u)50 = 396A^{0.69}\,IA^{0.38}$$
$$Q(u)100 = 444A^{0.69}\,IA^{0.39}$$

Reference

Olin, D.A., and Bingham, R.H., 1982, Synthesized flood frequency of urban streams in Alabama: U.S. Geological Survey Water-Resources Investigations Report 82-683, 23 p.

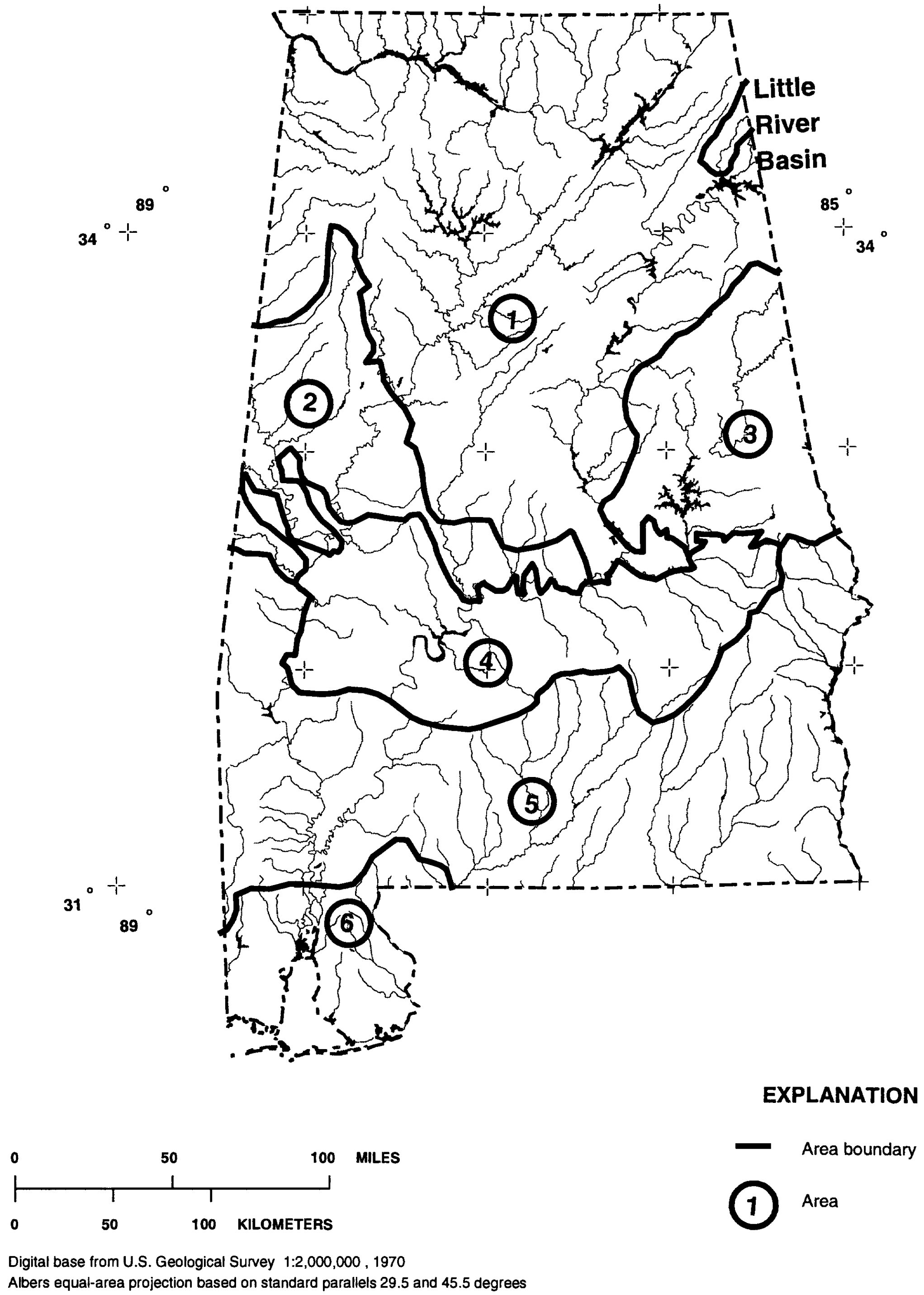


Figure 1. Flood-frequency area map for Alabama.

ALASKA

STATEWIDE RURAL

Summary

Alaska is divided into two hydrologic areas (fig. 1). The regression equations developed for these hydrologic areas are for estimating peak discharges (QT) having recurrence intervals T that range from 1.25 to 50 years. The explanatory basin variables used in the equations are drainage areas (A), in square miles; mean annual precipitation (P), in inches; mean minimum January temperature (T), in degrees Fahrenheit; lake storage area (St) as a percentage of drainage area; and forested area (F) as a percentage of drainage area. The constants fo 1 and 30 are added to T, St and F in the computer application of the equations. The user should enter the actual values of T, St and F. The mean annual precipitation and mean minimum January temperature can be obtained from figures in the report by Lamke (1979). The other variables can be measured from topographic maps. The regression equations were developed from peak-discharge records available as of 1975 for 260 streams with more than 5 years of record. The regression equations should not be used to estimate discharges on streams affected by outbursts of glacier-dammed lakes. Standard errors of estimate of the regression equations for the various recurrence intervals range from about 36 to 46 percent for hydrologic area 1 and from about 48 to 64 percent for hydrologic area 2.

Procedure

Topographic maps, the hydrologic area map (fig. 1), the mean annual precipitation map and the mean minimum January temperature map Lamke (1979) and the following regression equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Area I

$$M = 10.43\frac{A^{0.812}P^{0.522}(T+1)^{0.187}}{(St+1)^{0.266}}$$

$$D = \frac{1.63}{(T+1)^{0.049}}$$

$$\begin{aligned}
Q1.25 &= 1.02\,M^{1.003}\,D^{-0.85}\\
Q2 &= 1.16\,M^{0.988}\,D^{-0.05}\\
Q5 &= 1.24\,M^{0.984}\,D^{0.70}\\
Q10 &= 0.97\,M^{1.008}\,D^{1.30}\\
Q25 &= 0.66\,M^{1.050}\,D^{1.85}\\
Q50 &= 0.70\,M^{1.051}\,D^{2.20}
\end{aligned}$$

Area II

$$M = 1.94\frac{A^{0.949}P^{0.762}}{(St+1)^{0.192}(F+1)^{0.148}}$$

$$D = \frac{3.91}{A^{0.072}(T+30)^{0.141}}$$

$$\begin{aligned}
Q1.25 &= 1.15\,M^{0.984}\,D^{-0.857}\\
Q2 &= 1.22\,M^{0.977}\,D^{-0.088}\\
Q5 &= 1.04\,M^{0.988}\,D^{806}\\
Q10 &= 0.91\,M^{1.999}\,D^{1.325}\\
Q25 &= 0.65\,M^{1.025}\,D^{1.920}\\
Q50 &= 0.65\,M^{1.024}\,D^{2.325}
\end{aligned}$$

Reference

Lamke, R.D., 1979, Flood characteristics of Alaskan streams: U.S. Geological Survey Water-Resources Investigations Report 78-129, 61 p.

COOK INLET BASIN RURAL

Summary

The regression equations that follow this summary should be used for the Cook Inlet Basin in preference to those from the statewide report by Lamke (1979). The regression equations developed for the Cook Inlet Basin are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 50 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; percentage of total drainage area occupied by lakes and ponds (LP); and mean annual precipitation (P), in inches. The constant of 1 is added to LP in the computer application of the regression equations and the user should enter the actual value of LP. The first two variables can be measured from topographic maps, and the mean annual precipitation (P) can be determined from Lamke (1979). The regression equations are based on peak-discharge records for 50 gaging stations that had 10 or more years of record as of 1977. Standard errors of estimate for the regression equations range from about 42 to 50 percent. The report by Freethey and Scully (1980) describes other streamflow characteristics and the availability of ground water in the basin.

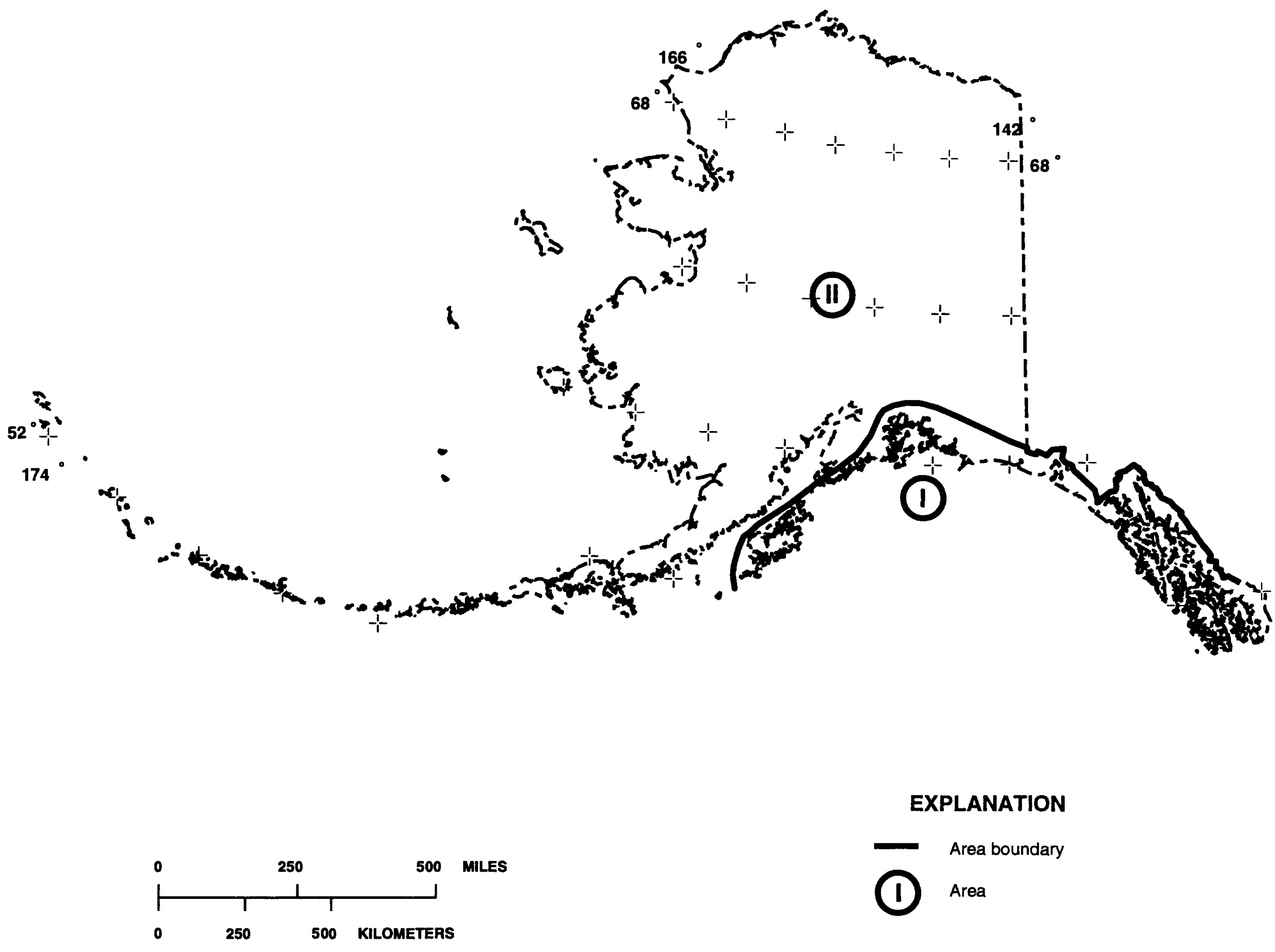
Procedure

Topographic maps, the hydrologic area map (fig. 1) (need to show Cook Inlet area on fig. 1), the mean annual precipitation map from Lamke (1979), and the following regression equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 0.154A^{0.97}P^{1.28}(LP+1)^{-0.31}$$
$$Q5 = .275A^{0.93}P^{1.27}(LP+1)^{-0.31}$$
$$Q10 = .385A^{0.90}P^{1.26}(LP+1)^{-0.32}$$
$$Q25 = .565A^{0.88}P^{1.26}(LP+1)^{-0.32}$$
$$Q50 = .737A^{0.86}P^{1.25}(LP+1)^{-0.33}$$

Reference

Freethey, G.W., and Scully, D.R., 1980, Water Resources of the Cook Inlet basin, Alaska: U.S. Geological Survey Hydrologic Atlas HA-620, 4 sheets.



Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 55 and 65 degrees

Figure 1. Flood-frequency region map for Alaska.

ARIZONA

STATEWIDE RURAL

Summary

Arizona is divided into six hydrologic regions (fig. 1). The regression equations developed for these hydrologic regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean basin elevation (E), in thousands of feet; and mean annual precipitation (P), in inches. The variables A and E can be measured from topographic maps, and P can be determined from figure 2. The regression equations were developed from peak-discharge records available through 1975 at 110 continuous-record gaging stations and 111 crest-stage gaging stations, and are applicable to unregulated streams that drain nonurban areas. The standard errors of estimate of the regression equations for the various T-year regression equations range from about 40 to 85 percent. The report by Roeske (1978) includes graphs relating flood characteristics to drainage area on the Little Colorado and Gila Rivers.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the map of mean annual precipitation (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1

$$Q2 = 19.0A^{0.660}$$
$$Q = 66.3A^{0.600}$$
$$Q10 = 127A^{0.566}$$
$$Q25 = 252A^{0.532}$$
$$Q50 = 393A^{0.510}$$
$$Q100 = 584A^{0.490}$$
$$Q500 = 1{,}300A^{0.451}$$

Region 2

$$Q2 = 87.0A^{0.433}$$
$$Q5 = 218A^{0.462}$$
$$Q10 = 352A^{0.475}$$
$$Q25 = 586A^{0.487}$$
$$Q50 = 815A^{0.494}$$
$$Q100 = 1{,}100A^{0.499}$$
$$Q500 = 2{,}000A^{0.509}$$

Region 3

$$Q2 = 5.66A^{0.673}E^{-0.605}P^{1.03}$$
$$Q5 = 31.6A^{0.650}E^{-0.868}P^{0.987}$$
$$Q10 = 74.7A^{0.638}E^{-1.00}P^{0.971}$$
$$Q25 = 186A^{0.626}E^{-1.14}P^{0.944}$$
$$Q50 = 329A^{0.617}E^{-1.22}P^{0.933}$$
$$Q100 = 553A^{0.610}E^{-1.30}P^{0.915}$$
$$Q500 = 1{,}530A^{0.595}E^{-1.45}P^{0.886}$$

Region 4

$$Q2 = 1.38A^{0.491}E^{2.25}$$
$$Q5 = 0.319A^{0.446}E^{3.60}$$
$$Q10 = 0.143A^{0.423}E^{4.31}$$
$$Q25 = 0.0590A^{0.398}E^{5.10}$$
$$Q50 = 0.0327A^{0.383}E^{5.60}$$
$$Q100 = 0.0188A^{0.369}E^{6.09}$$
$$Q500 = 0.0062A^{0.342}E^{7.04}$$

Region 5

$$Q2 = 96.6A^{0.555}$$
$$Q5 = 256A^{0.513}$$
$$Q10 = 416A^{0.492}$$
$$Q25 = 685A^{0.471}$$
$$Q50 = 937A^{0.458}$$
$$Q100 = 1{,}230A^{0.447}$$
$$Q500 = 2{,}120A^{0.425}$$

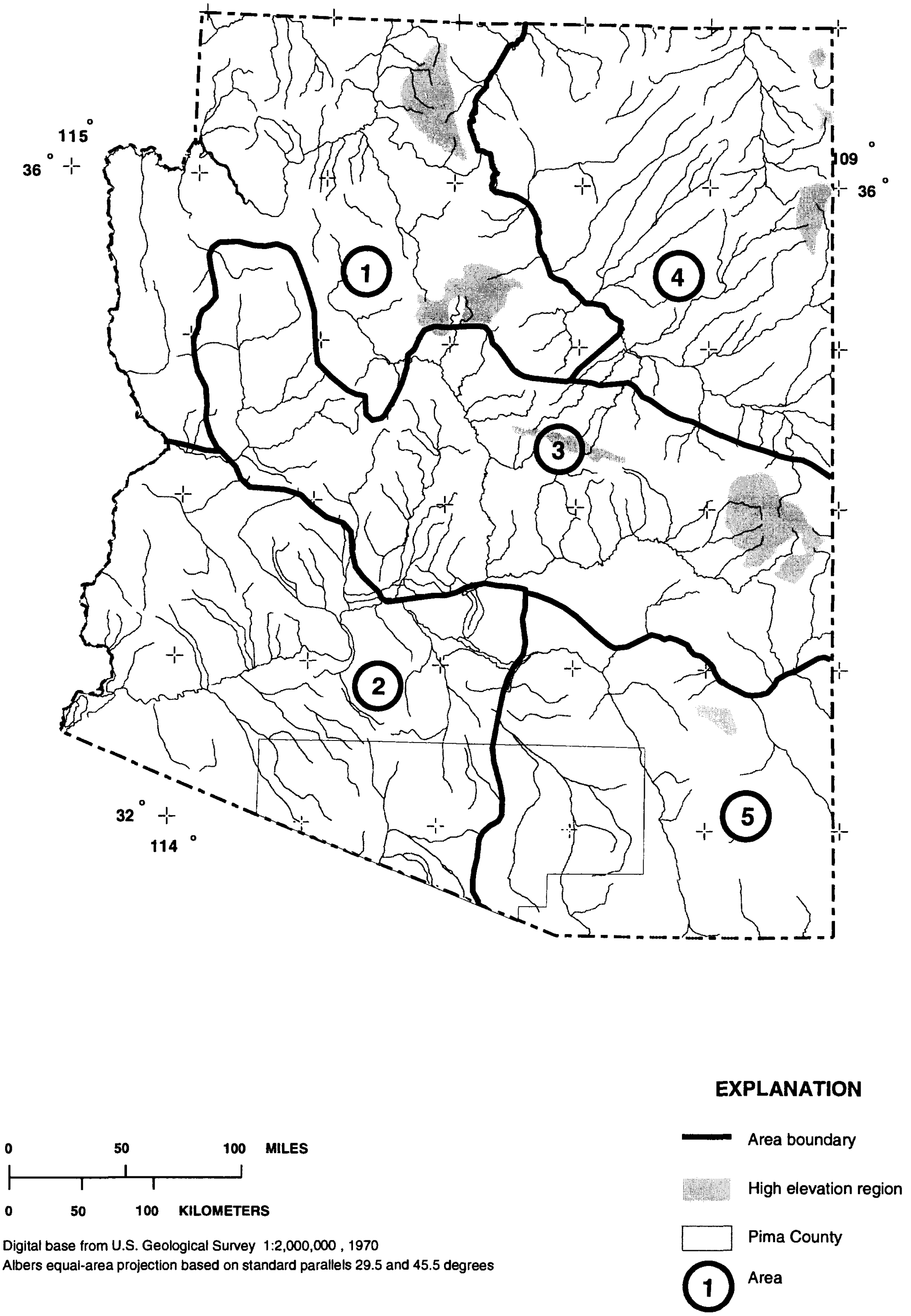
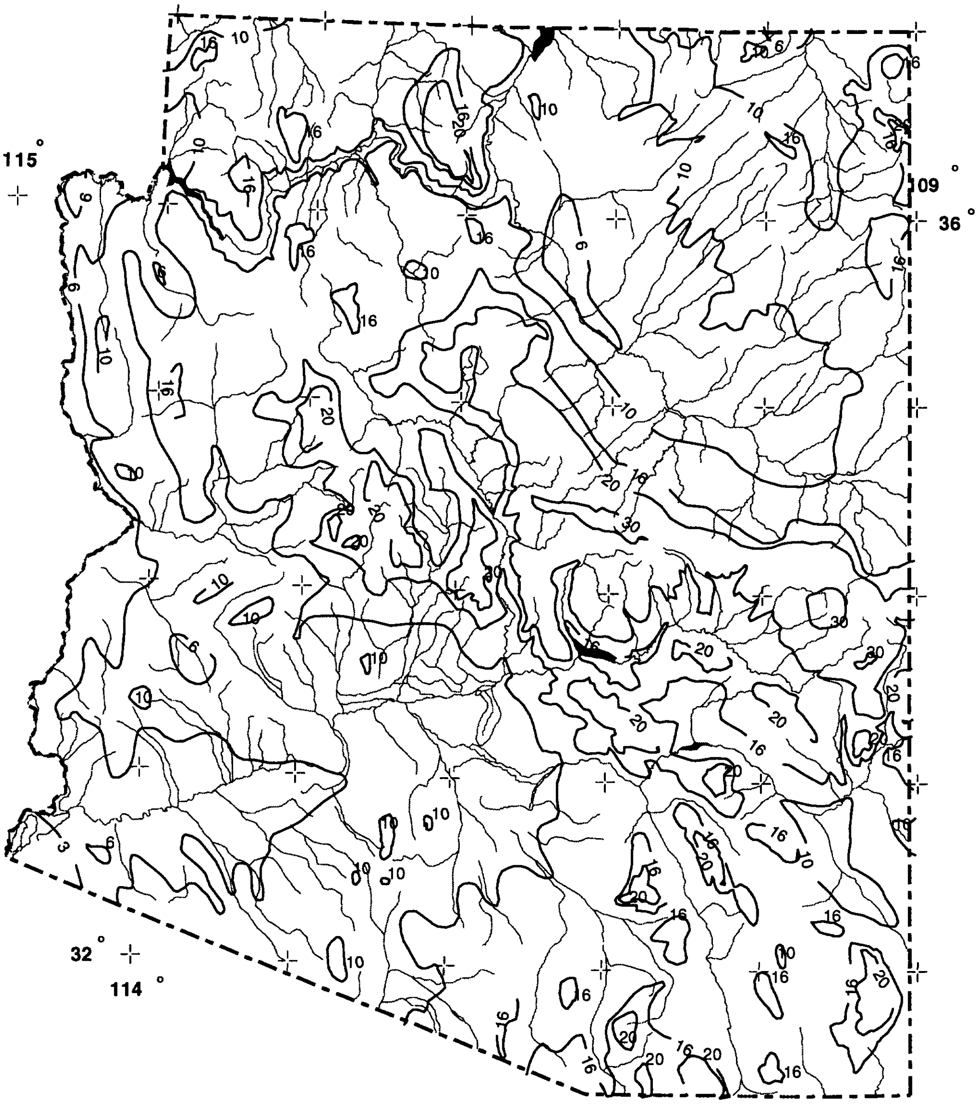


Figure 1. Flood-frequency region map for Arizona.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

—— 30 —— Line of equal mean annual precipitation (interval, in inches, is variable)

Figure 2. Mean annual precipitation in Arizona.

High Elevation (HE) Region

$$Q2 = 8.78A^{0.853}$$
$$Q5 = 19.9A^{0.826}$$
$$Q10 = 29.6A^{0.816}$$
$$Q25 = 44.9A^{0.805}$$
$$Q50 = 58.2A^{0.799}$$
$$Q100 = 72.9A^{0.795}$$
$$Q500 = 113A^{0.787}$$

Reference

Roeske, R.H., 1978, Methods for estimating the magnitude and frequency of floods in Arizona: U.S. Geological Survey Open-File Report 78-711, 82 p.

PIMA COUNTY RURAL

Summary

In a separate study, regression equations were developed for streams in and near Pima County. The study area is one region with regression equations for estimating peak discharges (RQT) having recurrence intervals that range from 2 to 500 years (fig. 1). The explanatory basin variables used in the equations are drainage area (A), in square miles; main-channel slope (S), in feet per mile; and shape factor (Sh), which is squared length of the watershed in miles divided by drainage area (L2/A). These variables can be measured from topographic maps. The regression equations are based on peak-discharge records for 101 stations in and near Pima County with the equations applicable to streams draining rural areas. Standard errors of estimate of the regression equations range from 42 to 60 percent. The report by Eychaner (1984) includes equations for streams draining urban areas based on Sauer and others (1983).

Procedure

Topographic maps, the hydrologic region map (fig. 1) and the following equations are used to estimate peak discharges (RQT), in cubic feet per second, having selected recurrence intervals T for sites in Pima County.

$$\text{LogRQ2} = 2.049 + 0.547\text{LogA} - 0.003(\text{LogA})^2 + 0.299\text{LogS} - 0.194(\text{LogS})^2 - 0.253(\text{LogS})(\text{LogSh})$$

$$\text{LogRQ5} = 2.430 + 0.591\text{LogA} - 0.023(\text{LogA})^2 + 0.489\text{LogS} - 0.275(\text{LogS})^2 - 0.408(\text{LogS})(\text{LogSh})$$

$$\text{LogRQ10} = 2.621 + 0.609\text{LogA} - 0.031(\text{LogA})^2 + 0.633\text{LogS} - 0.288(\text{LogS})^2 - 0.578(\text{LogS})(\text{LogSh})$$

$$\text{LogRQ25} = 2.814 + 0.625\text{LogA} - 0.039(\text{LogA})^2 + 0.679\text{LogS} - 0.329(\text{LogS})^2 - 0.590(\text{LogS})(\text{LogSh})$$

$$\text{LogRQ50} = 2.936 + 0.636\text{LogA} - 0.044(\text{LogA})^2 + 0.706\text{LogS} - 0.350(\text{LogS})^2 - 0.601(\text{LogS})(\text{LogSh})$$

$$\text{LogRQ100} = 3.044 + 0.646\text{LogA} - 0.049(\text{LogA})^2 + 0.729\text{LogS} - 0.367(\text{LogS})^2 - 0.614(\text{LogS})(\text{LogSh})$$

$$\text{LogRQ500} = 3.260 + 0.665\text{LogA} - 0.058(\text{LogA})^2 + 0.776\text{LogS} - 0.396(\text{LogS})^2 - 0.651(\text{LogS})(\text{LogSh})$$

Reference

Eychaner, J.H., 1984, Estimation of magnitude and frequency of floods in Pima County, Arizona, with comparisons of alternative methods: U.S. Geological Survey Water-Resources Investigations Report 84-4142, 69 p.

ARKANSAS

Summary

Arkansas is divided into two hydrologic regions (fig. 1). Region A includes most of the Mississippi River Alluvial Plain in Arkansas. Region B is the upland portion of the State. The regression equations developed for these hydrologic regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; channel length (L), in miles; mean annual precipitation (P), in inches; and mean basin elevation (E), in feet. Mean annual precipitation (P) can be determined from the map (fig. 2) and the other variables can be measured from topographic maps. The constant of 30 is substracted from P in the computer application of the equation and the user should enter the actual value of P from figure 2. The regression equations were developed from peak-discharge records collected through 1984 at 200 gaging stations, all of which had at least 20 years of record. The regression equations are applicable to streams draining less than 3000 square miles and which are free of significant regulation. Standard errors of estimate of the regression equations range from 28 to 42 percent. The report by Neely (1987) includes graphs of flood-frequency relations along the channels of seven major rivers, flood-frequency characteristics at gaging stations on both unregulated and regulated streams, and regression equations for estimating peak magnitude and frequency using hydraulic radius as a variable.

Procedure

Topographic maps, the hydrologic region map (fig. 1), the mean annual precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region A

$Q2 = 107\ A^{0.83}\ S^{0.28}\ L^{-0.33}$

$Q5 = 149\ A^{0.88}\ S^{0.36}\ L^{-0.40}$

$Q10 = 175\ A^{0.90}\ S^{0.40}\ L^{-0.42}$

$Q25 = 205\ A^{0.92}\ S^{0.45}\ L^{-0.44}$

$Q50 = 226\ A^{0.93}\ S^{0.48}\ L^{-0.45}$

$Q100 = 245\ A^{0.94}\ S^{0.51}\ L^{-0.46}$

Region B

$Q2 = 0.120\ A^{0.78}\ S^{0.42}\ (P\text{-}30)^{0.55}\ E^{0.75}$

$Q5 = 0.521\ A^{0.78}\ S^{0.48}\ (P\text{-}30)^{0.43}\ E^{0.64}$

$Q10 = 1.07\ A^{0.78}\ S^{0.51}\ (P\text{-}30)^{0.38}\ E^{0.59}$

$Q25 = 2.23\ A^{0.79}\ S^{0.53}\ (P\text{-}30)^{0.33}\ E^{0.53}$

$Q50 = 3.58\ A^{0.79}\ S^{0.55}\ (P\text{-}30)^{0.29}\ E^{0.50}$

$Q100 = 5.35\ A^{0.79}\ S^{0.56}\ (P\text{-}30)^{0.27}\ E^{0.47}$

Reference

Neeley, B.L., Jr., 1987, Magnitude and frequency of floods in Arkansas: U.S. Geological Survey Water-Resources Investigations Report 86-4335, 51 p.

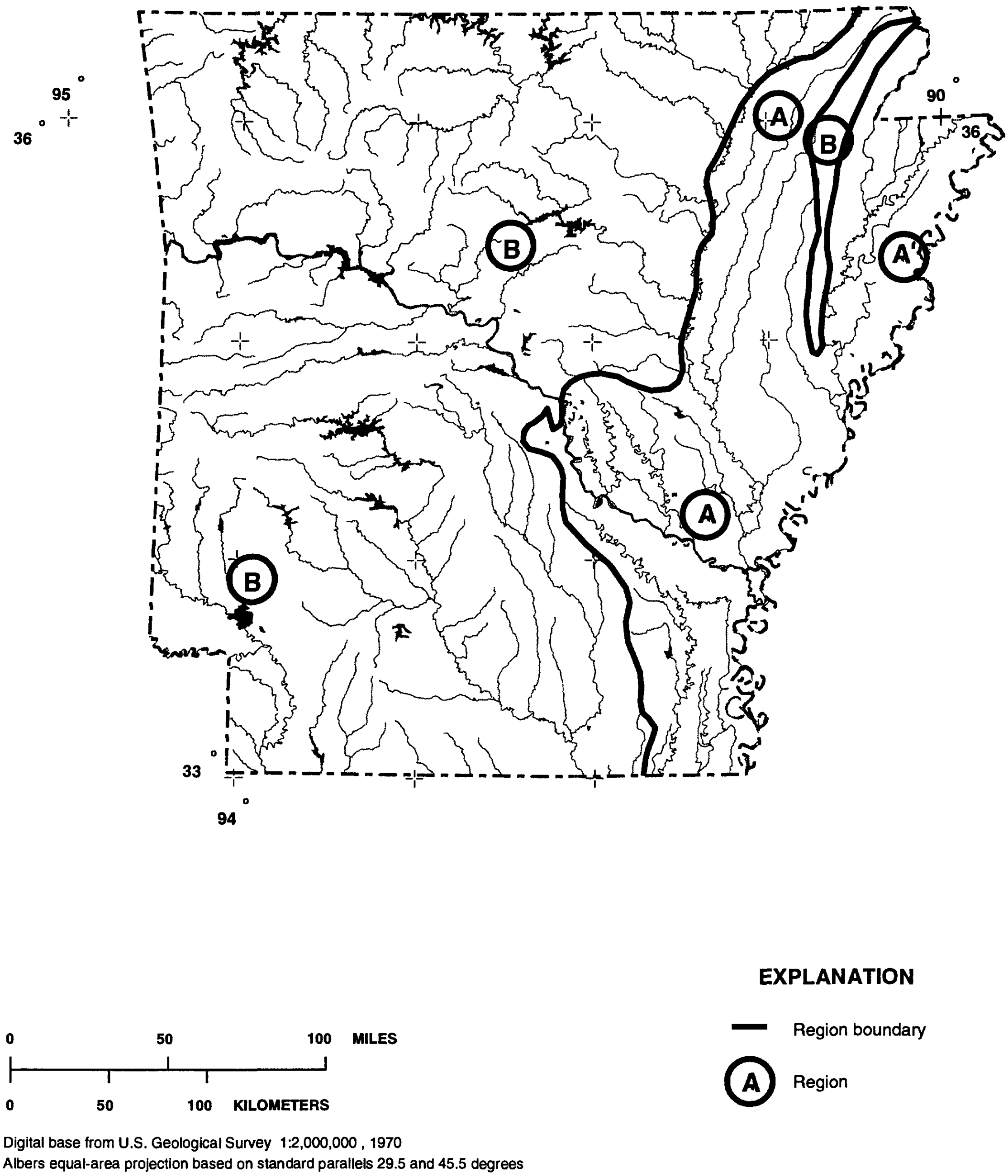


Figure 1. Flood-frequency region map for Arkansas.

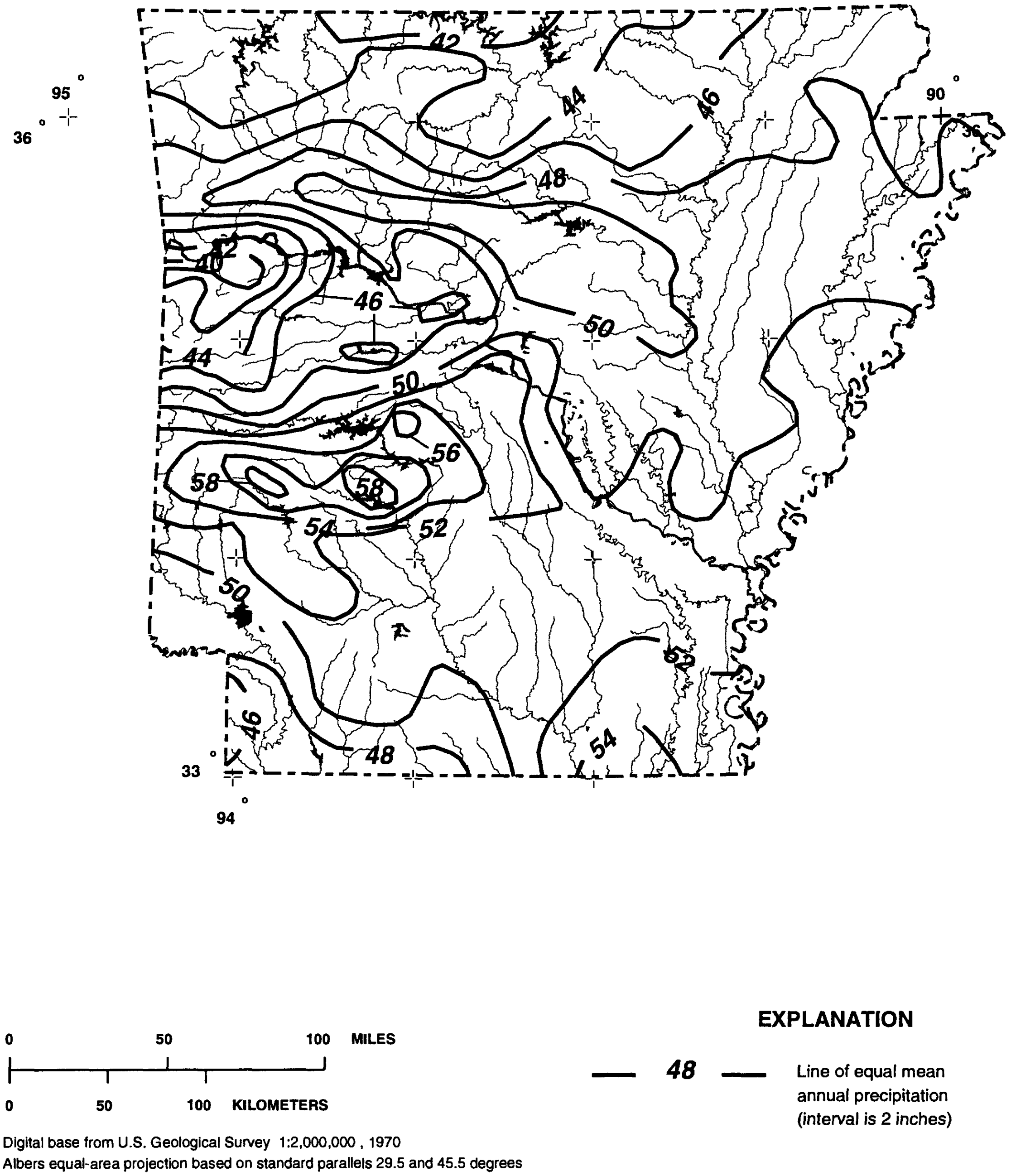


Figure 2. Mean annual precipitation in Arkansas.

CALIFORNIA

STATEWIDE RURAL

Summary

California is divided into six hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches; and an altitude index (H), which is the average of altitudes in thousands of feet at points along the main channel at 10 percent, and 85 percent of the distances from the site to the divide. The variables A and H may be measured from topographic maps. Mean annual precipitation (P) is determined from a map in Rantz (1969). The regression equations were developed from peak-discharge records of 10 years or longer, available as of 1975, at more than 700 gaging stations throughout the State. The regression equations are applicable to unregulated streams, but are not applicable to some parts of the State (see fig. 1). The standard errors of estimate for the regression equations for various recurrence intervals and regions, range from 60 to over 100 percent. The report by Waananen and Crippen (1977) includes an approximate procedure for increasing a rural discharge to account for the effect of urban development. The influences of fire and other basin changes on flood magnitudes are also discussed.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation from Rantz (1969) and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

North Coast Region

$$Q2 = 3.52\, A^{0.90} P^{0.89} H^{-0.47}$$
$$Q5 = 5.04\, A^{0.89} P^{0.91} H^{-0.35}$$
$$Q10 = 6.21\, A^{0.88} P^{0.93} H^{-0.27}$$
$$Q25 = 7.64\, A^{0.87} P^{0.94} H^{-0.17}$$
$$Q50 = 8.57\, A^{0.87} P^{0.96} H^{-0.08}$$
$$Q100 = 9.23\, A^{0.87} P^{0.97}$$

Northeast Region

$$Q2 = 22\, A^{0.40}$$
$$Q5 = 46\, A^{0.45}$$
$$Q10 = 61\, A^{0.49}$$
$$Q25 = 84\, A^{0.54}$$
$$Q50 = 103\, A^{0.57}$$
$$Q100 = 125\, A^{0.59}$$

Sierra Region

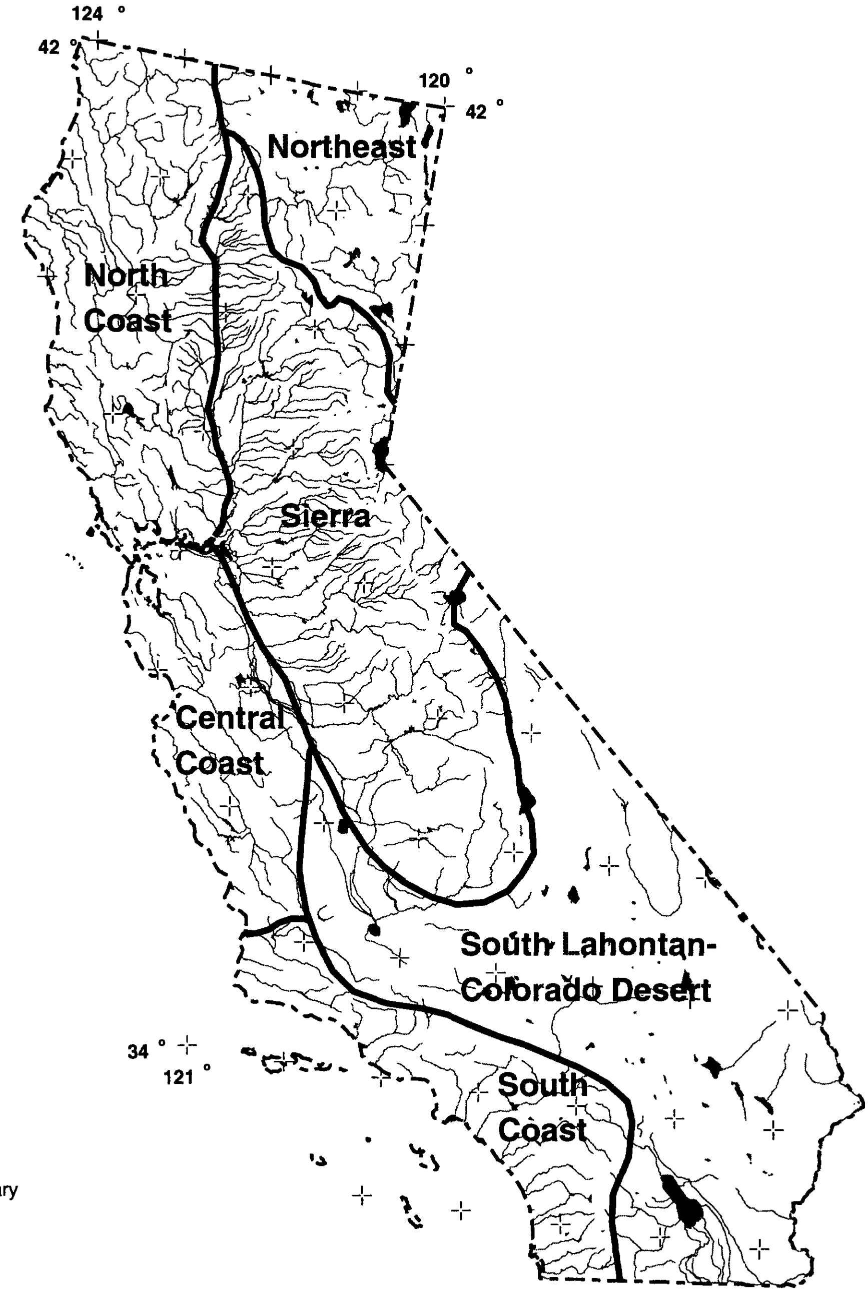
$$Q2 = 0.24\, A^{0.88} P^{1.58} H^{-0.80}$$
$$Q5 = 1.20\, A^{0.82} P^{1.37} H^{-0.64}$$
$$Q10 = 2.63\, A^{0.80} P^{1.25} H^{-0.58}$$
$$Q25 = 6.55\, A^{0.79} P^{1.12} H^{-0.52}$$
$$Q50 = 10.4\, A^{0.78} P^{1.06} H^{-0.48}$$
$$Q100 = 15.7\, A^{0.77} P^{1.02} H^{-0.43}$$

Central Coast Region

$$Q2 = 0.0061\, A^{0.92} P^{2.54} H^{-1.10}$$
$$Q5 = 0.118\, A^{0.91} P^{1.95} H^{-0.79}$$
$$Q10 = 0.583\, A^{0.90} P^{1.61} H^{-0.64}$$
$$Q25 = 2.91\, A^{0.89} P^{1.26} H^{-0.50}$$
$$Q50 = 8.20\, A^{0.89} P^{1.03} H^{-0.41}$$
$$Q100 = 19.7\, A^{0.88} P^{0.84} H^{-0.33}$$

South Coast Region

$$Q2 = 0.14\, A^{0.72} P^{1.62}$$
$$Q5 = 0.40\, A^{0.77} P^{1.69}$$
$$Q10 = 0.63\, A^{0.79} P^{1.75}$$
$$Q25 = 1.10\, A^{0.81} P^{1.81}$$
$$Q50 = 1.50\, A^{0.82} P^{1.85}$$
$$Q100 = 1.95\, A^{0.83} P^{1.87}$$



EXPLANATION

Regional boundary

North Coast — Region

0 50 100 150 MILES

0 50 100 150 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Flood-frequency region map for California.

South Lahontan-Colorado Desert Region

$$Q2 = 7.3A^{0.30}$$
$$Q5 = 53A^{0.44}$$
$$Q10 = 150A^{0.53}$$
$$Q25 = 410A^{0.63}$$
$$Q50 = 700A^{0.68}$$
$$Q100 = 1{,}080A^{0.71}$$

In the North Coast region, use a minimum value of 1.0 for the altitude index (H). Equations are defined only for basins of 25 mi^2 or less in the Northeast and South Lahontan-Colorado Desert regions.

Reference

Waananen, A.O. and Crippen, J.R., 1977, Magnitude and frequency of floods in California: U.S. Geological Survey Water-Resources Investigations Report 77-21, 96 p.

Additional Reference

Rantz, S.E., 1969, Mean annual precipitation in the California region: U.S. Geological Survey Open-File Map (Reprinted 1972, 1975).

COLORADO

Colorado is divided into three basic/general flood regions: the mountainous region, running north and south through the central part of the state, the plateau region to the west of the mountainous region, and the plains region to the east of the mountainous region (fig. 1). The mountainous region has two distinct subregions, the southern subregion (essentially defined by the Rio Grande basin) named the Rio Grande Region, and the northern subregion named the Mountain Region. The plateau region has two distinct subregions, the southern subregion named the Southwest Region, and the northern subregion named the Northwest Region. The plains region has two distinct subregions, the sandhills subregion and the non-sandhills subregion. There are insufficient data to describe the individual subregions, so the entire region is named the Plains Region.

A complicating factor in estimating the magnitude and frequency of floods in Colorado is mixed-population flood hydrology. A mixed-population flood-hydrology site is one where floods are caused by two or more distinct meteorological processes and can be located in a plains or plateau region and have part of its drainage area in an adjacent mountain region. The mixed-population sites are considered as being in the foothills or transition regions located between the mountain regions and the plains or plateau regions. An overall foothills region cannot be shown on a map, because within the drainage area of a site, that qualifies as being in a foothills region, there can be subregions that are entirely within a plains or plateau region and by themselves cannot be part of a foothills region. At a foothills region site, annual peak discharges are derived from snowmelt at higher elevations in the mountain regions, from rainfall at lower elevations in the plateau or plains regions, or from a combination of rain falling on snow. No one report describes the complicated flood hydrology of Colorado. In this summary, several reports are used.

WESTERN COLORADO

Summary

Western Colorado is divided into four hydrologic subregions (fig. 1). The regression equations developed for these hydrologic regions are for estimating peak discharge (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches, minus 10; mean basin elevation minus 5,000 feet, per 1,000 feet (EB); and mean basin slope (SB), in feet per foot. The variables P and EB are transformed by the constants in the computer application of the equations. The user should enter the actual value of P and EB. These variables, with the exception of P, can be measured from topographic maps and P can be determined from the mean annual precipitation map in U.S. Weather Bureau (1967). The regression equations were developed from peak-discharge records available through 1981 at 247 stations. The regression equations are applicable to streams whose flows are not significantly affected by the works of man. Standard errors of estimate of the regression equations range from 39 to 71 percent.

Procedure

Topographic maps, the map of hydrologic regions (fig. 1), the mean annual precipitation map in U.S. Weather Bureau (1967) and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Mountain Region

$$Q2 = 74.3A^{0.693} SB^{0.894}$$
$$Q5 = 81.5A^{0.698} SB^{0.719}$$
$$Q10 = 86.1A^{0.699} SB^{0.635}$$
$$Q25 = 91.5A^{0.699} SB^{0.550}$$
$$Q50 = 94.9A^{0.699} SB^{0.497}$$
$$Q100 = 98.5A^{0.698} SB^{0.452}$$
$$Q200 = 102A^{0.697} SB^{0.412}$$
$$Q500 = 106A^{0.696} SB^{0.364}$$

Rio Grande Region

$$Q2 = 0.0504\ A^{0.806} P^{1.87}$$
$$Q5 = 0.229\ A^{0.777} P^{1.55}$$
$$Q10 = 0.487\ A^{0.760} P^{1.40}$$
$$Q25 = 1.06\ A^{0.742} P^{1.25}$$
$$Q50 = 1.75\ A^{0.730} P^{1.16}$$
$$Q100 = 2.71\ A^{0.719} P^{1.07}$$
$$Q200 = 4.01\ A^{0.708} P^{1.00}$$
$$Q500 = 6.40\ A^{0.695} P^{0.918}$$

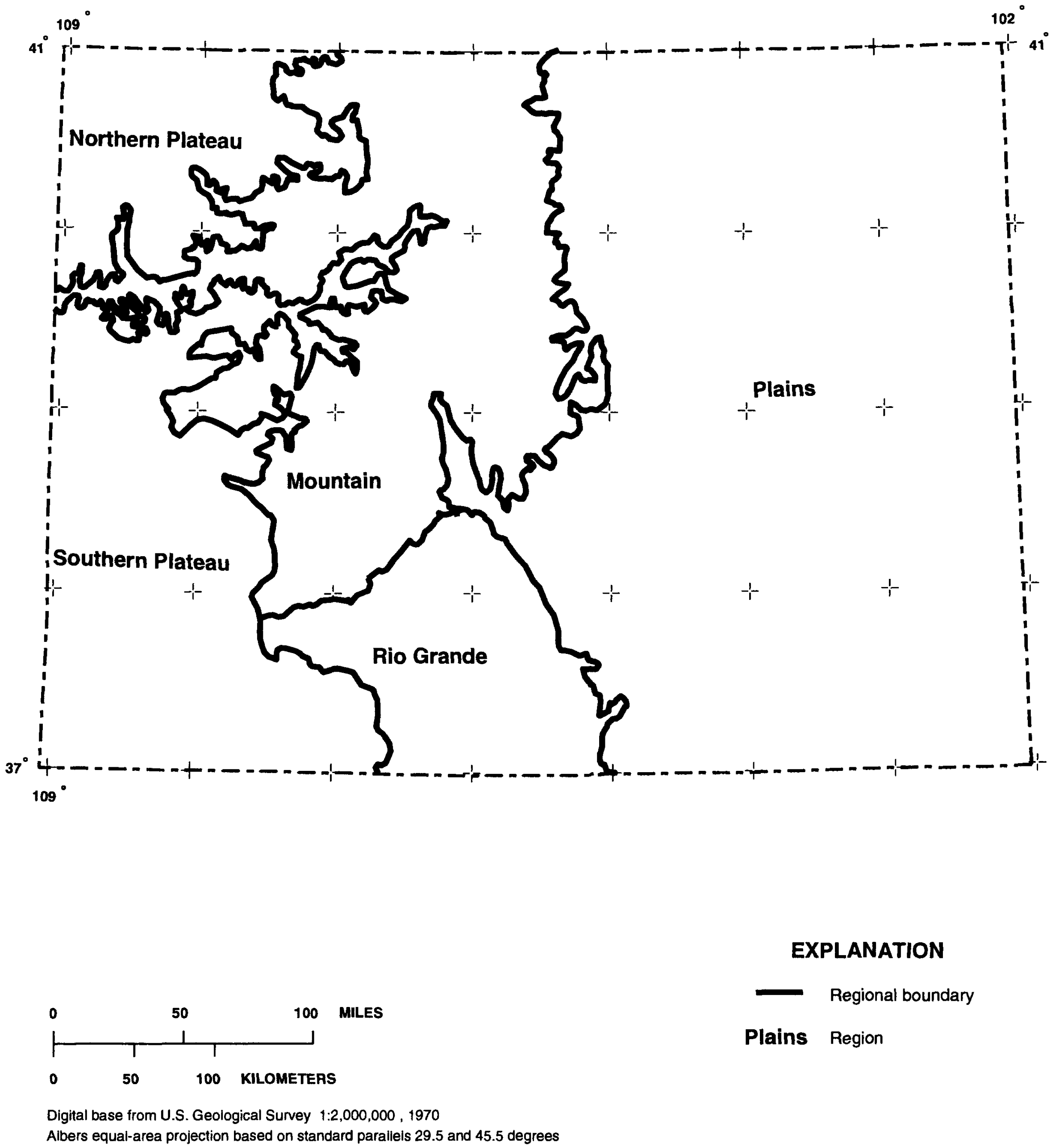


Figure 1. Flood-frequency region map for Colorado.

Southern Plateau/Southwest Region

$$Q2 = 7.87\, A^{0.732}\, EB^{0.847}$$

$$Q5 = 53.9\, A^{0.686}$$

$$Q10 = 69.4\, A^{0.685}$$

$$Q25 = 91.1\, A^{0.683}$$

$$Q50 = 109\, A^{0.682}$$

$$Q100 = 128\, A^{0.680}$$

$$Q200 = 149\, A^{0.679}$$

$$Q500 = 179\, A^{0.677}$$

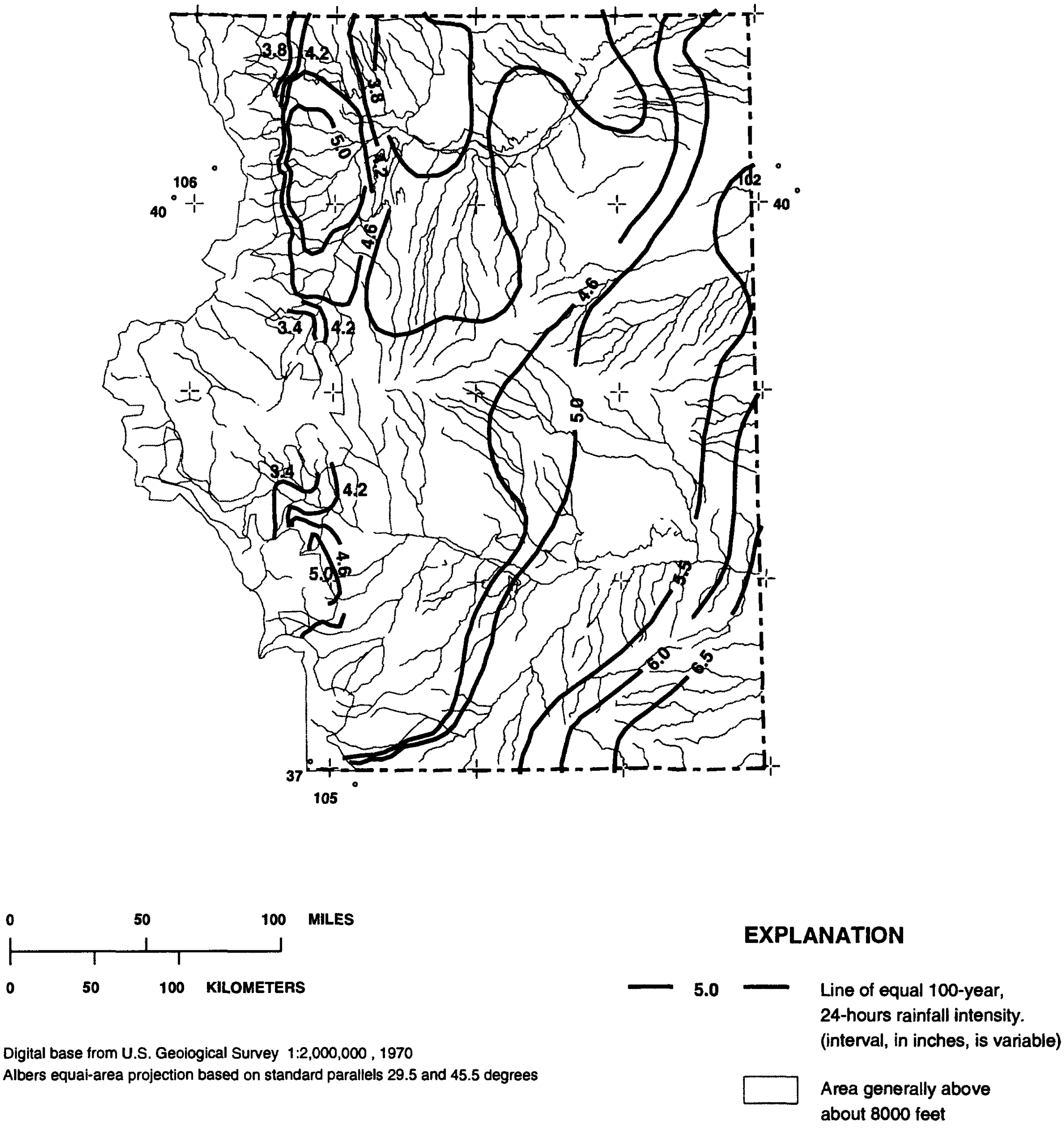


Figure 2. The 100-year 24-hour rainfall in Eastern Colorado.

Northwest Region

$$Q2 = 0.795\ A^{0.820}\ P^{1.00}$$
$$Q5 = 1.86\ A^{0.794}\ P^{0.871}$$
$$Q10 = 2.86\ A^{0.781}\ P^{0.802}$$
$$Q25 = 4.45\ A^{0.768}\ P^{0.732}$$
$$Q50 = 5.90\ A^{0.759}\ P^{0.686}$$
$$Q100 = 7.54\ A^{0.752}\ P^{0.646}$$
$$Q200 = 9.49\ A^{0.745}\ P^{0.609}$$
$$Q500 = 12.4\ A^{0.737}\ P^{0.565}$$

Reference

Kircher, J.E., Choquette, A.F., and Richter, B.D., 1985, Estimation of natural streamflow characteristics in western Colorado: U.S. Geological Survey Water-Resources Investigations Report 85-4086, 28 p.

Additional Reference

U.S. Weather Bureau, 1967, Normal annual precipitation, normal May-September precipitation 1931-60, Colorado: U.S. Weather Bureau map (Available from the Colorado Water Conservation Board).

EASTERN COLORADO, PLAINS REGION (DRAINAGE AREAS LESS THAN 20 MI^2)

Summary

Eastern Colorado is treated as a single (Plains) hydrologic region for drainage areas less than 20 mi^2; the sand-hill areas are excluded (fig. 1). The regression equations developed for this hydrologic region are for estimating peak discharges (QT) having recurrence intervals T that range from 5 to 100 years. The basin explanatory variables used in the equations are effective drainage area (AE), in square miles, which is the total drainage area minus the area upstream from all erosion-control or flood-retention structures; relief factor (RF), in feet, computed as the altitude difference between that for the highest point within the effective drainage area and that of the study site minus 18; and (I24-100) which is the 100-year 24-hour rainfall, in inches. The constant 18 is subtracted from RF in the equations. The user should enter the actual value of RF. The variables AE and RF can be measured from topographic maps, and I24-100 can be determined from figure 2. The regression equations were developed from rainfall-runoff data collected at 35 gaging stations operated in Colorado from 1969 through 1979, on peak-discharge data available for 17 gaging stations in adjoining States, and on long-term climatological records.

The regression equations are applicable to streams with effective drainage areas ranging from 0.3 to 20 square miles. Standard errors of estimate of the regression equations range from 36 to 47 percent using the three basin variables. Standard errors range from 39 to 51 percent when only effective drainage area is included in the regression equations. Both sets of regression equations are provided in the following sections.

The report includes a relation for estimating flood volume from peak discharge. Also included is a dimensionless-hydrograph technique that produces synthetic flood hydrographs very similar in shape to recorded flood hydrographs. Some information on rainfall-runoff data in the Plateau Region of western Colorado is also included.

Procedure

Topographic maps, the 100-year 24-hour rainfall map (fig. 2) and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$\text{Log } Q5 = 2.56 + 0.57\ (\text{Log RF})(\text{Log I24-100}) - 1.09\ AE^{-0.25}$$
$$\text{Log } Q10 = 3.05 + 0.53\ (\text{Log RF})(\text{Log I24-100}) - 1.29\ AE^{-0.25}$$
$$\text{Log } Q25 = 3.64 + 0.45\ (\text{Log RF})(\text{Log I24-100}) - 1.53\ AE^{-0.25}$$
$$\text{Log } Q50 = 4.03 + 0.39\ (\text{Log RF})(\text{Log I24-100}) - 1.70\ AE^{-0.25}$$
$$\text{Log } Q100 = 4.41 + 0.33\ (\text{Log RF})(\text{Log I24-100}) - 1.85\ AE^{-0.25}$$

Reference

Livingston, R. K., and Minges, D. R., 1987, Techniques for estimating regional flood characteristics of small rural watersheds in the plains region of eastern Colorado: U.S. Geological Survey Water-Resources Investigations Report 87-4094, 70 p.

EASTERN COLORADO, PLAINS REGION (DRAINAGE AREAS MORE THAN 20 MI^2)

Summary

A second Plains Region is for streams with drainage areas greater than 20 mi^2 (fig. 1). The regression equations developed for this region are for estimating peak discharges (QT) having recurrence intervals T of 10-, 50-, 100- and 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; and streambed (channel) slope (Sb), in feet per mile. The regression equations are applicable for unregulated streams draining areas greater than 20 mi^2. The standard errors of estimate for the regression equations range from 24 to 45 percent.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q10 = 144\ A^{0.528}\ Sb^{0.336}$$

$$Q50 = 891\ A^{0.482}\ Sb^{0.154}$$

$$Q100 = 1{,}770\ A^{0.463}\ Sb^{0.086}$$

$$Q500 = 5{,}770\ A^{0.432}$$

Reference

McCain, J.F., and Jarrett, R.D., 1976, Manual for estimating flood characteristics of natural-flow streams in Colorado: Colorado Department of Natural Resources Technical Manual No. 1, 68 p.

COLORADO FRONT RANGE

Summary

A multidisciplinary study of precipitation, and streamflow data, and paleoflood studies of channel features was made to analyze the flood hydrology of foothill and mountain streams in the Front Range of Colorado (South Platte River basin above the confluence of Cache La Poudre, fig. 2). The regression equations were developed for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The only explanatory basin variable used is the drainage area (AB8), in square miles, below 8,000 feet. The area above 8,000 feet is shown in figure 2 as a guide in determining AB8. The standard errors of estimates of the regression equations range from 42 to 100 percent.

Procedure

For the South Platte River basin above the confluence of Cache La Poudre with South Platte River, use topographic maps and the following equations to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 36.9\ (AB8)^{0.61}$$

$$Q10 = 111\ (AB8)^{0.75}$$

$$Q50 = 231\ (AB8)^{0.83}$$

$$Q100 = 302\ (AB8)^{0.86}$$

$$Q500 = 533\ (AB8)^{0.92}$$

Reference

Jarrett, R.D.,and Costa, J.E., 1988, Evaluation of the flood hydrology in the Colorado Front Range using precipitation, streamflow, and paleoflood data for the Big Thompson River basin: U.S. Geological Survey Water-Resources Investigations Report 87-4117, 37 p.

CONNECTICUT

STATEWIDE RURAL

Summary

The entire area of Connecticut is considered to be one hydrologic region. The statewide regression equations developed are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; 24-hour precipitation (I), in inches, for various recurrence intervals (T); channel length (L), in miles; channel slope (S_m), in feet per mile; and percentage of drainage area underlain by coarse-grained stratified drift (%Asd). The constant of 1 is added in the computer application of the regression equations. The user should enter the actual value of Asd. The variables A, L, and Sm can be measured from topographic maps. Stratified drift (%Asd) can be determined from a map by Henney (1981). The 24-hour precipitation for recurrence intervals of 2, 10, 25, 50 and 100 years can be determined from maps in figures 1-5, respectively. The regression equations were developed from peak-discharge records for 96 streams; those streams with drainage areas greater than 100 square miles had an average record length of 52 years; those of less than 100 square miles had an average record length of 20 years. The standard errors of estimate of the regression equations range from 37 to 47 percent. Also included in the report by Weiss (1983) are methods for estimating mean flows and low flows.

Procedure

Topographic maps, the maps of 24-hour precipitation for various recurrence intervals in figures 1-5, the map of stratified drift by Henney (1981) and the following equations are used to compute the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Drainage Area ≤10 Square Miles

$$Q2 = 8.1A^{0.88}\,I2^{2.14}\,(L/\sqrt{S_m})^{-0.05}\,(\%Asd+1)^{-0.2}$$

$$Q10 = 12.8A^{0.89}\,I10^{1.6}\,(L/\sqrt{S_m})^{-0.06}\,(\%Asd+1)^{-0.17}$$

$$Q25 = 63.1A^{0.89}\,I25^{0.71}\,(L/\sqrt{S_m})^{-0.06}\,(\%Asd+1)^{-0.17}$$

$$Q50 = 72.1A^{0.92}\,I50^{0.67}\,(L/\sqrt{S_m})^{-0.09}\,(\%Asd+1)^{-0.17}$$

$$Q100 = 73.5A^{0.91}\,I100^{0.74}\,(L/\sqrt{S_m})^{-0.08}\,(\%Asd+1)^{-0.18}$$

Drainage Area ≥10 and ≤100 Square Miles

$$Q2 = 7.7A^{1.05}\,I2^{1.74}\,(L/\sqrt{S_m})^{-0.26}\,(\%Asd+1)^{-0.16}$$

$$Q10 = 5.6A^{1.05}\,I10^{1.98}\,(L/\sqrt{S_m})^{-0.26}\,(\%Asd+1)^{-0.22}$$

$$Q25 = 16.2A^{1.03}\,I25^{1.41}\,(L/\sqrt{S_m})^{-0.23}\,(\%Asd+1)^{-0.26}$$

$$Q50 = 22.3A^{1.04}\,I50^{1.29}\,(L/\sqrt{S_m})^{-0.25}\,(\%Asd+1)^{-0.3}$$

$$Q100 = 35.9A^{1.07}\,I100^{1.1}\,(L/\sqrt{S_m})^{-0.24}\,(\%Asd+1)^{-0.34}$$

Drainage Area ≥100 Square Miles

$$Q2 = 25.6A^{0.85}\,I2^{1.95}\,(L/\sqrt{S_m})^{-0.07}\,(\%Asd+1)^{-0.46}$$

$$Q10 = 23.4A^{0.85}\,I10^{2.17}\,(L/\sqrt{S_m})^{-0.22}\,(\%Asd+1)^{-0.51}$$

$$Q25 = 44.7A^{0.87}\,I25^{1.91}\,(L/\sqrt{S_m})^{-0.23}\,(\%Asd+1)^{-0.63}$$

$$Q50 = 22.7A^{0.96}\,I50^{2.2}\,(L/\sqrt{S_m})^{-0.29}\,(\%Asd+1)^{-0.74}$$

$$Q100 = 39.4A^{0.99}\,I100^{1.91}\,(L/\sqrt{S_m})^{-0.38}\,(\%Asd+1)^{-0.75}$$

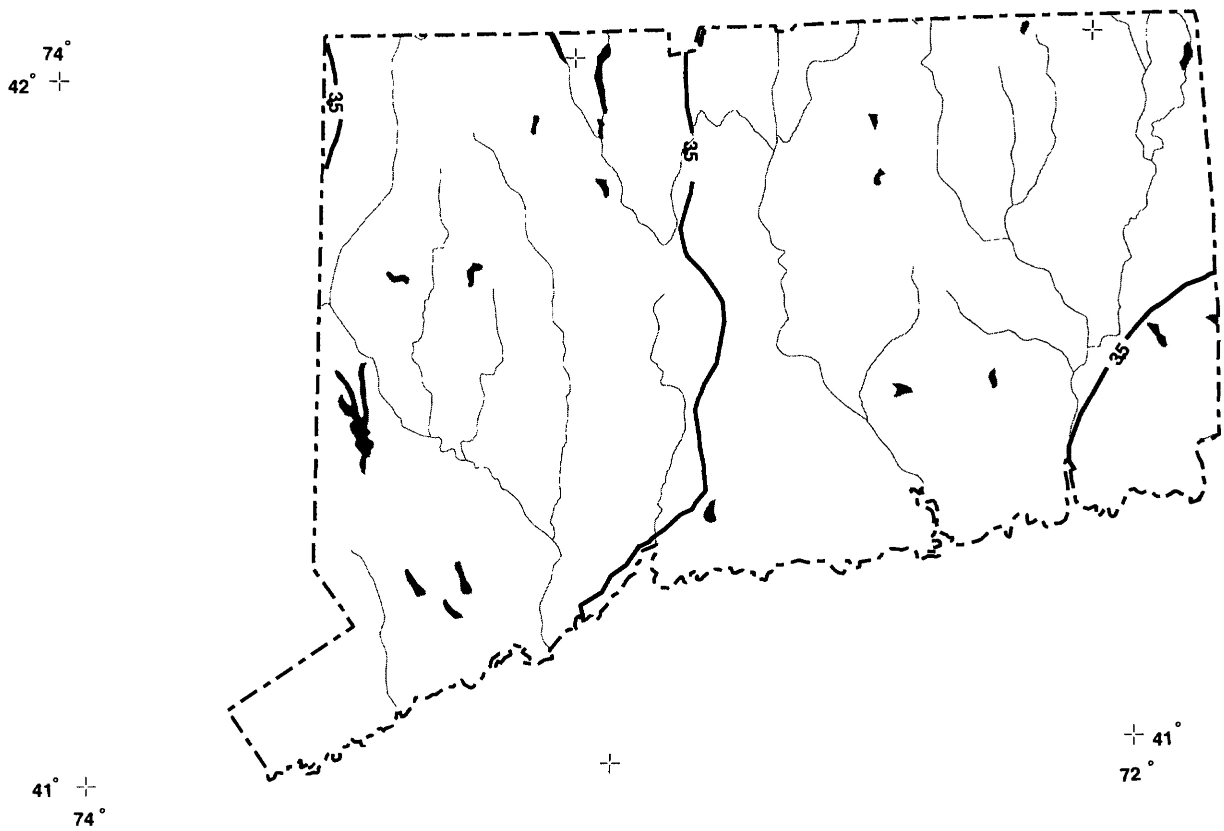
Reference

Weiss, L.A., 1983, Evaluation and design of a streamflow-data network for Connecticut: Connecticut Water-Resources Bulletin No. 36, 20 p.

Additional References

Weiss, L.A., 1975, Flood flow formula for urbanized and nonurbanized areas of Connecticut: Watershed Management Symposium, Logan, Utah, Irrigation and Drainage Division, American Society of Civil Engineers, p 658-675.

Henney, L.H., compiler, 1981, Natural resources information directory for the State of Connecticut: Connecticut Department of Environmental Protection, 39 p.



0 10 20 MILES

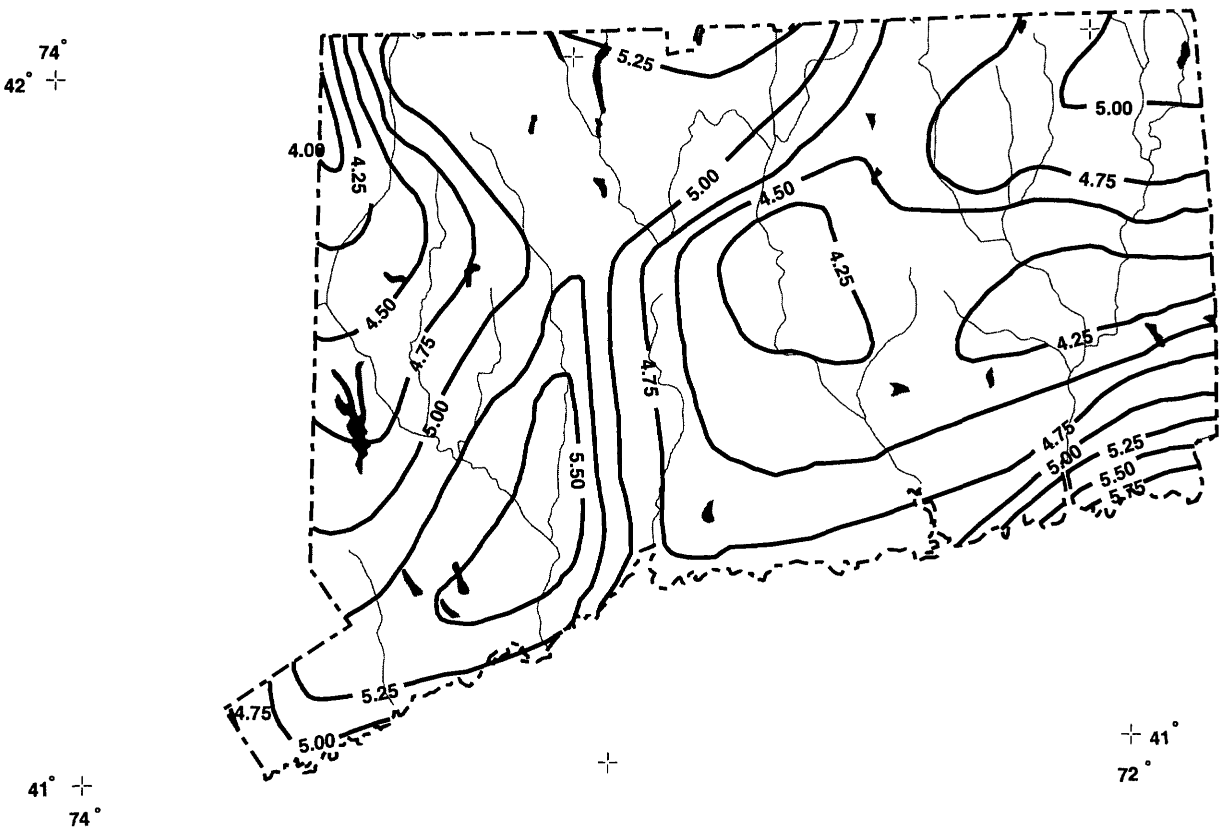
0 10 20 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— 35 — Line of equal 2-year, 24-hour precipitation, (interval, in inches, is constant)

Figure 1. The 2-year 24-hour precipitation for Connecticut.



0 10 20 MILES

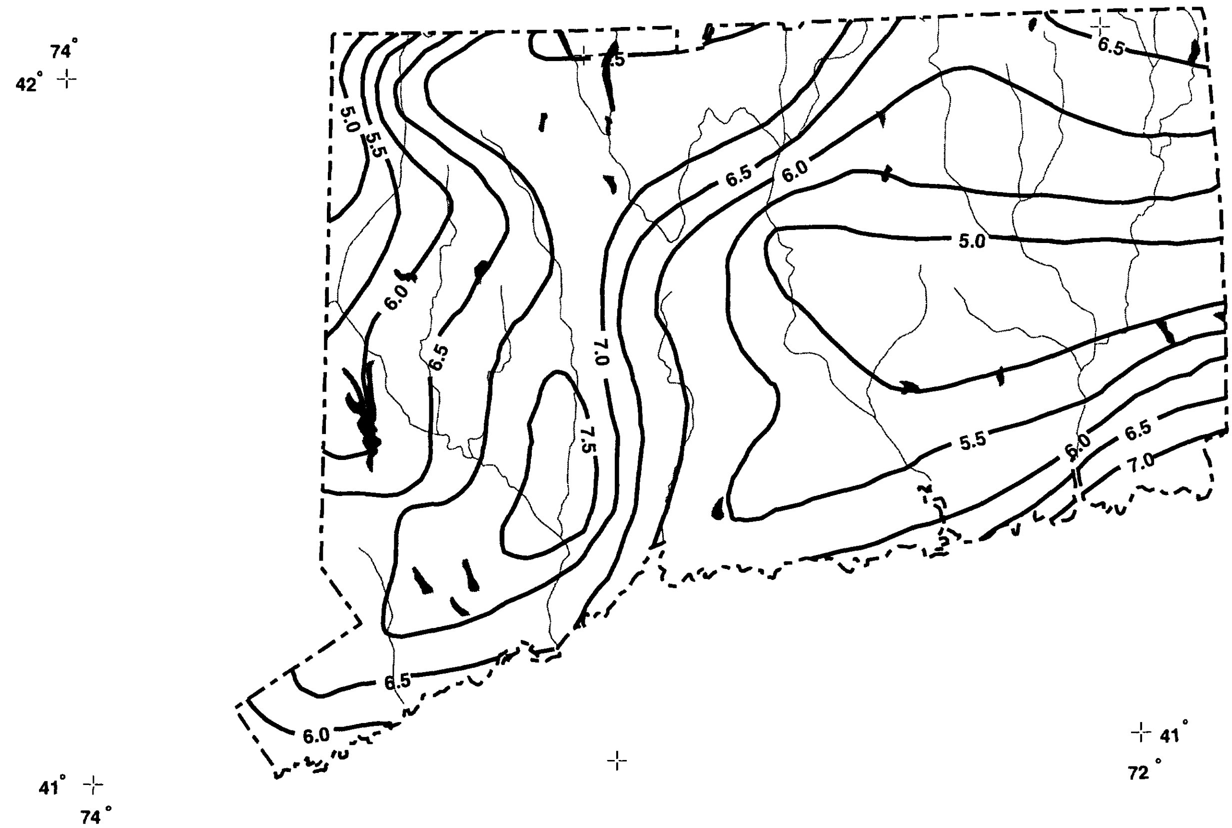
0 10 20 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

5.00 Line of equal 10-year, 24-hour precipitation, (interval is 0.25 inches)

Figure 2. The 10-year 24-hour precipitation for Connecticut.



EXPLANATION

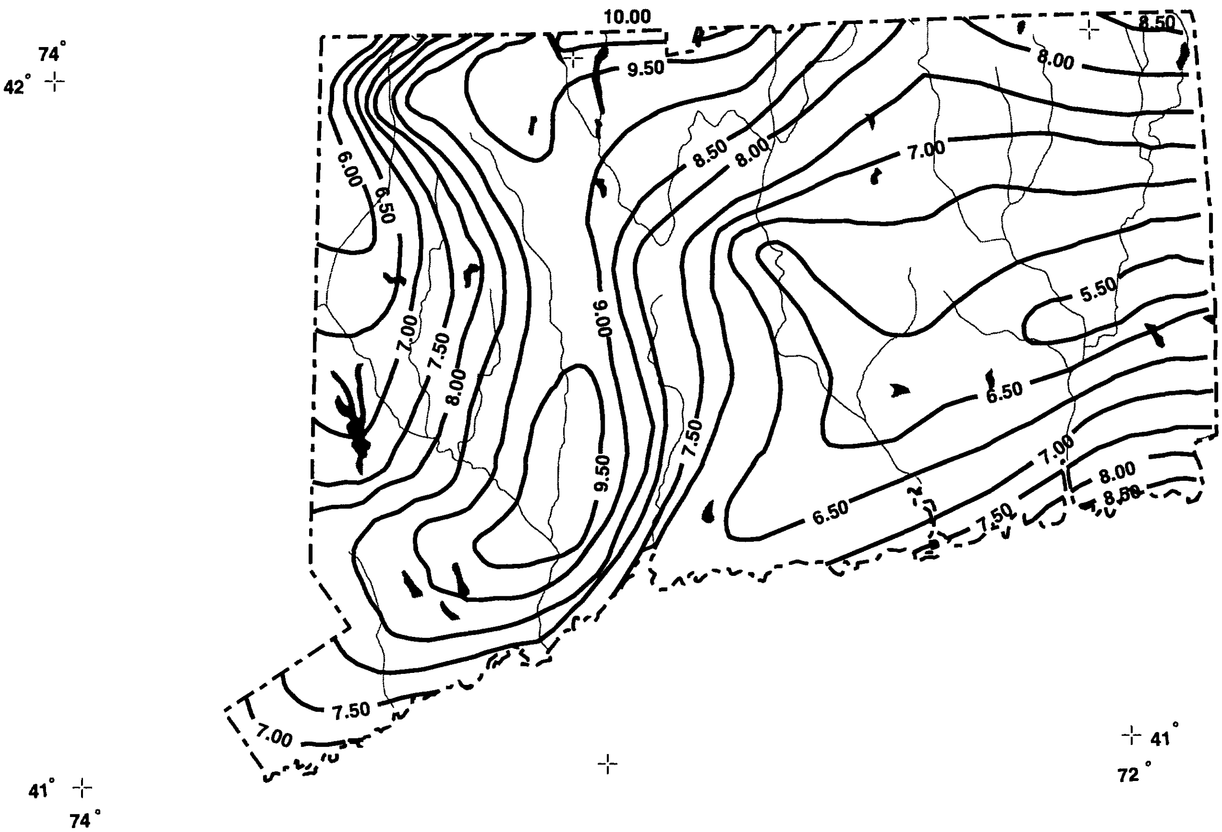
— 5.0 — Line of equal 25-year, 24-hour precipitation, (interval is 0.5 inches)

0 10 20 MILES

0 10 20 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 3. The 25-year 24-hour precipitation for Connecticut.



0 10 20 MILES

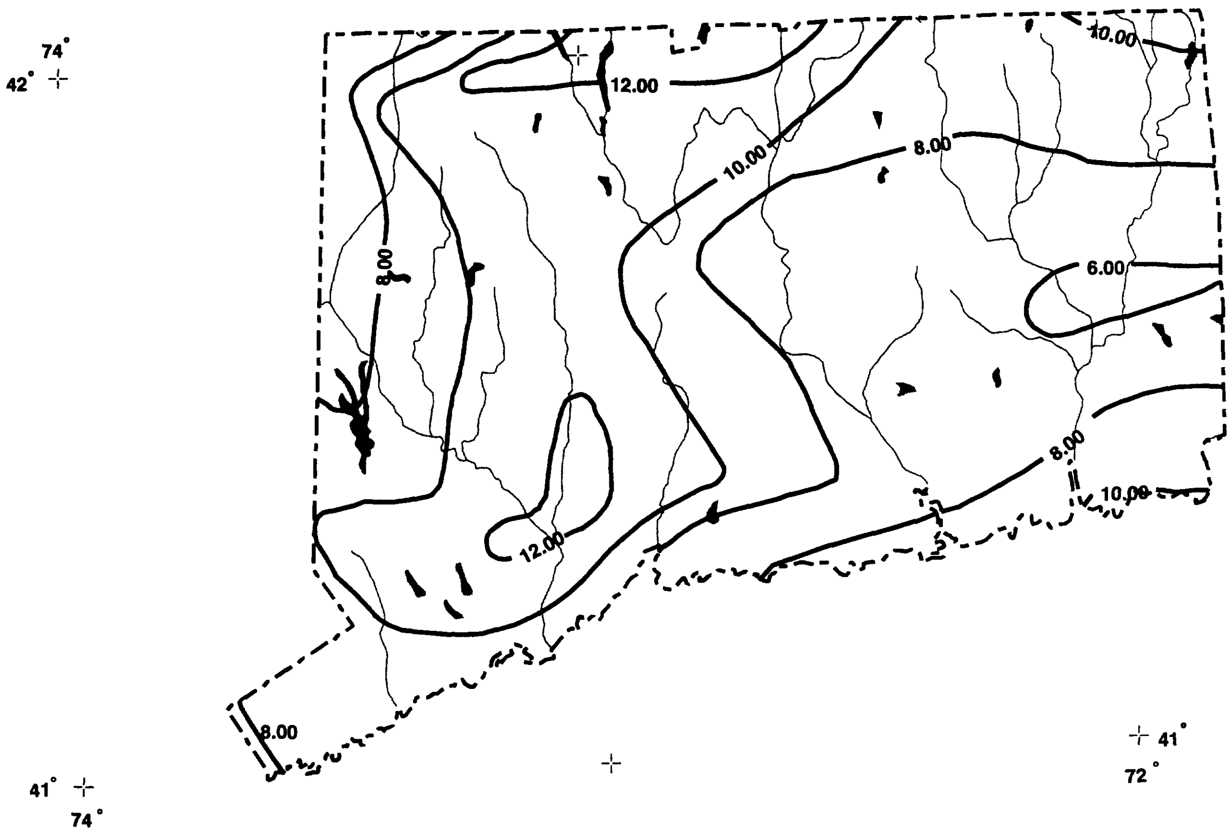
0 10 20 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

—— 6.00 —— Line of equal 50-year, 24-hour precipitation, (interval is 0.5 inches)

Figure 4. The 50-year 24-hour precipitation for Connecticut.



EXPLANATION

0 10 20 MILES

0 10 20 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

—— 8.00 —— Line of equal 100-year, 24-hour precipitation, (interval is 2.0 inches)

Figure 5. The 100-year 24-hour precipitation for Connecticut.

DELAWARE

Summary

Delaware is divided into northern and southern hydrologic regions (fig. 1). The regression equations developed for these hydrologic regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; storage (St), the percentage of basin covered by lakes, ponds, and swamps; channel slope (Sl), in feet per mile; percentage of basin covered by forest (F); and percentage of basin which has the Soil Conservation Service type A and type D soils (Sa and Sd). A constant of 10 is added to St, F, Sa, and Sd in the computer application of the regression equations. The user should enter the actual values for St, F, Sa, and Sd. The variables A, ST, SL, and F can be measured from topographic maps, and the percentage of type A and D soils can be computed from maps in the reference report by Simmons and Carpenter (1978). The regression equations were developed from peak-discharge records, available as of 1976, for 60 streams in Delaware, Maryland, and Pennsylvania. The regression equations apply to drainage basins without urban development. Standard errors of estimate of the regression equations range from 30 to 39 percent for the northern region and from 37 to 40 percent for the southern region. Standard errors of estimate of the alternative equations for the southern region (without Sl, Sa and Sd) range from 57 to 70 percent.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Soil indices needed for use in the complete southern region equations must be obtained from soils maps in Simmons and Carpenter (1978).

NORTHERN REGION

$$Q2 = 13{,}600\, A^{0.742}\, St^{-1.948}$$
$$Q5 = 23{,}700\, A^{0.703}\, St^{-1.914}$$
$$Q10 = 33{,}200\, A^{0.675}\, St^{-1.893}$$
$$Q25 = 52{,}000\, A^{0.640}\, St^{-1.887}$$
$$Q50 = 68{,}200\, A^{0.616}\, St^{-1.868}$$
$$Q100 = 89{,}300\, A^{0.591}\, St^{-1.853}$$

SOUTHERN REGION

$$Q2 = 28.6\, A^{0.910}\, Sl^{0.681}\, St^{-0.148}\, F^{-0.647}\, Sa^{-0.309}\, Sd^{0.560}$$
$$Q5 = 119\, A^{0.989}\, Sl^{0.843}\, St^{-0.533}\, F^{-0.731}\, Sa^{-0.369}\, Sd^{0.577}$$
$$Q10 = 306\, A^{1.016}\, Sl^{0.911}\, St^{-0.820}\, F^{-0.804}\, Sa^{-0.367}\, Sd^{0.624}$$
$$Q25 = 936\, A^{1.039}\, Sl^{0.974}\, St^{-1.114}\, F^{-0.868}\, Sa^{-0.384}\, Sd^{0.655}$$
$$Q50 = 2{,}120\, A^{1.051}\, Sl^{1.009}\, St^{-1.321}\, F^{-0.916}\, Sa^{-0.396}\, Sd^{0.676}$$
$$Q100 = 4{,}800\, A^{1.060}\, Sl^{1.035}\, St^{-1.519}\, F^{-0.963}\, Sa^{-0.410}\, Sd^{0.695}$$

SOUTHERN REGION (ALTERNATE)

$$Q2 = 1{,}450\, A^{0.757}\, St^{-0.229}\, F^{-0.849}$$
$$Q5 = 14{,}300\, A^{0.784}\, St^{-0.642}\, F^{-1.056}$$
$$Q10 = 53{,}100\, A^{0.791}\, St^{-0.926}\, F^{-1.132}$$
$$Q25 = 2.29\times10^{5}\, A^{0.795}\, St^{-1.226}\, F^{-1.222}$$
$$Q50 = 6.34\times10^{5}\, A^{0.799}\, St^{-1.437}\, F^{-1.284}$$
$$Q100 = 1.66\times10^{6}\, A^{0.801}\, St^{-1.639}\, F^{-1.341}$$

Reference

Simmons, R.H., and Carpenter, D.H., 1978, Technique for estimating magnitude and frequency of floods in Delaware: U.S. Geological Survey Water-Resources Investigations Report 78-93, 69 p.

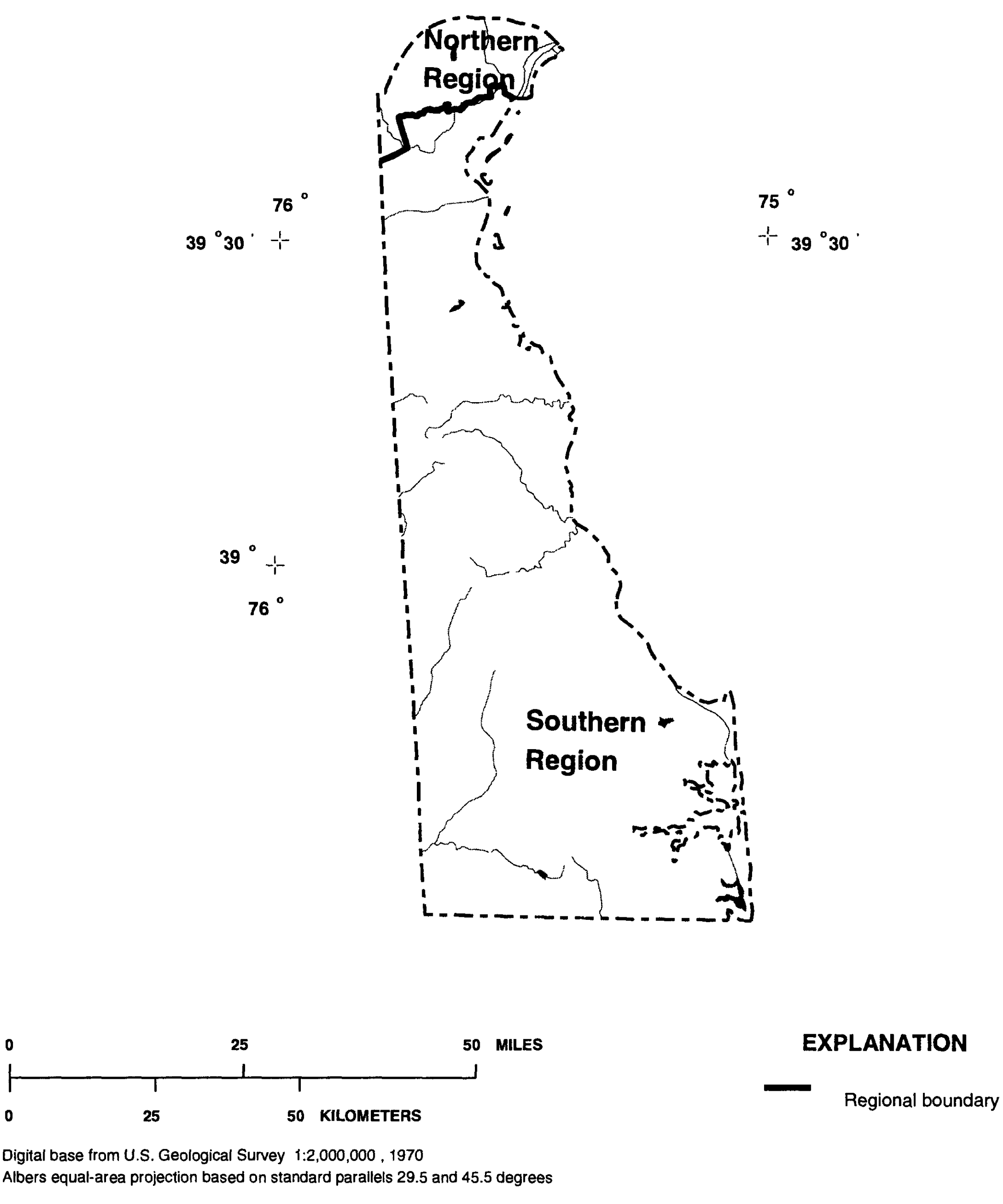


Figure 1. Flood-frequency region map for Delaware.

FLORIDA

STATEWIDE RURAL

Summary

Florida is divided into four hydrologic regions (fig. 1) in one of which floods are undefined. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (SL), in feet per mile; and the area of lakes and ponds (LK) as percentage of drainage area. The constants of 3 and 0.6 are added to LK in the computer application of the rgression equations. The user should enter the actual value of LK. These variables can be measured from topographic maps. The regression equations were developed from peak-discharge records for 182 gaging stations. The regression equations are applicable to natural-flow streams and they do not apply to the undefined area shown on figure 1. The standard errors of estimate of the regression equations range from 40 to 60 percent for Region A, 60 to 65 percent for Region B, and 44 to 76 percent for Region C. The report by Bridges (1982) includes a graph showing relations of flood characteristics to drainage area along a reach of the Apalachicola River.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region A

$$Q2 = 93.4DA^{0.756}\,SL^{0.268}\,(LK+3)^{-0.803}$$
$$Q5 = 192DA^{0.722}\,SL^{0.255}\,(LK+3)^{-0.759}$$
$$Q10 = 274DA^{0.708}\,SL^{0.248}\,(LK+3)^{-0.738}$$
$$Q25 = 395DA^{0.696}\,SL^{0.240}\,(LK+3)^{-0.717}$$
$$Q50 = 496DA^{0.690}\,SL^{0.234}\,(LK+3)^{-0.705}$$
$$Q100 = 609DA^{0.685}\,SL^{0.227}\,(LK+3)^{-0.695}$$
$$Q500 = 985DA^{0.668}\,SL^{0.196}\,(LK+3)^{-0.687}$$

Region B

$$Q2 = 44.2DA^{0.658}\,(LK+0.6)^{-0.561}$$
$$Q5 = 113DA^{0.614}\,(LK+0.6)^{-0.573}$$
$$Q10 = 182DA^{0.592}\,(LK+0.6)^{-0.580}$$
$$Q25 = 298DA^{0.570}\,(LK+0.6)^{-0.585}$$
$$Q50 = 410DA^{0.556}\,(LK+0.6)^{-0.589}$$
$$Q100 = 584DA^{0.543}\,(LK+0.6)^{-0.591}$$
$$Q500 = 936DA^{0.521}\,(LK+0.6)^{-0.594}$$

Region C

$$Q2 = 58.9DA^{0.824}\,SL^{0.387}\,(LK+3)^{-0.785}$$
$$Q5 = 117DA^{0.844}\,SL^{0.482}\,(LK+3)^{-1.06}$$
$$Q10 = 164DA^{0.860}\,SL^{0.534}\,(LK+3)^{-1.21}$$
$$Q25 = 234DA^{0.882}\,SL^{0.586}\,(LK+3)^{-1.37}$$
$$Q50 = 291DA^{0.900}\,SL^{0.626}\,(LK+3)^{-1.48}$$
$$Q100 = 351DA^{0.918}\,SL^{0.658}\,(LK+3)^{-1.58}$$
$$Q500 = 507DA^{0.960}\,DA^{0.725}\,(LK+3)^{-1.79}$$

Reference

Bridges, W.C., 1982, Technique for estimating magnitude and frequency of floods on natural-flow streams in Florida: U.S. Geological Survey Water-Resources Investigations Report 82-4012, 45 p.

TAMPA URBAN

Summary

A separate flood-frequency analysis was performed using data for urban streams in the western part of Hillsborough County and all of Pinellas County near Tampa. The regression equations developed for this area are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years.

The explanatory basin variables used in the equations are drainage area (A), in square miles; basin development factor (BDF) (defined earlier in this report in the section entitled Urban Flood Frequency Techniques); main-channel slope (S), in feet per mile; and detention storage area (DTENA), which is the percentage of the drainage area covered by natural lakes or ponds, detention basins, and retention basins. A constant of 0.01 is added to DTENA in computer application of the regression equations. The user should enter the actual

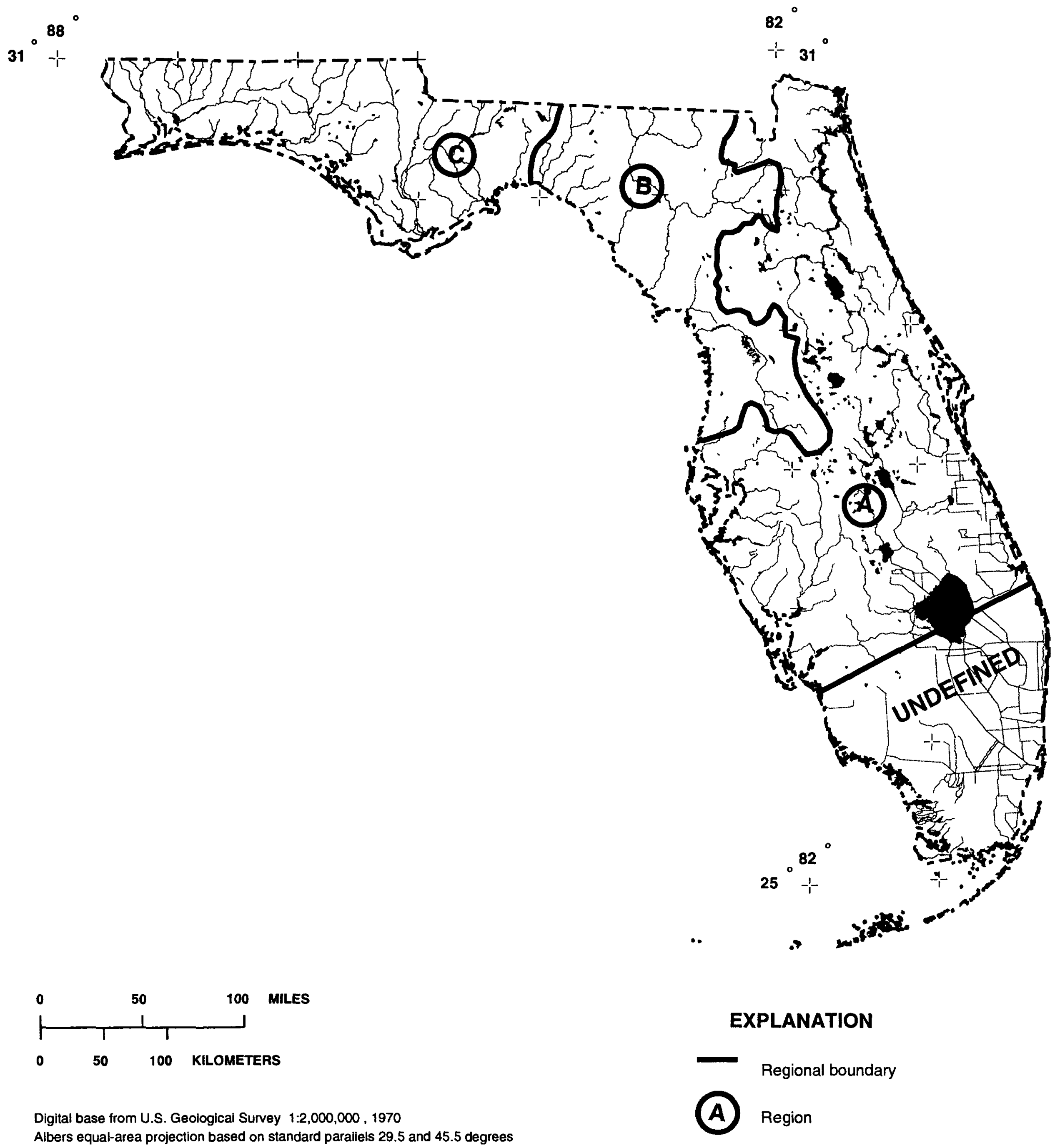


Figure 1. Flood-frequency region map for Florida.

value of DTENA. These variables can be measured from topographic maps. The regression equations were developed from peak-discharge records of 9 streams and rainfall records at 13 sites and are applicable to urban streams in the Tampa Bay area draining less than 10 square miles with DTENA less than 5 percent. The standard errors of estimate of the regression equations range from 32 to 42 percent.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

TAMPA BAY AREA URBAN

$$Q2 = 3.72DA^{1.07}\,BDF^{1.05}\,S^{0.77}\,DTENA^{-0.11}$$
$$Q5 = 7.94DA^{1.03}\,BDF^{0.87}\,S^{0.81}\,DTENA^{-0.10}$$
$$Q10 = 12.9DA^{1.04}\,BDF^{0.75}\,S^{0.83}\,DTENA^{-0.10}$$
$$Q25 = 214DA^{1.13}\,(13\text{-}BDF)^{-0.59}\,S^{0.73}$$
$$Q50 = 245DA^{1.14}\,(13\text{-}BDF)^{-0.55}\,S^{0.74}$$
$$Q100 = 282DA^{1.16}\,(13\text{-}BDF)^{-0.51}\,S^{0.76}$$

Reference

Lopez, M.A., and Woodham, W.M., Magnitude and frequency of flooding on small urban watersheds in the Tampa Bay area, west-central Florida: U.S. Geological Survey Investigations Report 82-42, 52 p.

LEON COUNTY URBAN

Summary

A separate flood-frequency analysis was performed using data for urban streams in Leon County, Florida. Two sets of regression equations were developed for estimating peak discharges (QT)--one set for streams in Lake Lafayette basin, and the other for streams in Leon County, outside Lake Lafayette basin. The range of recurrence intervals T for the regression equations range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (DA), in square miles; and impervious area (IA) as a percentage of the drainage area. These variables can be measured from topographic maps and, in the case of IA, from aerial photographs. The regression equations were developed from peak-discharge records based on rainfall-runoff modeling at 15 gaged streams in the county and are applicable to developing basins in Leon County. The drainage areas ranged from 0.2 to 16 square miles and impervious area ranged from 5.8 to 54 percent. The standard errors of estimate of the regression equations range from 18 to 30 percent.

Procedure

Topographic maps and (or) aerial photographs and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

LEON COUNTY, EXCLUDING LAKE LAFAYETTE BASIN

$$Q2 = 10.7DA^{0.766}\,IA^{1.07}$$
$$Q5 = 24.5DA^{0.770}\,IA^{0.943}$$
$$Q10 = 39.1DA^{0.776}\,IA^{0.867}$$
$$Q25 = 63.2DA^{0.787}\,IA^{0.791}$$
$$Q50 = 88.0DA^{0.797}\,IA^{0.736}$$
$$Q100 = 118DA^{0.808}\,IA^{0.687}$$
$$Q500 = 218DA^{0.834}\,IA^{0.589}$$

LAKE LAFAYETTE BASIN

$$Q2 = 1.71DA^{0.766}\,IA^{1.07}$$
$$Q5 = 4.51DA^{0.770}\,IA^{0.943}$$
$$Q10 = 7.98DA^{0.776}\,IA^{0.867}$$
$$Q25 = 14.6DA^{0.787}\,IA^{0.791}$$
$$Q50 = 22.1DA^{0.797}\,IA^{0.736}$$
$$Q100 = 32.4DA^{0.808}\,IA^{0.687}$$
$$Q500 = 71.7DA^{0.834}\,IA^{0.589}$$

Reference

Franklin, M.A., and Losey, G.T., 1984, Magnitude and frequency of floods from urban streams in Leon County, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4004, 37 p.

GEORGIA

STATEWIDE RURAL

Summary

Georgia is divided into five hydrologic regions (fig. 1) with one undefined flood-frequency region in southeast Georgia. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. Drainage area (A), in square miles, is the only explanatory basin variable used in the equations and can be measured from topographic maps. The regression equations were developed from peak-discharge records for 426 streams in Georgia, and adjacent parts of Alabama, Florida, North Carolina, South Carolina and Tennessee having 10 or more years of record as of 1990. The regression equations are applicable to ungaged sites having drainage areas between 0.1 and 3,000 square miles. However, the equations should not be used for streams in Okefenokee Swamp, streams affected by significant regulation, tidal fluctuations, urban development, or an area in southeast Georgia (see fig. 1) where large limestone sinkholes have a significant storage potential. The standard errors of prediction of the regression equations range from 26 to 38 percent. The report by Stamey and Hess (1993) also provides relations of peak discharge to drainage area for reaches of the mainstems of the Ocmulgee, Oconee, Altamaha, and Flint Rivers.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1

$Q2 = 207A^{0.654}$
$Q5 = 357A^{0.632}$
$Q10 = 482A^{0.619}$
$Q25 = 666A^{0.605}$
$Q50 = 827A^{0.595}$
$Q100 = 1{,}010A^{0.584}$
$Q200 = 1{,}220A^{0.575}$
$Q500 = 1{,}530A^{0.563}$

Region 2

$Q2 = 182A^{0.622}$
$Q5 = 311A^{0.616}$
$Q10 = 411A^{0.613}$
$Q25 = 552A^{0.610}$
$Q50 = 669A^{0.607}$
$Q100 = 794A^{0.605}$
$Q200 = 931A^{0.603}$
$Q500 = 1{,}130A^{0.601}$

Region 3

$Q2 = 76A^{0.620}$
$Q5 = 133A^{0.620}$
$Q10 = 176A^{0.621}$
$Q25 = 237A^{0.623}$
$Q50 = 287A^{0.625}$
$Q100 = 340A^{0.627}$
$Q200 = 396A^{0.629}$
$Q500 = 474A^{0.632}$

Region 4

$Q2 = 142A^{0.591}$
$Q5 = 288A^{0.589}$
$Q10 = 410A^{0.591}$
$Q25 = 591A^{0.595}$
$Q50 = 748A^{0.599}$
$Q100 = 926A^{0.602}$
$Q200 = 1{,}120A^{0.606}$
$Q500 = 1{,}420A^{0.611}$

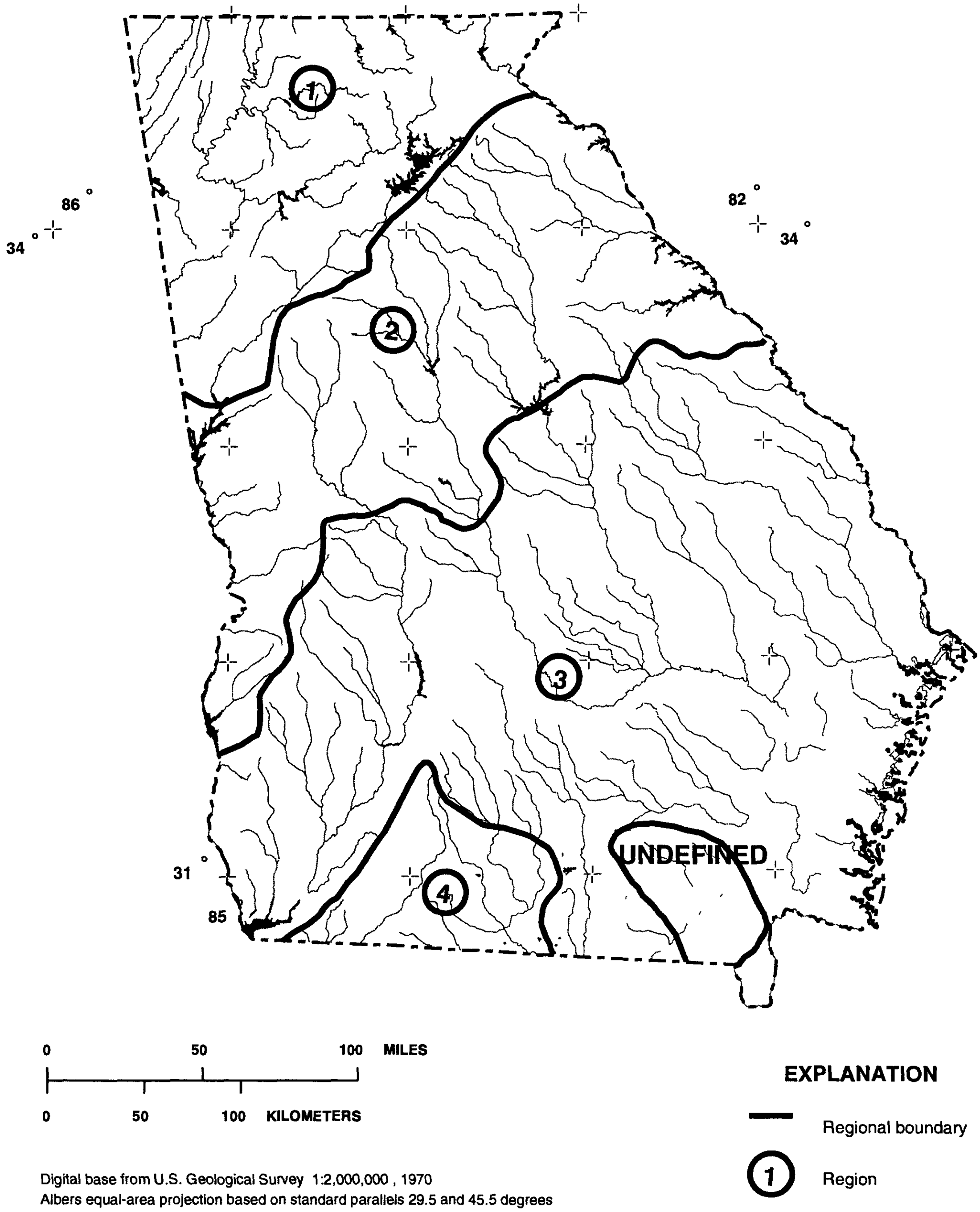


Figure 1. Flood-frequency region map for Georgia.

Reference

Stamey, T.C., and Hess, G.W., 1993, Techniques for estimating magnitude and frequency of floods in rural basins of Georgia: U.S. Geological Survey Water-Resources Investigations Report 93-4016, 75 p.

GEORGIA STATEWIDE URBAN

Summary

Georgia is considered one hydrologic region for urban flood-frequency estimation, but the equations include a variable, the equivalent rural discharge, which varies by region as defined by Price (1979) (report by Price described below). The regression equations developed for urban areas in the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; percentage of drainage area that is impervious (TIA); and rural peak discharge (RQt), in cubic feet per second, from Price (1979) for an equivalent rural drainage basin in the same hydrologic region as the urban basin. The regression equations were developed from peak-discharge records collected at 45 urban stations and are applicable to urban streams having drainage areas less than about 20 square miles, and with impervious percentages from 1 to 60. The standard errors of estimate of the regression equations are about 29 percent.

Procedure

Topographic and land-use maps, the following equations, and the equivalent rural discharges computed from Price (1979) are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 4.93A^{.29}T1A^{.28}\ RQ2^{0.64}$$
$$Q5 = 6.73A^{.29}T1A^{.25}\ RQ5^{0.63}$$
$$Q10 = 8.33A^{.30}T1A^{.23}\ RQ10^{0.62}$$
$$Q25 = 14.8A^{.35}T1A^{.21}\ RQ25^{0.55}$$
$$Q50 = 16.4A^{.35}T1A^{.20}\ RQ50^{0.55}$$
$$Q100 = 20.3A^{.37}T1A^{.19}\ RQ100^{0.53}$$

Reference

Inman, Ernest J., 1988, Flood-frequency relations for urban streams in Georgia: U.S. Geological Survey Water-Resources Investigations Report 88-4085, 36 p.

STATEWIDE RURAL EQUATIONS TO BE USED WITH URBAN EQUATIONS

Summary

Rural equations developed by Price (1979) are to be used to obtain the equivalent rural discharge for the urban equations developed by Inman (1988). For these rural equations, Georgia is divided into five hydrologic regions (fig. 2) with one undefined flood-frequency area in southeast Georgia. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. Drainage area (A), in square miles, is the only explanatory basin variable used in the equations and can be measured from topographic maps. The regression equations were developed from peak-discharge records for 308 streams with 10 or more years of record as of 1974. The regression equations are applicable to ungaged sites having drainage areas between 0.1 and 1,000 square miles. However, the equations should not be used for streams in Okefenokee Swamp, streams affected by significant man-made works, including urbanization, nor for certain areas in southeast Georgia (see fig. 2) where large limestone sinkholes have a significant storage potential. The standard errors of estimate of the regression equations range from 20 to 35 percent for regions 1, 2, 3, and 5 with those for region 3 somewhat higher for 50 and 100-year floods. The relation of peak discharge to drainage area are given for reaches of the main stems of 12 major streams. Also included is a compilation of flood records at all stations in Georgia.

Procedure

Topographic maps, the hydrologic regions map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

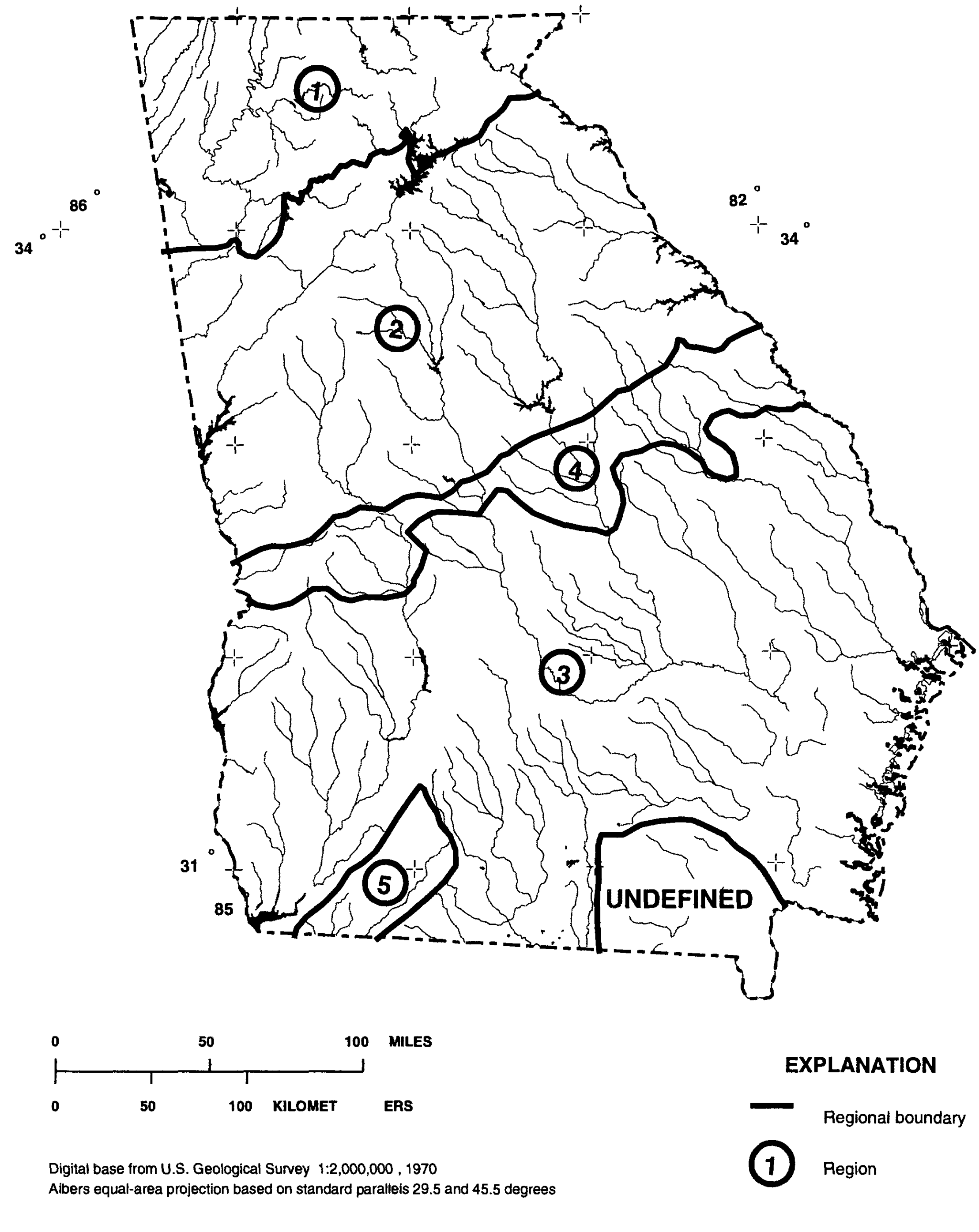


Figure 2. Flood-frequency region map for Georgia. (Price, 1979.)

Region 1

$$Q2 = 169A^{0.70}$$
$$Q5 = 269A^{0.70}$$
$$Q10 = 344A^{0.69}$$
$$Q25 = 443A^{0.69}$$
$$Q50 = 524A^{0.69}$$
$$Q100 = 610A^{0.68}$$

Region 2

$$Q2 = 195A^{0.60}$$
$$Q5 = 337A^{0.59}$$
$$Q10 = 446A^{0.59}$$
$$Q25 = 600A^{0.58}$$
$$Q50 = 727A^{0.58}$$
$$Q100 = 862A^{0.57}$$

Region 3

$$Q2 = 99A^{0.58}$$
$$Q5 = 167A^{0.59}$$
$$Q10 = 216A^{0.59}$$
$$Q25 = 280A^{0.59}$$
$$Q50 = 332A^{0.60}$$
$$Q100 = 384A^{0.61}$$

Region 4

$$Q2 = 55A^{0.60}$$
$$Q5 = 92A^{0.60}$$
$$Q10 = 120A^{0.60}$$
$$Q25 = 150A^{0.60}$$
$$Q50 = 180A^{0.60}$$
$$Q100 = 215A^{0.60}$$

Region 5

$$Q2 = 120A^{0.65}$$
$$Q5 = 250A^{0.65}$$
$$Q10 = 337A^{0.65}$$
$$Q25 = 491A^{0.65}$$
$$Q50 = 629A^{0.65}$$
$$Q100 = 785A^{0.65}$$

Reference

Price, McGlone, 1979, Floods in Georgia, magnitude and frequency: U.S. Geological Survey Water-Resources Investigations Report 78-137, 269 p.

HAWAII, ISLAND OF OAHU RURAL

Summary

The Island of Oahu, Hawaii is divided into three hydrologic regions or groups (fig. 1). The regression equations developed for these groups are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; the 2-year 24-hour precipitation (P2-24), in inches (fig. 2); and the ratio of drainage area covered by forests and/or other vegetation (FC), as shown in green on 1:24,000 topographic maps, to the total drainage area. The variables A and FC are measured from topographic maps and P2-24 is determined from figure 2. The regression equations were developed from peak-discharge records as follows: Group A, 22 stations; Groups B and C, 26 stations each with record lengths ranging from 10 to 50 years. The regression equations are applicable only to unregulated streams on the Island of Oahu. Standard errors of estimate of the regression equations are about 60 percent for group A, 45 percent for group B, and 36 percent for group C.

Procedure

Topographic maps, the map showing hydrologic regions/groups (fig. 1), and the 2-year 24-hour precipitation from figure 2 and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Group A

$$Q2 = 620\ A^{0.76}$$
$$Q5 = 1{,}310\ A^{0.74}$$
$$Q10 = 1{,}940\ A^{0.73}$$
$$Q25 = 2{,}920\ A^{0.72}$$
$$Q50 = 3{,}800\ A^{0.72}$$
$$Q100 = 4{,}820\ A^{0.71}$$

Group B

$$Q2 = 1.08\ A^{0.62}\ P2\text{-}24^{3.02}$$
$$Q5 = 7.73\ A^{0.66}\ P2\text{-}24^{2.37}$$
$$Q10 = 21.5\ A^{0.68}\ P2\text{-}24^{2.02}$$
$$Q25 = 63.2\ A^{0.71}\ P2\text{-}24^{1.66}$$
$$Q50 = 127\ A^{0.72}\ P2\text{-}24^{1.43}$$
$$Q50 = 238\ A^{0.74}\ P2\text{-}24^{1.22}$$

Group C

$$Q2 = 0.98\ A^{0.86}\ FC^{1.37}$$
$$Q5 = 3.11\ A^{0.83}\ FC^{1.26}$$
$$Q10 = 5.75\ A^{0.82}\ FC^{1.20}$$
$$Q25 = 11.1\ A^{0.81}\ FC^{1.13}$$
$$Q50 = 17.1\ A^{0.80}\ FC^{1.09}$$
$$Q100 = 25.4\ A^{0.79}\ FC^{1.05}$$

Reference

Nakahara, R.H., 1979, An analysis of the magnitude and frequency of floods on Oahu, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 80-45, 30 p.

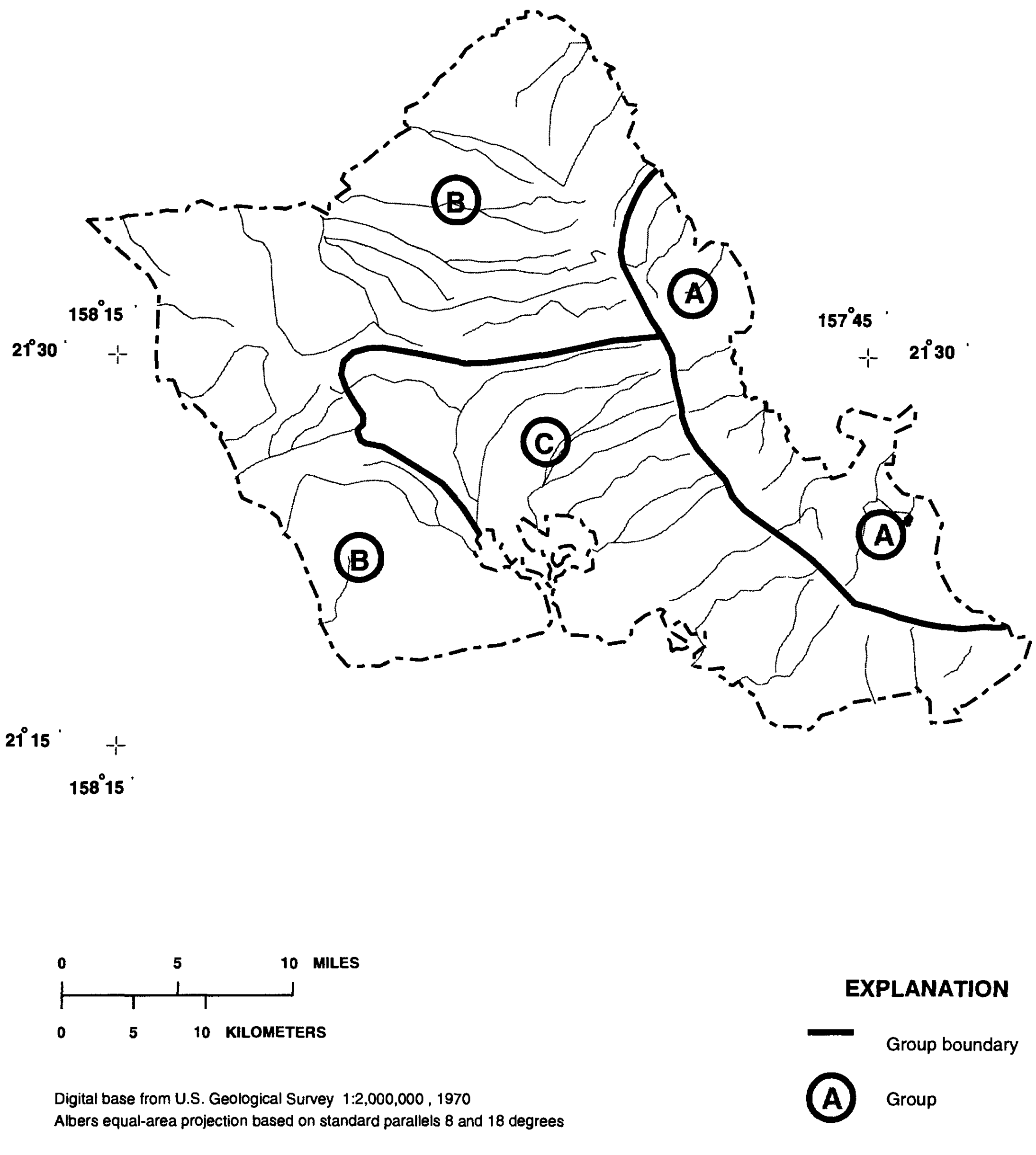


Figure 1. Flood-frequency region map for Island of Oahu.

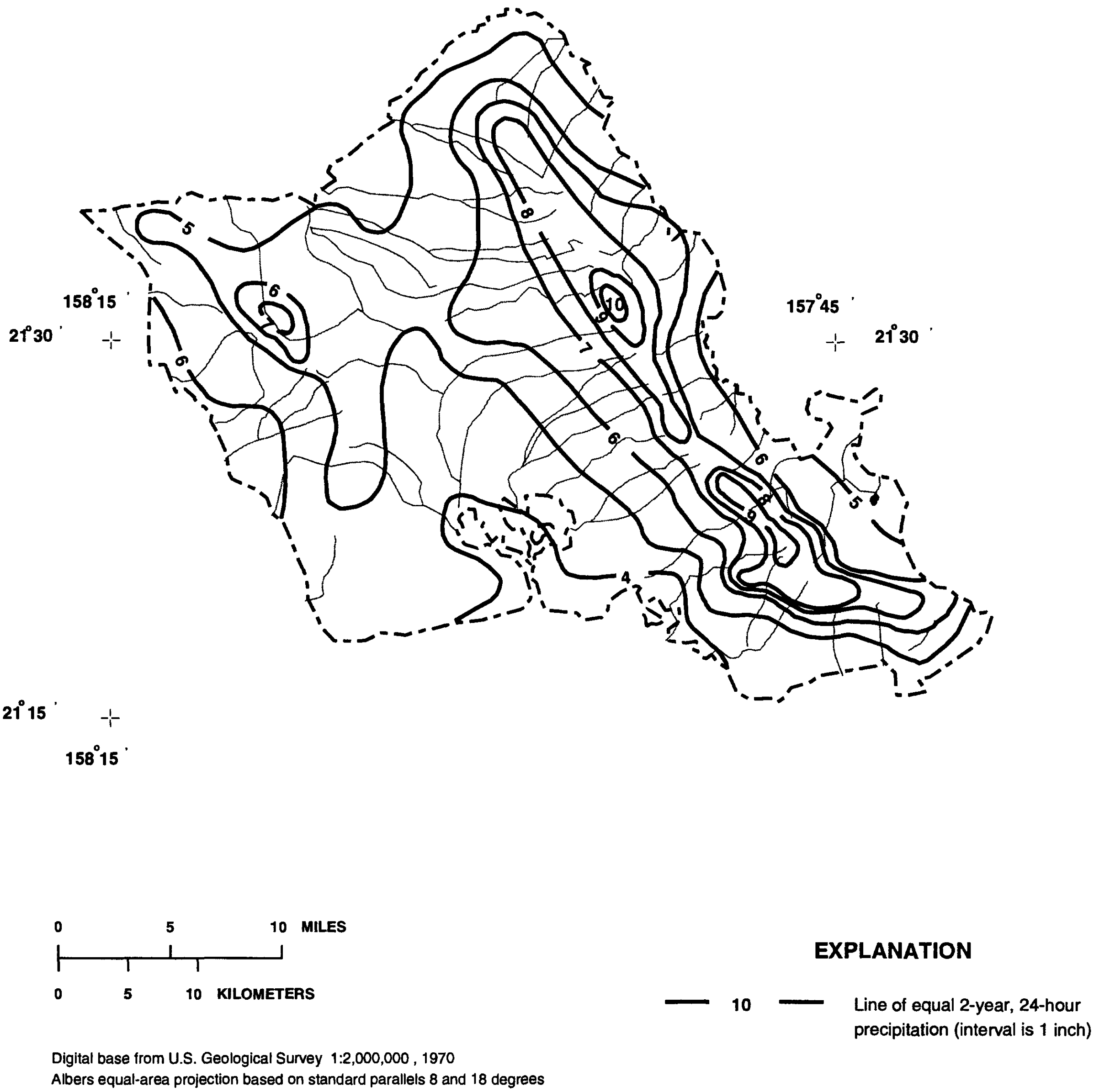


Figure 2. The 2-year 24-hour precipitation in Island of Oahu.

IDAHO

STATEWIDE RURAL

Summary

Idaho is divided into eight hydrologic regions (fig. 1). Regression equations developed for these regions are for estimating peak discharges (QT) for watersheds less than 20,000 square miles, most of which are in southern Idaho. Regression equations were developed only for the 10-year flood. The 25-year flood and the 50-year flood can be obtained by ratios to the 10-year flood. These ratios were defined for each of the eight regions. The explanatory basin variables used in the equations are drainage area (A), in square miles; forest cover (F) expressed as a percentage, plus one percent, of the drainage area covered by forests as shown on USGS 1:250,000 scale maps; latitude (N) of the centroid of the basin in decimal degrees minus 40 degrees; area of lakes and ponds (La) expressed as a percentage, plus one percent, of the drainage area covered by lakes, ponds, or swamps; and longitude (W) of the centroid of the basin in decimal degrees minus 110 degrees. The constants of 1, -40 and -110 are added to F, La, N and W in the computer application of the regression equations. The user should enter the actual values for F, La, N and W. All of these variables can be measured from topographic maps. The regression equations were developed from peak-discharge records for 303 sites and are applicable to those streams with drainage areas ranging from 0.5 to 200 square miles that are not affected by urbanization, regulation, or unusual climatic and physical basin characteristics. Areas in which regressions were not defined are shown on the region map (need to show these areas). Standard errors of estimate of the regression equations for the 10-year flood range from 41 to 62 percent. Reliability of the 25-year and 50-year estimates is not given. The report by Thomas and others (1973) also includes maximum peak discharges at selected sites, a graph of maximum peak discharges in relation to drainage area, and a description of various climatic or geologic characteristics that make the regression equations inapplicable.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations and ratios are used to estimate the 10-, 25- and 50-year peak discharges.

Region	Regression	Q25/Q10	Q50/Q10
1	$Q10=49.8\ A^{0.862}$	1.3	1.5
2	$Q10=66.5\ A^{0.801}F^{-0.236}$	1.3	1.5
3	$Q10=3.81\ A^{0.875}F^{-0.216}\ N^{2.02}$	1.3	1.5
4	$Q10=43.4\ A^{0.857}\ F^{-0.210}$	1.4	1.8
5	$Q10=13.0\ A^{0.918}$	1.3	1.5
6	$Q10=188\ A^{0.873}\ La^{0.773}\ N^{-1.82}$	1.2	1.3
7	$Q10=20.6\ A^{0.806}\ W^{-1.05}$	1.2	1.4
8	$Q10=193\ A^{0.758}\ F^{0.222}N^{-4.25}$	1.4	1.7

Reference

Thomas, C.A., Harenberg, W.A., and Anderson, J.M., 1973, Magnitude and frequency of floods in small drainage basins in Idaho: U.S. Geological Survey Water-Resources Investigations Report 7-73, 61 p.

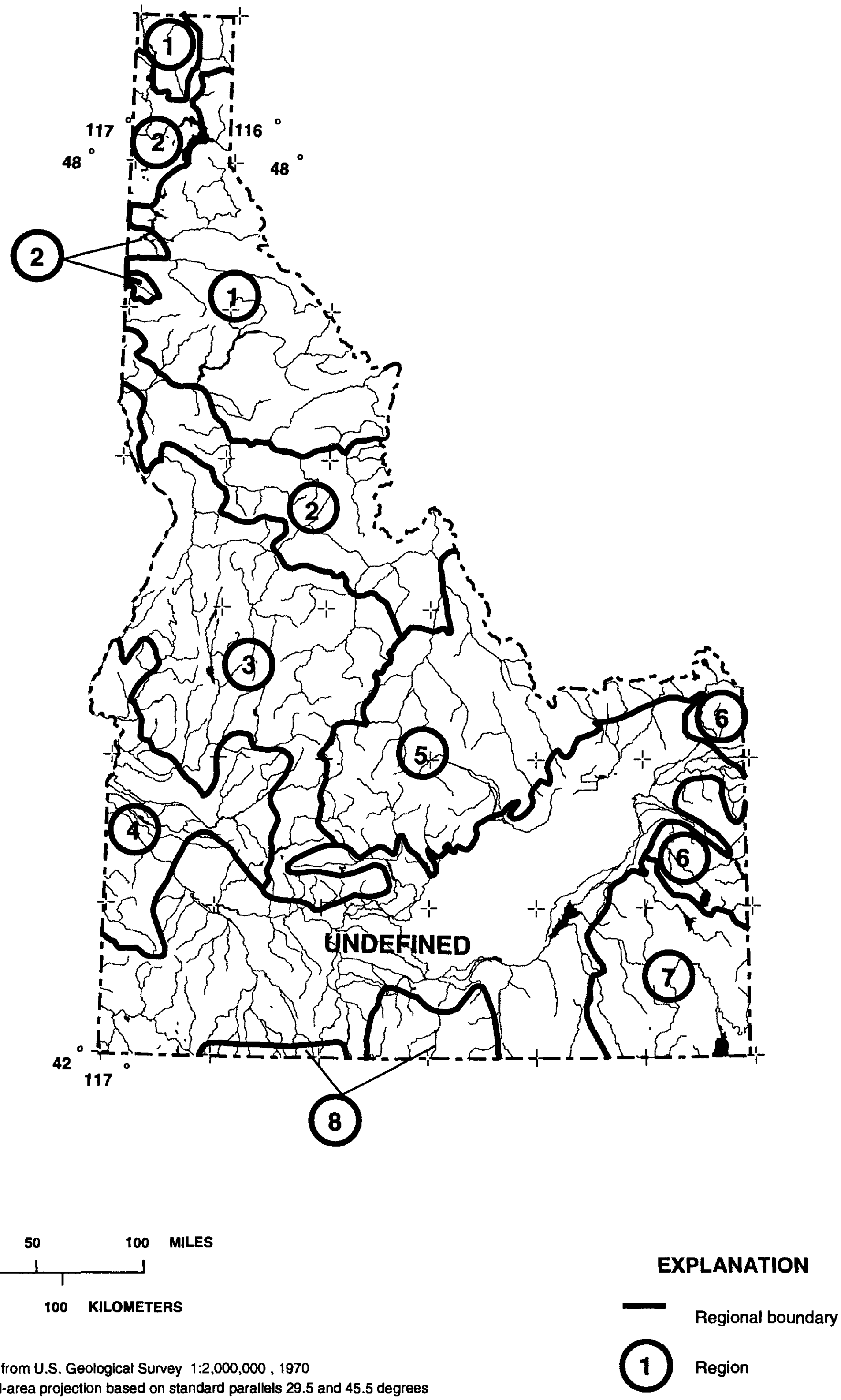


Figure 1. Flood-frequency region map for Idaho.

ILLINOIS

STATEWIDE RURAL

Summary

Illinois is divided into four hydrologic regions (fig. 1), each of which is assigned a regional factor. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage are (A), in square miles; main-channel slope (S), in feet per mile; rainfall (I), in inches, which is the 2-year 24-hour precipitation (fig. 2); and a regional factor (Rf). The constant 2.5 is subtracted from I in the computer application of the regression equations. The user should enter the actual value of I from figure 2. The variables A and S can be measured from topographic maps and I can be determined from figure 2. The regional boundaries can be determined from figure 1 and a table of regional factors (Rf) is given below. The regression equations were developed from peak-discharge records for 268 gaged sites in Illinois, Indiana, and Wisconsin. The regression equations are applicable to streams with drainage areas ranging from 0.02 to 10,000 square miles. Standard errors of prediction for the regression equations range from 35 to 50 percent. The report by Curtis (1987) also includes graphical relations of flood characteristics to drainage area for the regulated Big Muddy, Fox, and Illinois Rivers.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the table of regional factors (Rf), and the 2-year 24-hour precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 38.1\ A^{0.790}\ S^{0.481}\ (I\text{-}2.5)^{0.677}\ Rf$$
$$Q5 = 63.0\ A^{0.786}\ S^{0.513}\ (I\text{-}2.5)^{0.719}\ Rf$$
$$Q10 = 78.9\ A^{0.785}\ S^{0.532}\ (I\text{-}2.5)^{0.742}\ Rf$$
$$Q25 = 98.2\ A^{0.786}\ S^{0.552}\ (I\text{-}2.5)^{0.768}\ Rf$$
$$Q50 = 112\ A^{0.786}\ S^{0.566}\ (I\text{-}2.5)^{0.786}\ Rf$$
$$Q100 = 125\ A^{0.787}\ S^{0.578}\ (I\text{-}2.5)^{0.803}\ Rf$$
$$Q500 = 155\ A^{0.789}\ S^{0.601}\ (I\text{-}2.5)^{0.838}\ Rf$$

Regional factors (Rf)

	Region			
	I	II	III	IV
Q2	1.057	0.578	0.805	0.983
Q5	1.053	.576	.822	.894
Q10	1.053	.574	.837	.859
Q25	1.051	.570	.853	.826
Q50	1.050	.567	.862	.806
Q100	1.048	.563	.870	.790
Q500	1.044	.555	.886	.759

Reference

Curtis, G.W., 1987, Technique for estimating flood-peak discharges and frequencies on rural streams in Illinois: U.S. Geological Survey Water-Resources Investigations Report 87-4207, 79 p.

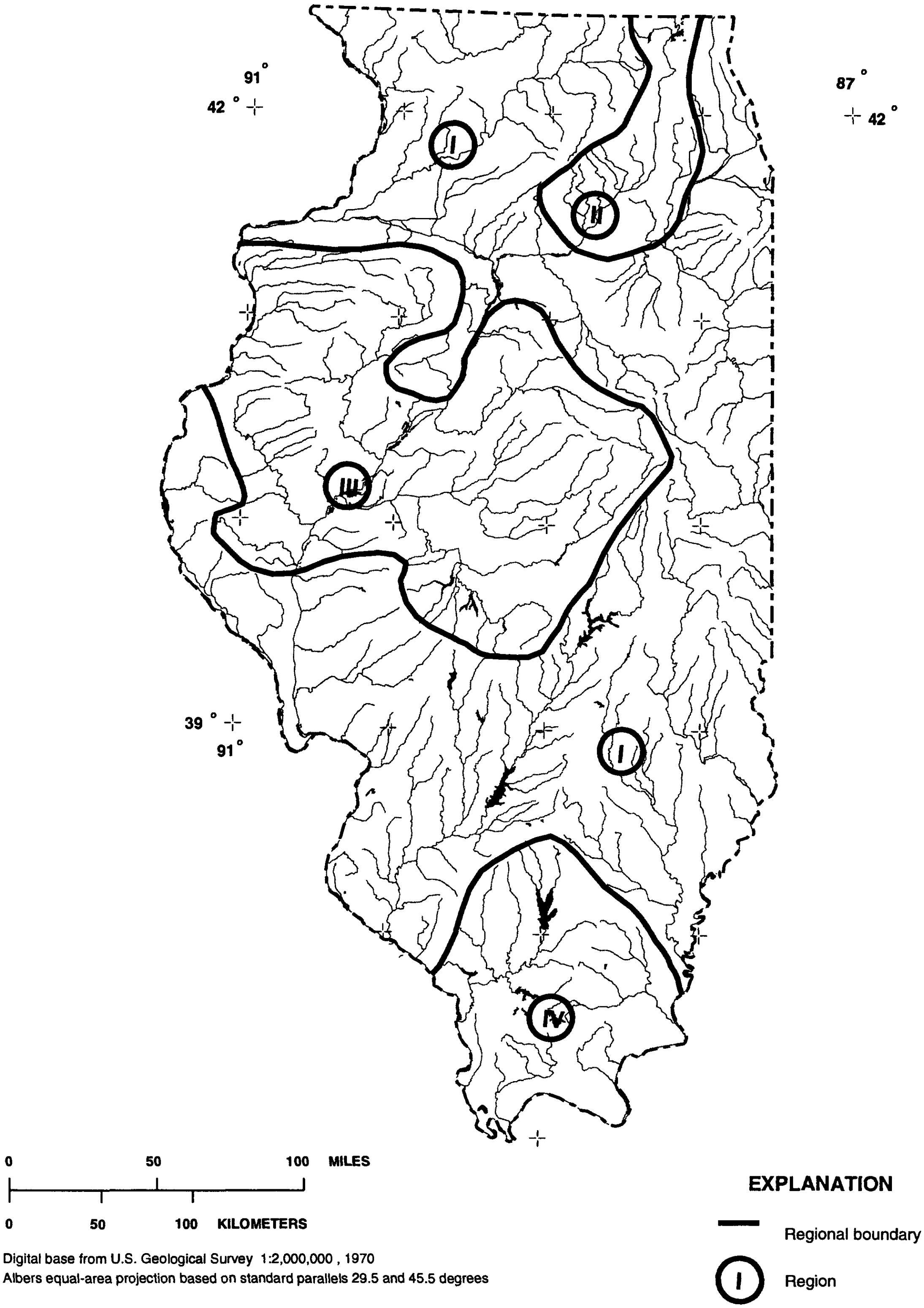
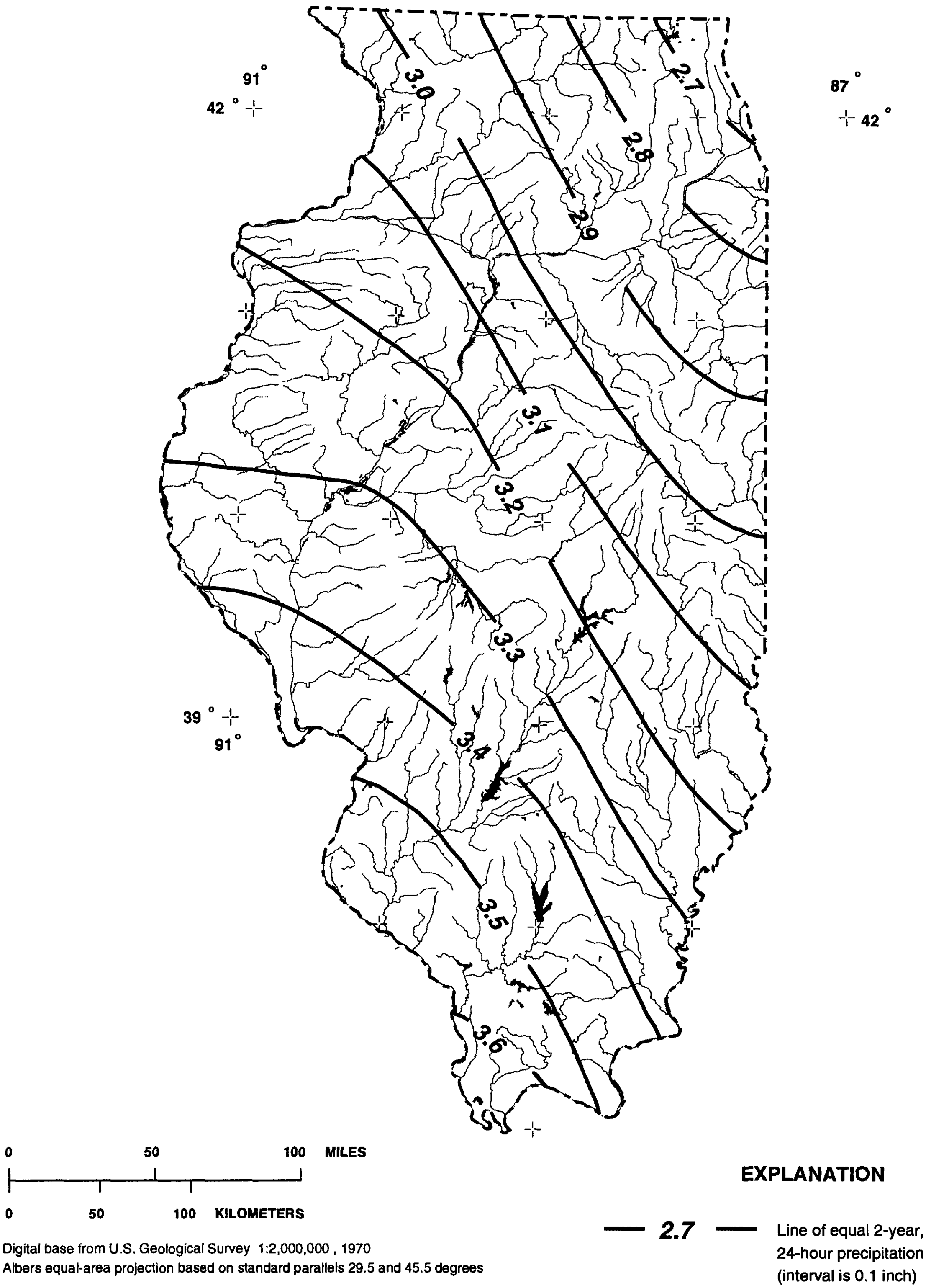


Figure 1. Flood-frequency region map for Illinois.



Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 2. The 2-year 24-hour precipitation in Illinois.

INDIANA

STATEWIDE RURAL

Summary

Indiana is divided into seven hydrologic areas (fig. 1). The regression equations developed for these areas are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are contributing drainage area (DA), in square miles; storage (STOR), which is the percentage of the contributing drainage area covered by lakes, ponds, and wetlands; mean annual precipitation (PREC), in inches; runoff coefficient (RC), that relates storm runoff to soil permeability; main-channel slope (SL), in feet per mile; precipitation (I24,2), in inches, the 2-year 24-hour precipitation; and main-channel length (L), in miles. The constants of 1, -30 and -2.5 are added to STOR, PREC and I24,2 in the computer application of the regression equations. The user should enter the actual values of STOR, PREC and I24,2. The variables DA, STOR, SL and L can be measured from topographic maps. Variable PREC can be determined from figure 2, I24,2 can be determined from figure 3 and RC from figure 4. The regression equations were developed from peak-discharge records for 242 stations in Indiana, Ohio, and Illinois. The equations should be used only for unregulated, nonurbanized streams. Standard errors of estimate of the regression equations range from 24 to 45 percent. The report by Glatfelter (1984) includes flood-frequency data based on observed peaks for 270 gaged locations.

Procedure

Topographic maps, the hydrologic area map (fig. 1), the mean annual precipitation map (fig. 2), the 2-year 24-hour precipitation map (fig. 3), the map showing major soil groups and runoff coefficients (fig. 4), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Area 1

$$Q2 = 6.72\ DA^{0.714}(STOR + 1)^{-0.289}(PREC-30)^{0.965}$$
$$Q10 = 10.3\ DA^{0.701}(STOR + 1)^{-0.262}(PREC - 30)^{1.060}$$
$$Q25 = 11.8\ DA^{0.697}(STOR + 1)^{-0.253}(PREC - 30)^{1.093}$$
$$Q50 = 12.9\ DA^{0.696}(STOR + 1)^{-0.248}(PREC - 30)^{1.114}$$
$$Q100 = 13.8\ DA^{0.695}(STOR + 1)^{-0.243}(PREC - 30)^{1.132}$$

Area 2

$$Q2 = 26.4\ DA^{0.708}(STOR + 1)^{-0.207}RC^{0.479}(PREC - 30)^{0.653}$$
$$Q10 = 61.8\ DA^{0.655}(STOR + 1)^{-0.312}RC^{0.697}(PREC - 30)^{0.696}$$
$$Q25 = 85.0\ DA^{0.635}(STOR + 1)^{-0.357}RC^{0.782}(PREC - 30)^{0.702}$$
$$Q50 = 106\ DA^{0.619}(STOR + 1)^{-0.391}RC^{0.859}(PREC -30)^{0.707}$$
$$Q100 = 127\ DA^{0.608}(STOR + 1)^{-0.418}RC^{0.902}(PREC - 30)^{0.708}$$

Area 3

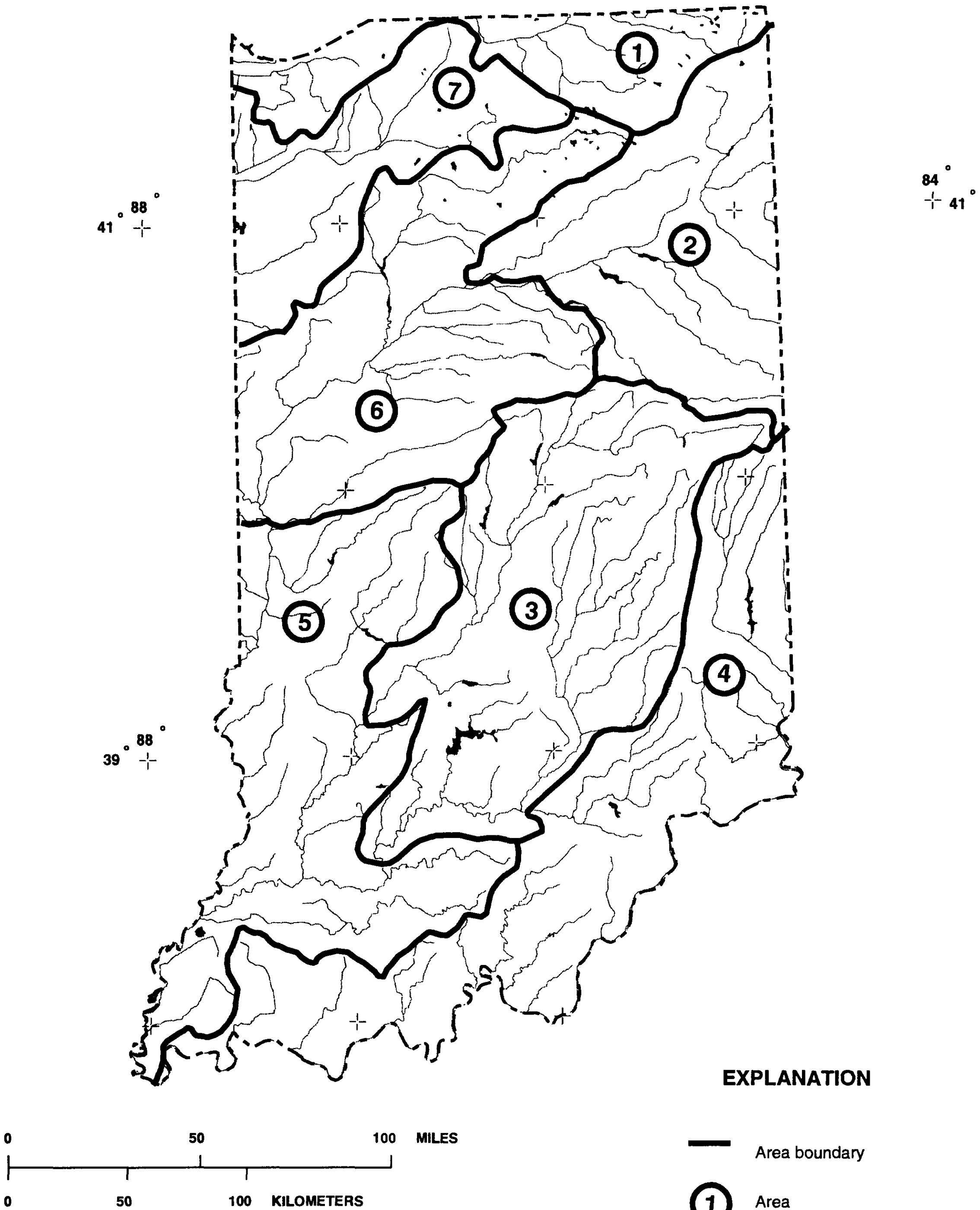
$$Q2 = 102\ DA^{0.758}SL^{0.273}(I24,2 - 2.5)^{0.948}$$
$$Q10 = 141\ DA^{0.772}SL^{0.384}(I24,2 - 2.5)^{0.894}$$
$$Q25 = 158\ DA^{0.776}SL^{0.423}(I24,2 - 2.5)^{0.868}$$
$$Q50 = 170\ DA^{0.777}SL^{0.445}(I24,2 - 2.5)^{0.847}$$
$$Q100 = 181\ DA^{0.779}SL^{0.466}(I24,2 - 2.5)^{0.831}$$

Area 4

$$Q2 = 16.8\ DA^{0.435}SL^{0.528}L^{0.860}(I24,2 - 2.5)^{0.459}$$
$$Q10 = 24.1\ DA^{0.517}SL^{0.628}L^{0.769}(I24,2 - 2.5)^{0.445}$$
$$Q25 = 27.4\ DA^{0.545}SL^{0.664}L^{0.741}(I24,2 - 2.5)^{0.448}$$
$$Q50 = 29.6\ DA^{0.554}SL^{0.687}L^{0.738}(I24,2 - 2.5)^{0.458}$$
$$Q100 = 32.0\ DA^{0.565}SL^{0.705}L^{0.730}(I24,2 - 2.5)^{0.464}$$

Area 5

$$Q2 = 45.5\ DA^{0.760}SL^{0.390}$$
$$Q10 = 67.7\ DA^{0.780}SL^{0.469}$$
$$Q25 = 77.0\ DA^{0.790}SL^{0.499}$$
$$Q50 = 83.8\ DA^{0.805}SL^{0.516}$$
$$Q100 = 91.2\ DA^{0.811}SL^{0.529}$$

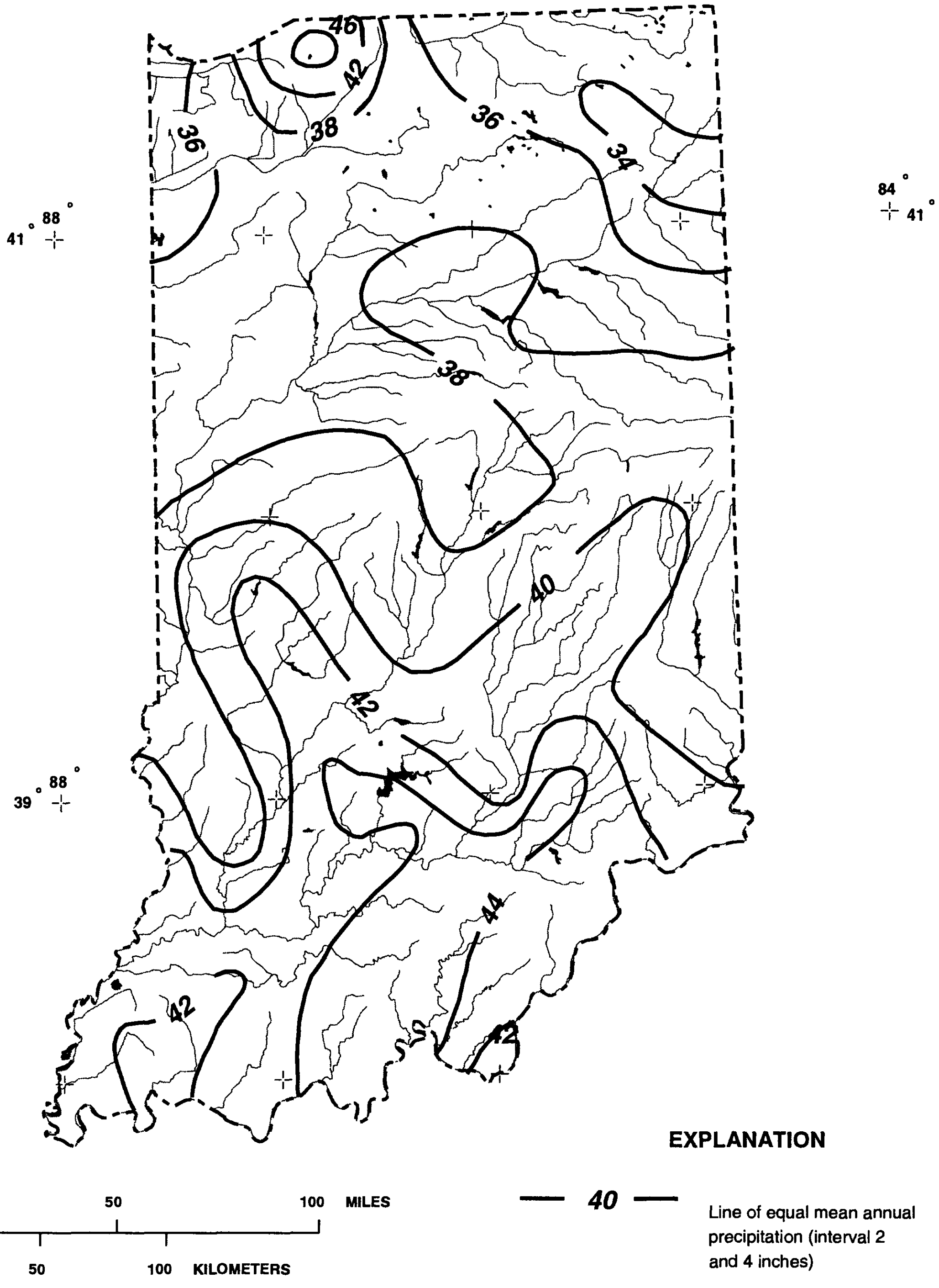


Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Flood-frequency region map for Indiana.

Area 6

$$Q2 = 681\ DA^{0.691}RC^{0.856}(I24{,}2 - 2.5)^{1.771}$$
$$Q10 = 2{,}177\ DA^{0.622}RC^{0.865}(I24{,}2 - 2.5)^{1.980}$$
$$Q25 = 3{,}165\ DA^{0.598}RC^{0.852}(I24{,}2 - 2.5)^{2.035}$$
$$Q50 = 3{,}908\ DA^{0.584}RC^{0.849}(I24{,}2 - 2.5)^{2.049}$$
$$Q100 = 4{,}734\ DA^{0.570}RC^{0.834}(I24{,}2 - 2.5)^{2.068}$$



Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 2. Mean annual precipitation in Indiana.

Area 7

$$Q2 = 22.6\ DA^{0.468} SL^{0.414} L^{0.624} RC^{0.846}$$
$$Q10 = 45.7\ DA^{0.350} SL^{0.439} L^{0.726} RC^{0.862}$$
$$Q25 = 56.4\ DA^{0.318} SL^{0.458} L^{0.754} RC^{0.862}$$
$$Q50 = 63.6\ DA^{0.300} SL^{0.473} L^{0.770} RC^{0.860}$$
$$Q100 = 70.1\ DA^{0.285} SL^{0.488} L^{0.785} RC^{0.854}$$

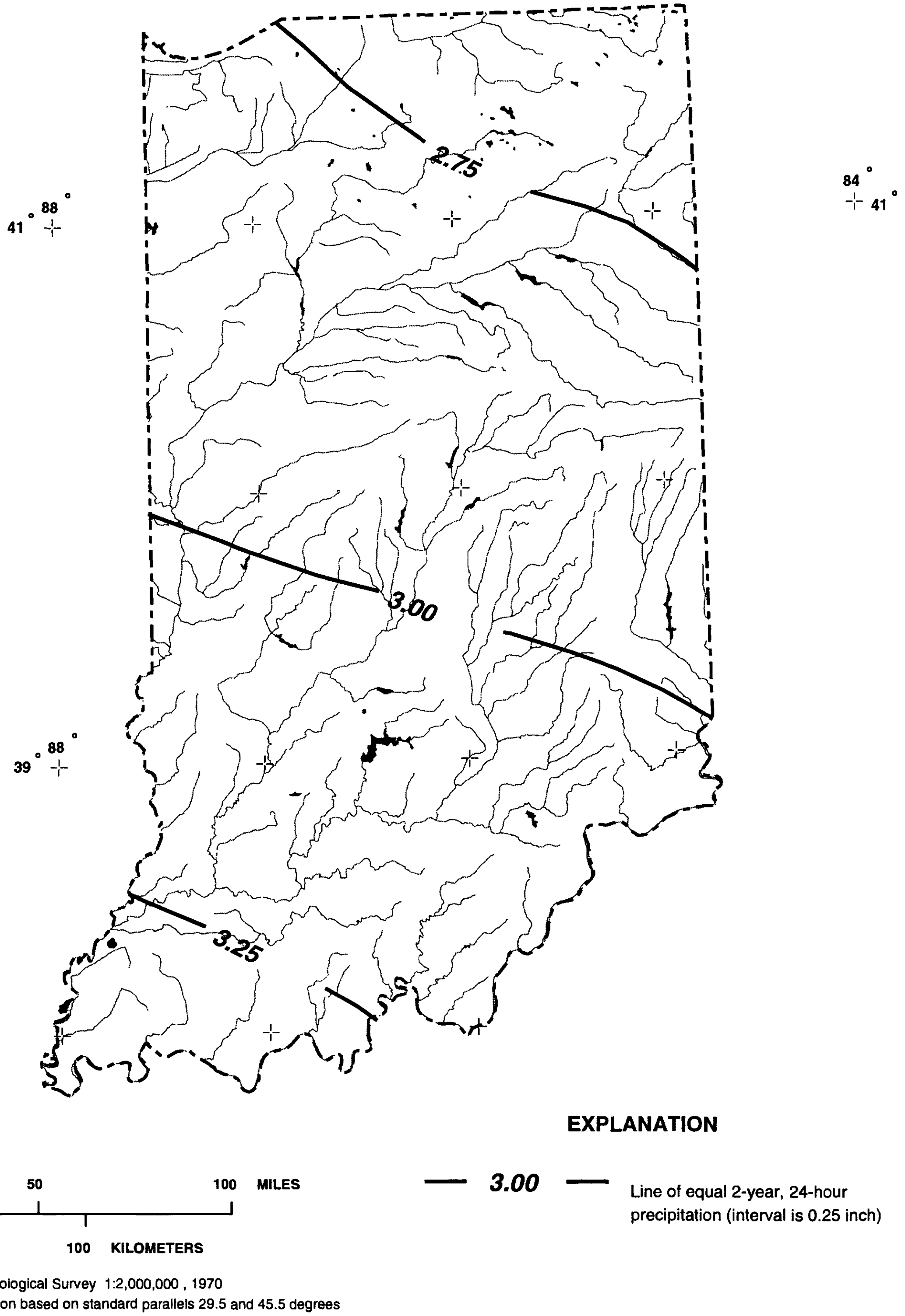
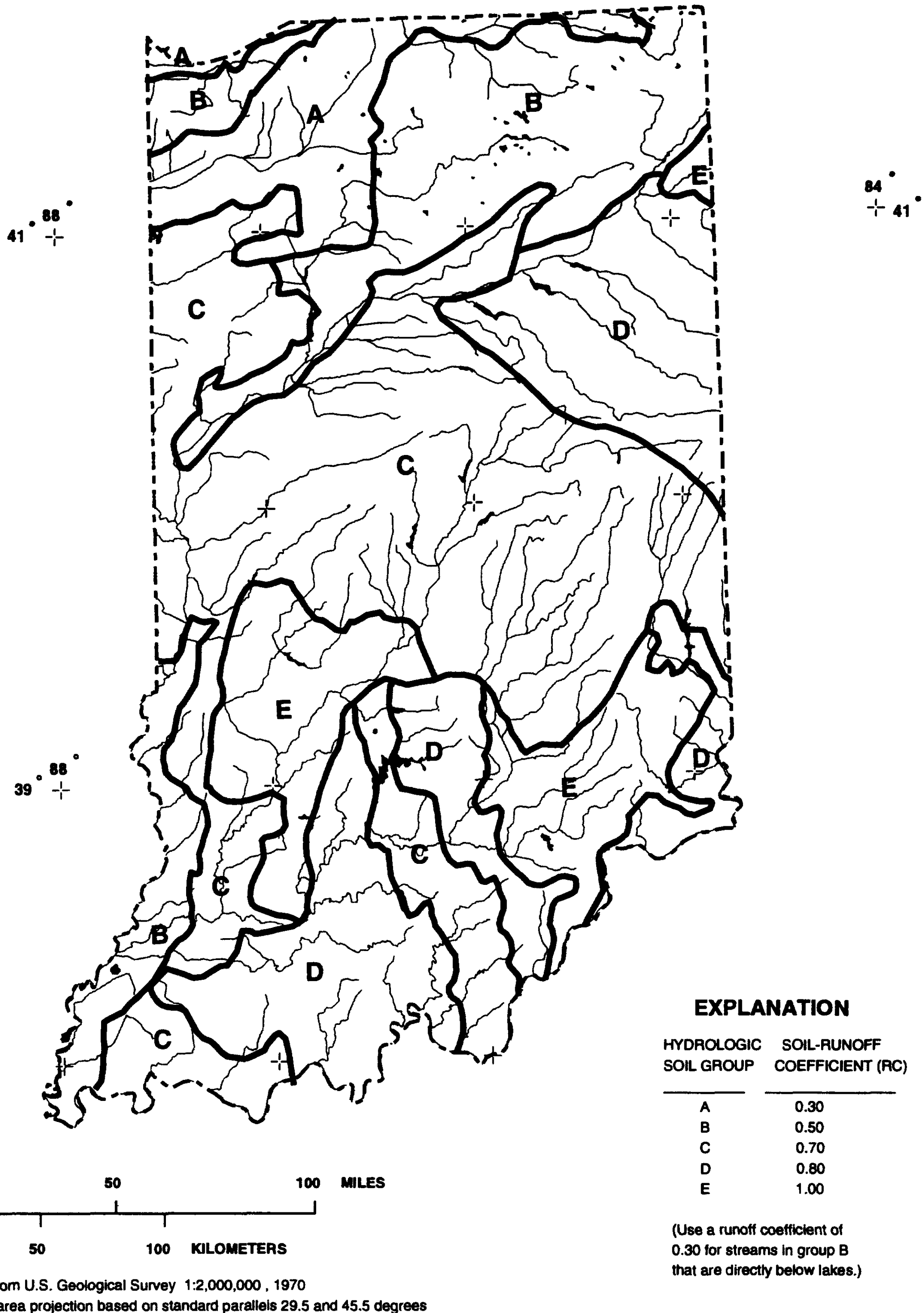


Figure 3. The 2-year 24-hour precipitation in Indiana.

Reference

Glatfelter, D.R., 1984, Techniques for estimating magnitude and frequency of floods on streams in Indiana: U.S. Geological Survey Water-Resources Investigations Report 84-4134, 110 p.



EXPLANATION

HYDROLOGIC SOIL GROUP	SOIL-RUNOFF COEFFICIENT (RC)
A	0.30
B	0.50
C	0.70
D	0.80
E	1.00

(Use a runoff coefficient of 0.30 for streams in group B that are directly below lakes.)

Hydrologic soil group boundary

Figure 4. Hydrologic soil groups map for Indiana.

IOWA

Summary

Iowa is considered to be one hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory variables used in the equations are contributing drainage area (CDA), in square miles, defined as the total area that contributes to surface-water runoff at the basin outlet, computed as TDA - NCDA, where TDA is the total drainage area, in square miles, including non-contributing areas and NCDA is the non-contributing drainage area, in square miles, that does not contribute to surface-water runoff at the basin outlet as measured from 1:250,000-scale topographic maps; relative relief (RR), in feet per mile, computed as BR / BP, where BR is the basin relief, in feet, measured as the sea-level elevation difference between the highest contour elevation and the lowest interpolated elevation at the basin outlet within the CDA and BP is the basin perimeter, in miles, measured along entire drainage-basin divide from 1:250,000-scale topographic maps;.drainage frequency (DF), in number of first-order streams per square mile within the CDA using Strahler's method of ordering streams as measured from 1:100,000-scale topographic maps; and 2-year, 24-hour precipitation intensity (TTF), in inches, defined as the maximum 24-hour precipitation expected to be exceeded on the average once every 2 years, computed as a weighted average within the TDA and measured from figure 1. The constant 2.5 is subtracted from TTF in the computer application of the regression equations. The user should enter the actual value of TTF from figure 1. The regression equations were developed from peak-discharge records available as of 1990 from 164 streamflow-gaging stations located in the State by relating flood-frequency data collected through the 1990 water year to basin-characteristic data quantified using a geographic-information-system procedure. The equations are applicable to unregulated rural streams in Iowa with drainage areas less than 1,060 square miles. The average standard errors of prediction for the drainage-basin equations ranged from 38.6 to 50.2 percent.

Procedure

Topographic maps, 1:250,000- and 1:100,000-scale, the precipitation map (fig. 1), and the following statewide equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 53.1\ CDA^{0.799}\ RR^{0.643}\ DF^{0.381}\ (TTF - 2.5)^{1.36}$$

$$Q5 = 98.8\ CDA^{0.755}\ RR^{0.652}\ DF^{0.380}\ (TTF - 2.5)^{0.985}$$

$$Q10 = 136\ CDA^{0.733}\ RR^{0.654}\ DF^{0.384}\ (TTF - 2.5)^{0.801}$$

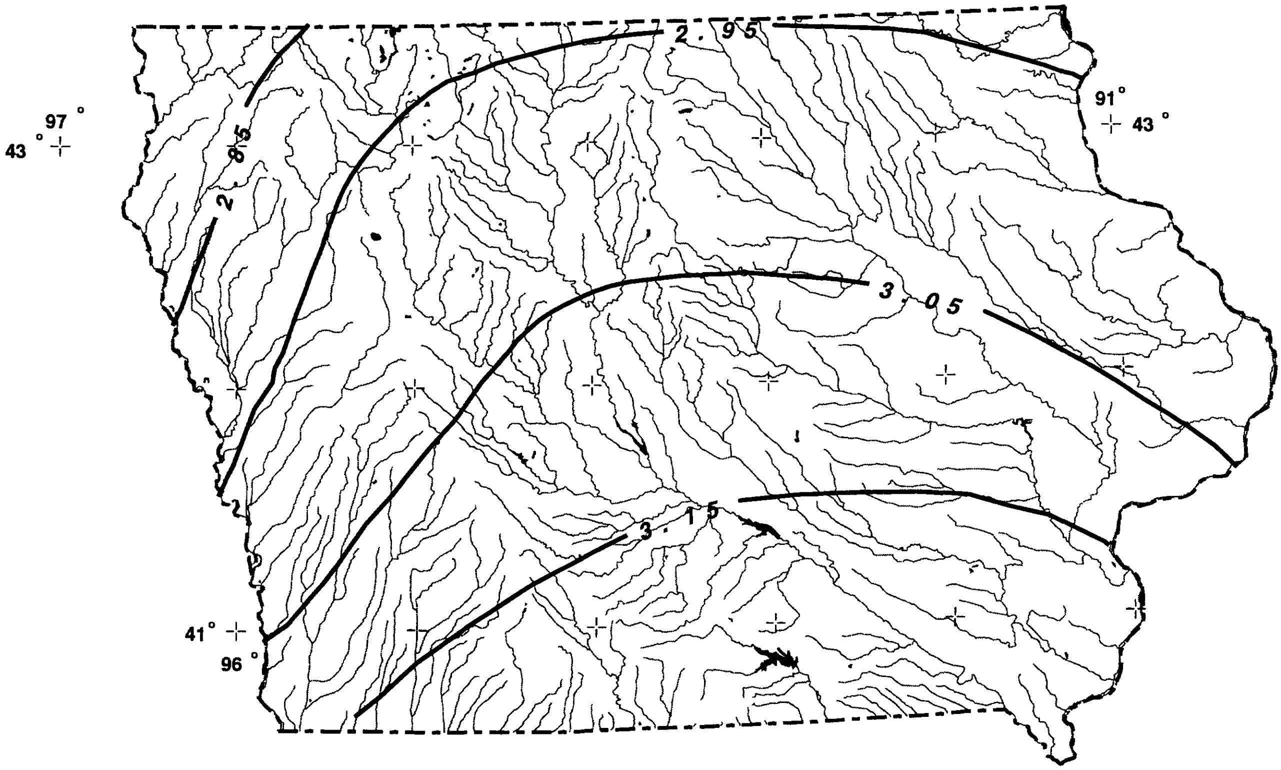
$$Q25 = 188\ CDA^{0.709}\ RR^{0.655}\ DF^{0.393}\ (TTF - 2.5)^{0.610}$$

$$Q50 = 231\ CDA^{0.694}\ RR^{0.656}\ DF^{0.401}\ (TTF - 2.5)^{0.491}$$

$$Q100 = 277\ CDA^{0.681}\ RR^{0.656}\ DF^{0.409}\ (TTF - 2.5)^{0.389}$$

Reference

Eash, D.A., 1993, Estimating design-flood discharges for streams in Iowa using drainage-basin and channel-geometry characteristics: U.S. Geological Survey Water-Resources Investigations Report 93-4062, 96 p.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— 3.15 — Line of equal 2-year, 24-hour precipitation (interval is 0.1 inch)

Figure 1. The 2-year 24-hour precipitation for Iowa.

KANSAS

STATEWIDE RURAL

Summary

Kansas is considered to be one hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals that range from 2 to 100 years. The explanatory basin variables used in the equations are contributing drainage area (CDA), in square miles, 2-year 24-hour rainfall (I2), in inches; main-channel slope (Sl), in feet per mile; and soil permeability index (SP), in inches per hour. The variables CDA and Sl can be measured from topographic maps, and the variables I2 and SP can be determined from figures 1 and 2, respectively. The regression equations were developed from peak-discharge records through 1983 for 218 streams with drainage areas less than 10,000 square miles. The regression equations are applicable to unregulated rural streams with drainage areas between 0.17 and 10,000 square miles. Standard errors of estimate of the regression equations range from about 30 to 40 percent. The report by Clement (1987) includes flood-frequency characteristics at 245 gaging stations, maximum observed floods, and information on the seasonal distribution of floods.

Procedure

Topographic maps, the 2-year 24-hour rainfall map (fig. 1), the soil permeability index map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having recurrence intervals T.

Equation form:

$$QT = a\,CDA^{b1\,CDA^{-0.04}}I2^{b2}Sl^{b3}SP^{b4}$$

QT	a	b1	b2	b3	b4
Q2	.067	.873	5.496	.343	-0.149
Q5	.571	.855	4.405	.327	-.159
Q10	1.56	.868	3.885	.319	-.158
Q25	4.43	.864	3.339	.310	-.156
Q50	8.69	.869	2.980	.303	-.156
Q100	16.0	.873	2.651	.295	-.156

Reference

Clement, R.W., 1987, Floods in Kansas and techniques for estimating their magnitude and frequency on unregulated streams: U.S. Geological Survey Water-Resources Investigations Report 87-4008, 49 p.

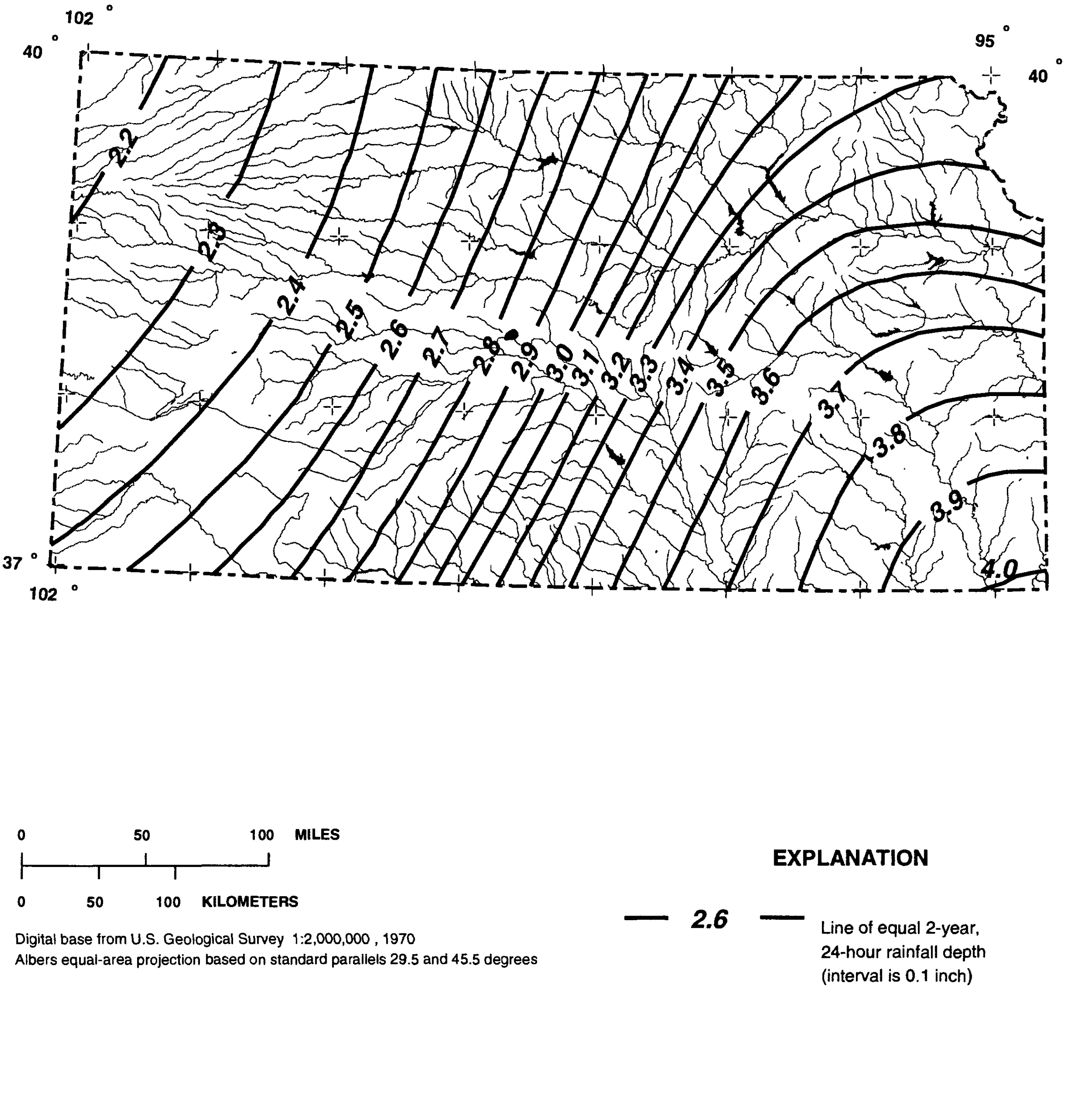
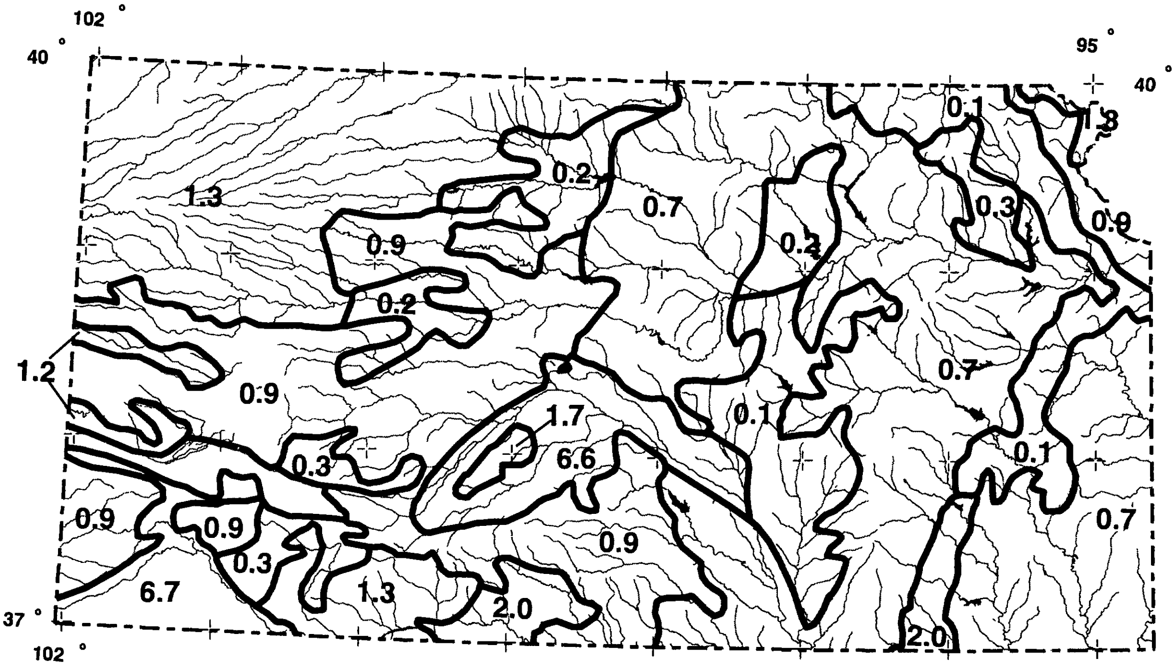


Figure 1. The 2-year 24-hour rainfall in Kansas.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

Boundary of area of equal average soil permeability

1.3 Soil permeability, in inches per hour

Figure 2. The soil permeability map for Kansas.

KENTUCKY

STATEWIDE RURAL

Summary

Kentucky is divided into seven hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are contributing drainage area (Ac), in square miles; main-channel slope (Sc), in feet per mile; basin shape index (Bs), which is the ratio of basin length, in miles, squared to total drainage area, in square miles; and main channel sinuosity (Ss), which is the ratio of main channel length to basin length. All of these basin variables can be measured from topographic maps. The regression equations were developed from peak-discharge records through water year 1985 at 266 continuous and partial-record stations. The regression equations are applicable only to natural-flow streams draining less than 1,000 square miles. Standard errors of the regression equations range from 21 to 52 percent. The report by Choquette (1987) includes a list of gaging stations used in the analysis, the periods of record, maximum observed discharges and values of selected basin variables for each station.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1

$$Q2 = 105\ Ac^{0.824}\ Sc^{0.224}$$
$$Q5 = 81.7\ Ac^{0.882}\ Sc^{0.389}$$
$$Q10 = 72.9\ Ac^{0.910}\ Sc^{0.472}$$
$$Q25 = 65.2\ Ac^{0.940}\ Sc^{0.560}$$
$$Q50 = 61.0\ Ac^{0.959}\ Sc^{0.617}$$
$$Q100 = 57.0\ Ac^{0.978}\ Sc^{0.669}$$

Region 2

$$Q2 = 189\ Ac^{0.764}\ Bs^{-0.174}\ Ss^{-0.304}$$
$$Q5 = 322\ Ac^{0.773}\ Bs^{-0.256}\ Ss^{-0.522}$$
$$Q10 = 428\ Ac^{0.776}\ Bs^{-0.297}\ Ss^{-0.628}$$
$$Q25 = 579\ Ac^{0.777}\ Bs^{-0.330}\ Ss^{-0.739}$$
$$Q50 = 708\ Ac^{0.777}\ Bs^{-0.356}\ Ss^{-0.803}$$
$$Q100 = 846\ Ac^{0.777}\ Bs^{-0.373}\ Ss^{-0.862}$$

Region 3

$$Q2 = 211\ Ac^{0.743}\ Ss^{-0.111}$$
$$Q5 = 373\ Ac^{0.730}\ Ss^{-0.205}$$
$$Q10 = 506\ Ac^{0.723}\ Ss^{-0.264}$$
$$Q25 = 704\ Ac^{0.717}\ Ss^{-0.338}$$
$$Q50 = 872\ Ac^{0.714}\ Ss^{-0.392}$$
$$Q100 = 1{,}061\ Ac^{0.711}\ Ss^{-0.447}$$

Region 4

$$Q2 = 114\ Ac^{0.825}$$
$$Q5 = 187\ Ac^{0.804}$$
$$Q10 = 242\ Ac^{0.794}$$
$$Q25 = 317\ Ac^{0.785}$$
$$Q50 = 376\ Ac^{0.780}$$
$$Q100 = 437\ Ac^{0.775}$$

Region 5

$$Q2 = 287\ Ac^{0.707}$$
$$Q5 = 484\ Ac^{0.698}$$
$$Q10 = 637\ Ac^{0.695}$$
$$Q25 = 860\ Ac^{0.692}$$
$$Q50 = 1{,}045\ Ac^{0.690}$$
$$Q100 = 1{,}242\ Ac^{0.689}$$

Region 6

$$Q2 = 55.0\ Ac^{0.821}\ Sc^{0.368}$$
$$Q5 = 66.0\ Ac^{0.839}\ Sc^{0.422}$$
$$Q10 = 71.1\ Ac^{0.850}\ Sc^{0.454}$$
$$Q25 = 75.5\ Ac^{0.865}\ Sc^{0.494}$$
$$Q50 = 78.8\ Ac^{0.873}\ Sc^{0.520}$$
$$Q100 = 81.3\ Ac^{0.882}\ Sc^{0.545}$$

Region 7

$$Q2 = 642\ Ac^{0.659}\ Bs^{-0.569}\ Sc^{-0.964}$$
$$Q5 = 946\ Ac^{0.647}\ Bs^{-0.523}\ Ss^{-0.809}$$
$$Q10 = 1{,}154\ Ac^{0.642}\ Bs^{-0.501}\ Ss^{-0.725}$$
$$Q25 = 1{,}424\ Ac^{0.640}\ Bs^{-0.482}\ Ss^{-0.635}$$
$$Q50 = 1{,}636\ Ac^{0.639}\ Bs^{-0.472}\ Ss^{-0.579}$$
$$Q100 = 1{,}838\ Ac^{0.639}\ Bs^{-0.466}\ Ss^{-0.528}$$

Reference

Choquette, A.F., 1987, Regionalization of peak discharges for streams in Kentucky: U.S. Geological Survey Water-Resources Investigations Report 87-4209, 105 p.

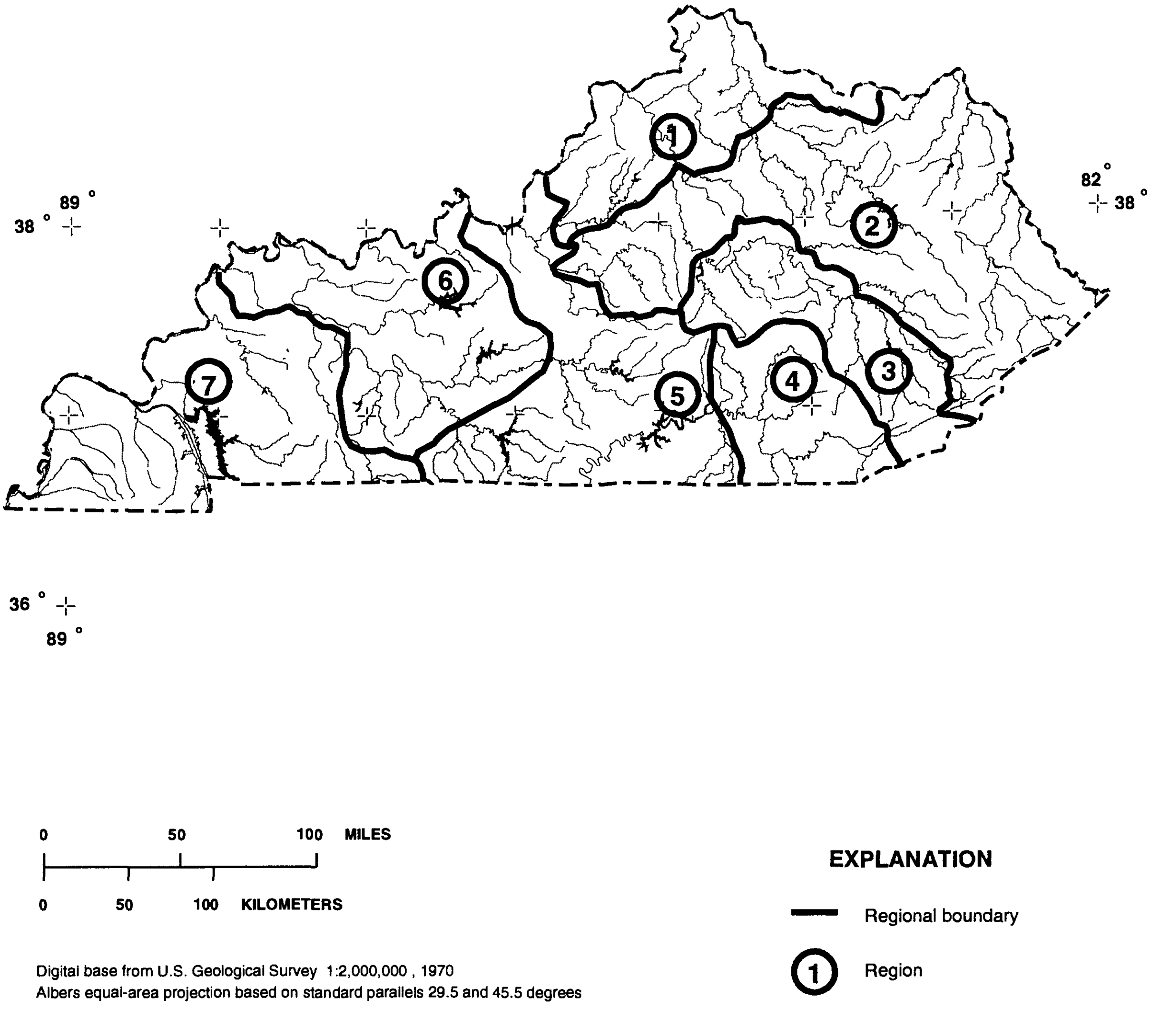


Figure 1. Flood-frequency region map for Kentucky.

LOUISIANA

STATEWIDE RURAL

Summary

Louisiana is considered to be one hydrologic region, but additional equations are provided for the Mississippi River Alluvial Plain (fig. 1). The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches; and channel slope (S), in feet per mile. The constant 35 is subtracted from P in the computer application of the regression equations. The user should enter the actual value of P from figure 2. The variables A and S can be measured from topographic maps, and P is determined from figure 2. The regression equations were developed from peak-discharge records through 1983 at 217 sites and are applicable only to natural, unaltered streams. The regression equations should not be used in the large, swampy areas along the coast. Standard errors of estimate of the regression equations range from 35 to 43 percent. The report by Lee (1985) includes a table showing basin characteristics and flood peak characteristics at gaging stations, and graphs showing flood characteristics on Red, Pearl, and Sabine Rivers.

Procedure

Topographic maps, the region map of the Mississippi River alluvial plain (fig. 1), the precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 5.45\ A^{0.62}\ (P\text{-}35)^{1.00}\ S^{0.33}$$
$$Q5 = 5.50\ A^{0.68}\ (P\text{-}35)^{1.01}\ S^{0.51}$$
$$Q10 = 5.25\ A^{0.71}\ (P\text{-}35)^{1.03}\ S^{0.61}$$
$$Q25 = 4.85\ A^{0.74}\ (P\text{-}35)^{1.06}\ S^{0.71}$$
$$Q50 = 4.25\ A^{0.77}\ (P\text{-}35)^{1.10}\ S^{0.78}$$
$$Q100 = 3.85\ A^{0.79}\ (P\text{-}35)^{1.13}\ S^{0.84}$$

Reference

Lee, F.N., 1985, Floods in Louisiana, magnitude and frequency, Fourth Edition: Louisiana Office of Highways Water Resources Technical Report No. 36, 30 p.

MISSISSIPPI RIVER ALLUVIAL PLAIN

Regression equations developed by Landers (1985) can be used to estimate peak discharges (QT), in the alluvial plain of the Mississippi River, having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; and channel length (L), in miles. All these variables can be measured from topographic maps. The regression equations were developed from peak-discharge records for 6 sites in Mississippi, 11 in Arkansas, and 13 in Louisiana, and are applicable to unregulated streams in the alluvial plain of Mississippi River. Standard errors of estimate of the regression equations range from 34 to 40 percent. The report by Landers (1985) includes a table of basin and flood frequency characteristics for stations used in the analysis.

Procedure

Topographic maps, the region map of the alluvial plain for the Mississippi River (fig. 1), and the following equations are used to estimate peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Note that the statewide equations above also apply to the alluvial plain of the Mississippi River.

$$Q2 = 171\ A^{0.87}\ S^{0.25}\ L^{-0.52}$$
$$Q5 = 192\ A^{0.93}\ S^{0.37}\ L^{-0.54}$$
$$Q10 = 205\ A^{0.96}\ S^{0.42}\ L^{-0.56}$$
$$Q25 = 224\ A^{0.99}\ S^{0.48}\ L^{-0.58}$$
$$Q50 = 232\ A^{1.00}\ S^{0.52}\ L^{-0.57}$$
$$Q100 = 236\ A^{1.00}\ S^{0.57}\ L^{-0.55}$$

Reference

Landers, M.N., 1985, Floodflow frequency of streams in the alluvial plain of the lower Mississippi River in Mississippi, Arkansas, and Louisiana: U.S. Geological Survey Water-Resources Investigations Report 85-4150, 21 p.

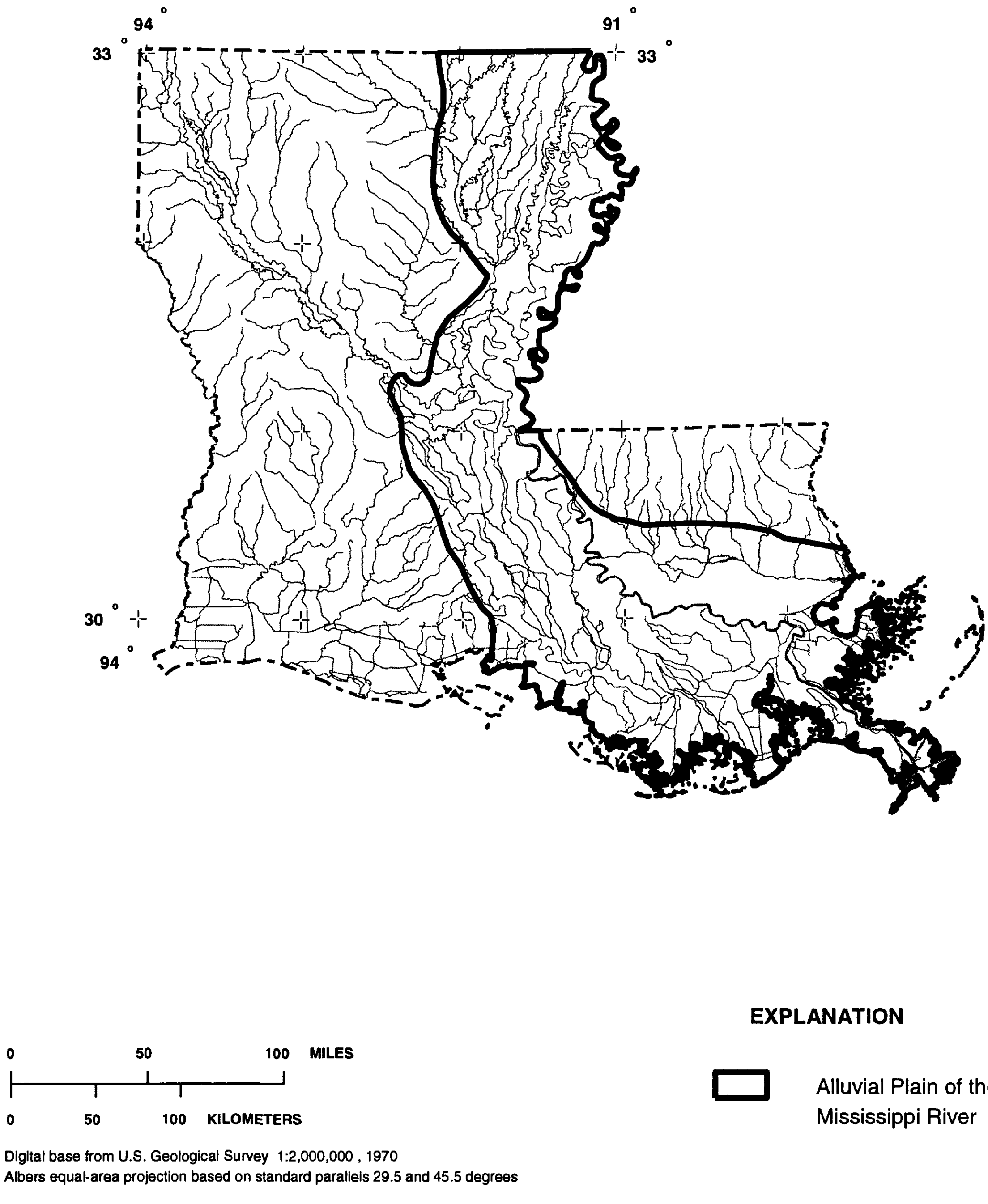


Figure 1. The alluvial plain of the Mississippi River in Louisiana.

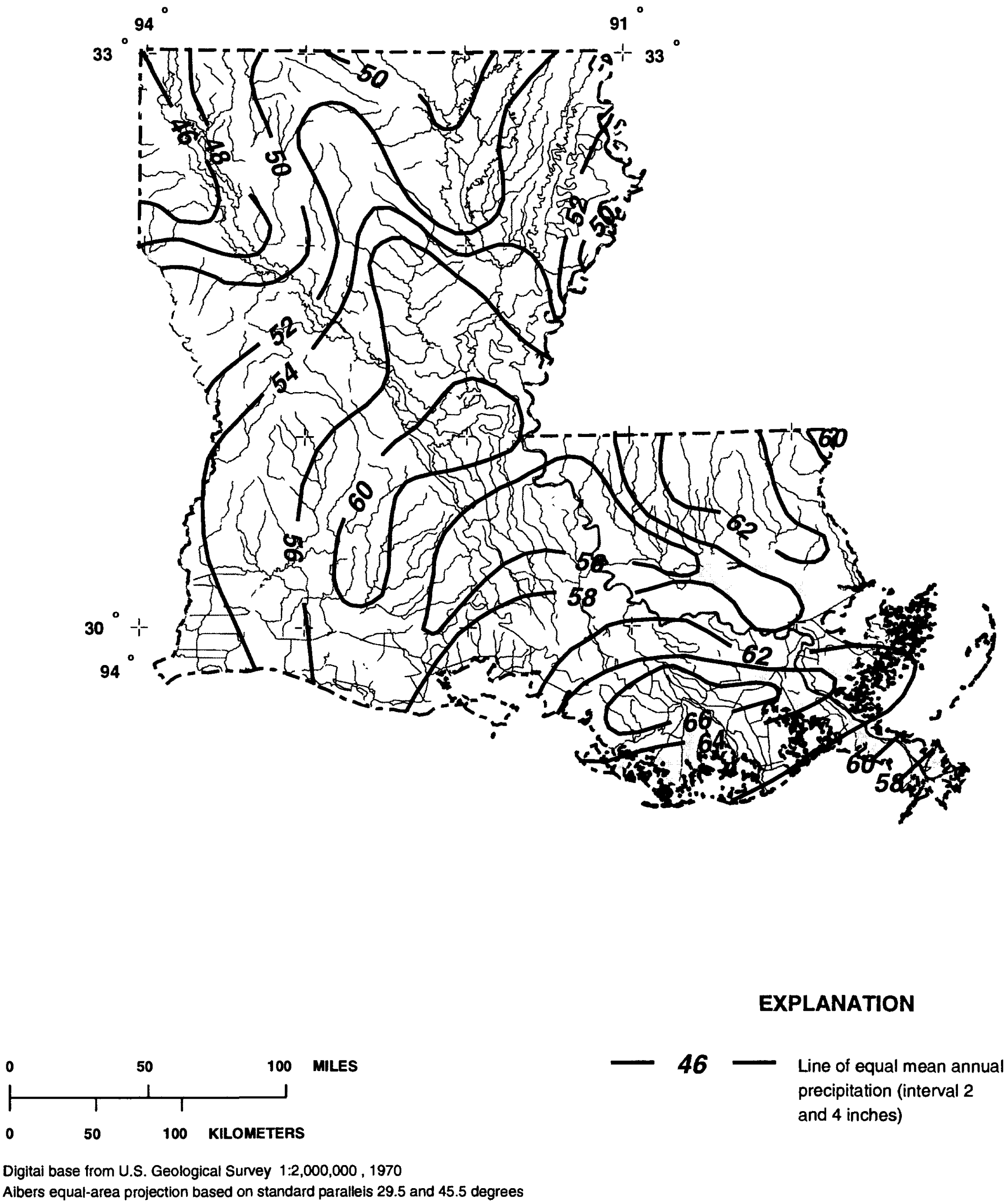


Figure 2. Mean annual precipitation for Louisiana.

MAINE

STATEWIDE RURAL

Summary

Maine is considered to be a single hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; and storage (St), which is the area of lakes and ponds in the basin in percentage of total area. The constant 1 is added to St in the computer application of the regression equations. The user should enter the actual value of St. All variables can be measured from topographic maps. The regression equations were developed from peak-discharge records through 1974 for 60 sites with records of at least 10 years in length. The regression equations apply to streams having drainage areas greater than 1 square mile and virtually natural flood flows. Standard errors of estimate of the regression equations range from 31 to 49 percent.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 14.0.A^{0.962} S^{0.268} St^{-0.212}$$
$$Q5 = 21.2 A^{0.946} S^{0.298} St^{-0.239}$$
$$Q10 = 26.9 A^{0.936} S^{0.315} St^{-0.252}$$
$$Q25 = 35.6 A^{0.923} S^{0.333} St^{-0.266}$$
$$Q50 = 42.7 A^{0.915} S^{0.346} ST^{-0.275}$$
$$Q100 = 50.9 A^{0.907} S^{0.358} St^{-0.282}$$

Reference

Morrill, R.A., 1975, A technique for estimating the magnitude and frequency of floods in Maine: U.S. Geological Survey Open-File Report No. 75-292, 43 p.

MARYLAND

STATEWIDE RURAL

Summary

Maryland is divided into three hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (Sl), in feet per mile; percentage of basin area covered by forests (F); percentage of basin area occupied by lakes, ponds, and swamps (St); 2-year 24-hour precipitation (I), in inches; and two composite soil indexes, Sa and Sd, expressed as a percentage of that soil type in the basin area. The constant 10 is added to F, St, Sa and Sd in the computer application of the regression equations. The user should enter the actual values of F, St, Sa and Sd. The variables A, Sl, St, and F can be measured from topographic maps; I can be determined from figure 2; Sa, and Sd can be determined from maps in the reference report by Carpenter (1980). The regression equations were developed from peak-discharge records at 224 sites in Maryland and adjacent States. The regression equations are applicable to streams draining natural basins without urban development or regulated flow. Standard errors of estimate (in percent) of the regression equations by region are summarized below:

Region	Northern	Southern	Eastern	Eastern (Alternate Equation)
	39-49	52-86	37-40	57-70

The report by Carpenter (1980) includes a table showing basin and flood characteristics at gaging stations and a graph of flood characteristics along the Potomac River.

Procedure

Topographic maps, the hydrologic regions map (fig. 1) and the 2-year 24-hour precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. For the Eastern region, only the alternate equations can be used unless the soil maps in Carpenter (1980) are available.

Northern Region

$$Q2 = 142A^{0.745}(F+10)^{-0.273}\, I^{0.669}$$
$$Q5 = 120A^{0.731}(F+10)^{-0.275}\, I^{1.358}$$
$$Q10 = 106A^{0.724}(F+10)^{-0.286}\, I^{1.810}$$
$$Q25 = 90.1A^{0.717}(F+10)^{-0.307}\, I^{2.376}$$
$$Q50 = 78.5A^{0.712}(F+10)^{-0.323}\, I^{2.793}$$
$$Q100 = 66.6A^{0.708}(F+10)^{-0.336}\, I^{3.212}$$

Southern Region

$$Q2 = 55.1\, A^{0.672}$$
$$Q5 = 112\, A^{0.670}$$
$$Q10 = 172\, A^{0.667}$$
$$Q25 = 280\, A^{0.666}$$
$$Q50 = 394\, A^{0.665}$$
$$Q100 = 548\, A^{0.662}$$

Eastern Region

$$Q2 = 28.6A^{0.910}Sl^{0.681}(St+10)^{-0.148}(F+10)^{-0.647}(Sa+10)^{-0.309}(Sd+10)^{0.560}$$
$$Q5 = 119\, A^{0.989}Sl^{0.843}(St+10)^{-0.533}(F+10)^{-0.731}(Sa+10)^{-0.369}(Sd+10)^{0.577}$$
$$Q10 = 306\, A^{1.016}Sl^{0.911}(St+10)^{-0.820}(F+10)^{-0.804}(Sa+10)^{-0.367}(Sd+10)^{0.624}$$
$$Q25 = 936\, A^{1.039}Sl^{0.974}(St+10)^{-1.114}(F+10)^{-0.868}(Sa+10)^{-0.384}(Sd+10)^{0.655}$$
$$Q50 = 2120\, A^{1.051}Sl^{1.009}(St+10)^{-1.321}(F+10)^{-0.916}(Sa+10)^{-0.396}(Sd+10)^{0.676}$$
$$Q100 = 4800\, A^{1.060}Sl^{1.035}(St+10)^{-1.519}(F+10)^{-0.963}(Sa+10)^{-0.410}(Sd+10)^{0.695}$$

Eastern Region (Atlernate)

$$Q2 = 1{,}450\,A^{0.757}\,(St+10)^{-0.229}\,(F+10)^{-0.849}$$
$$Q5 = 14{,}300\,A^{0.784}\,(St+10)^{-0.642}\,(F+10)^{-1.056}$$
$$Q10 = 53{,}100\,A^{0.791}\,(St+10)^{-0.926}\,(F+10)^{-1.132}$$
$$Q25 = 2.29 \times 10^{5}\,A^{0.795}\,(St+10)^{-1.226}\,(F+10)^{-1.222}$$
$$Q50 = 6.34 \times 10^{5}\,A^{0.799}\,(St+10)^{-1.437}\,(F+10)^{-1.284}$$
$$Q100 = 1.66 \times 10^{6}\,A^{0.801}\,(St+10)^{-1.639}\,(F+10)^{-1.341}$$

Reference

Carpenter, D.H., 1980, Technique of estimating magnitude and frequency of floods in Maryland: U.S. Geological Survey Open-File Report 80-1016, 79 p.

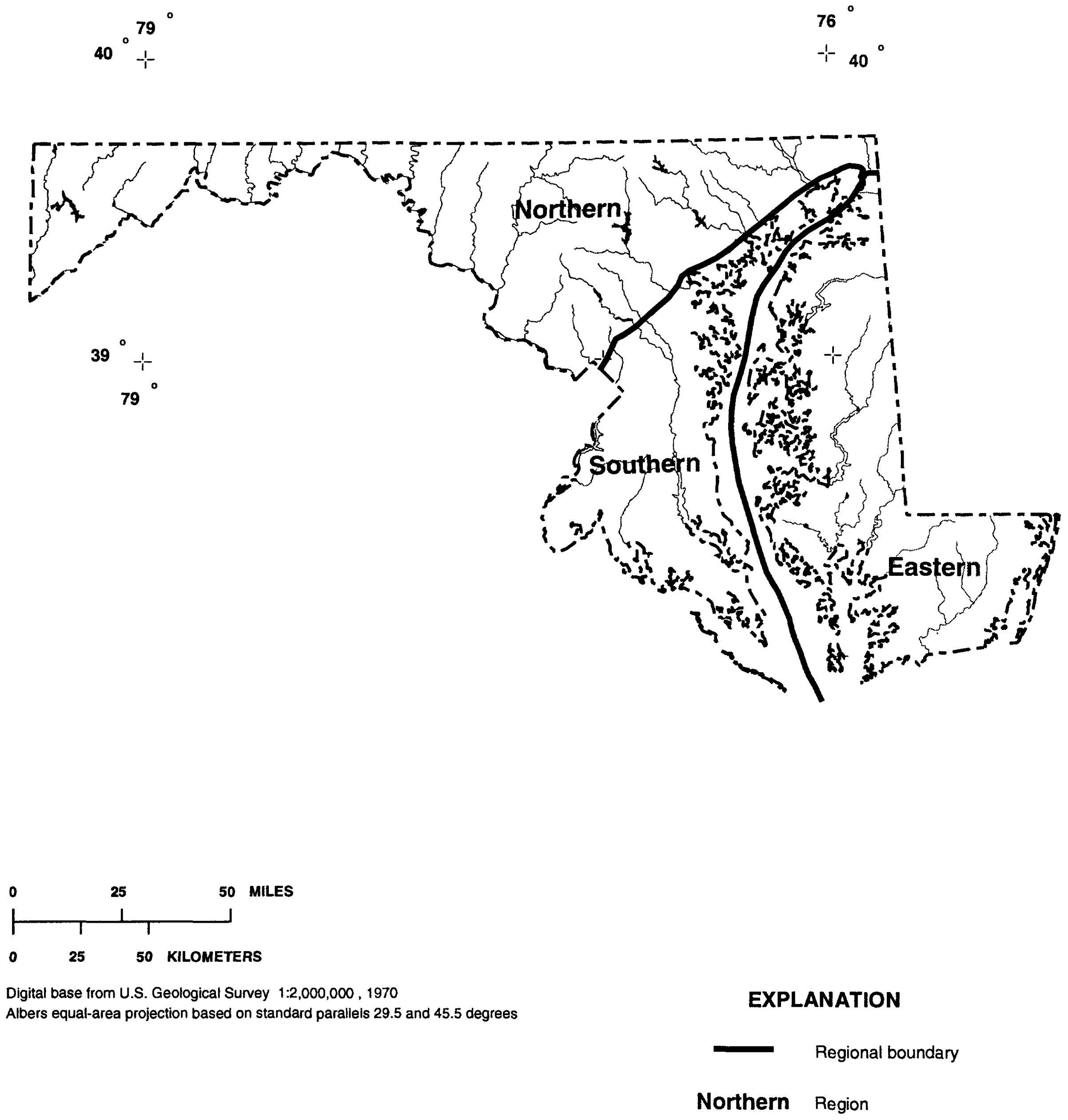


Figure 1. Flood-frequency region map for Maryland.

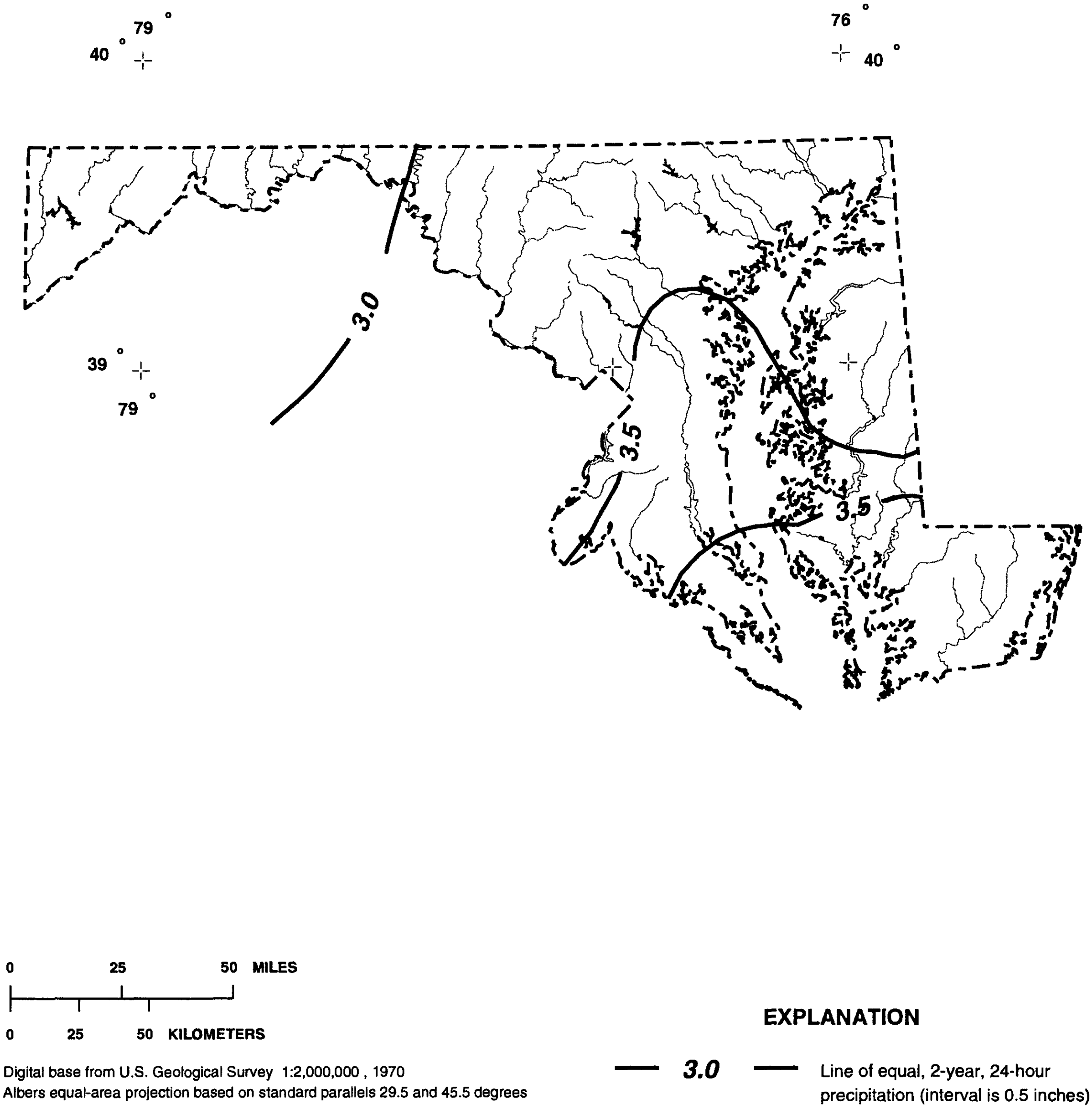


Figure 2. The 2-year 24-hour precipitation in Maryland.

MASSACHUSETTS

STATEWIDE RURAL

Summary

Massachusetts is divided into three hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; basin storage (St), as a percentage of the basin area; main-channel slope (Sl), in feet per mile; and mean basin elevation (E), in feet. The constant 0.5 is added to St in the computer application of the regression equations. The user should enter the actual value of St. All of these variables can be measured from topographic maps. The regression equations were developed from peak-discharge records available at 95 sites. The regression equations are applicable to streams draining between 0.25 and 260 square miles, which are unaffected by regulation or appreciable manmade storage. Standard errors of estimate of the regression equations are: Eastern Region, 44 to 52 percent; Central Region, 25 to 41 percent; and Western Region 27 to 45 percent. The report by Wandle (1983) includes flood characteristics at 95 gaged sites.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

EASTERN MASSACHUSETTS

Merrimack River basin, Coastal river basins (Parker River to Ten Mile River excluding basins in eastern Plymouth County)

$$Q2 = 36.30A^{0.682}$$
$$Q5 = 55.38A^{0.670}$$
$$Q10 = 72.12A^{0.660}$$
$$Q25 = 96.71A^{0.651}$$
$$Q50 = 118.1A^{0.645}$$
$$Q100 = 143.1A^{0.638}$$

CENTRAL MASSACHUSETTS

Blackstone River basin, French River basin, Quinebaug River basin, Millers River basin, Chicopee River basin and minor basins draining into the Connecticut River from the east side.

$$Q2 = 41.11A^{0.743}St^{-0.097}$$
$$Q5 = 65.17A^{0.751}St^{-0.139}$$
$$Q10 = 84.98A^{0.760}St^{-0.166}$$
$$Q25 = 114.9A^{0.775}St^{-0.195}$$
$$Q50 = 141.9A^{0.785}St^{-0.217}$$
$$Q100 = 172.7A^{0.797}St^{-0.237}$$

WESTERN MASSACHUSETTS

Deerfield River basin, Westfield River basin and minor basins draining into the Connecticut River from the west, Housatonic River basin, Hoosic River basin

$$Q2 = 0.933A^{0.970}Sl^{0.158}E^{0.429}$$
$$Q5 = 1.05A^{0.969}Sl^{0.178}E^{0.469}$$
$$Q10 = 1.23A^{0.969}Sl^{0.187}E^{0.480}$$
$$Q25 = 1.31A^{0.969}Sl^{0.205}E^{0.505}$$
$$Q50 = 1.41A^{0.970}Sl^{0.215}E^{0.520}$$
$$Q100 = 1.51A^{0.971}Sl^{0.225}E^{0.533}$$

Reference

Wandle, S.W., 1983, Estimating peak discharges of small, rural streams in Massachusetts: U.S. Geological Survey Water-Supply Paper 2214, 26 p.

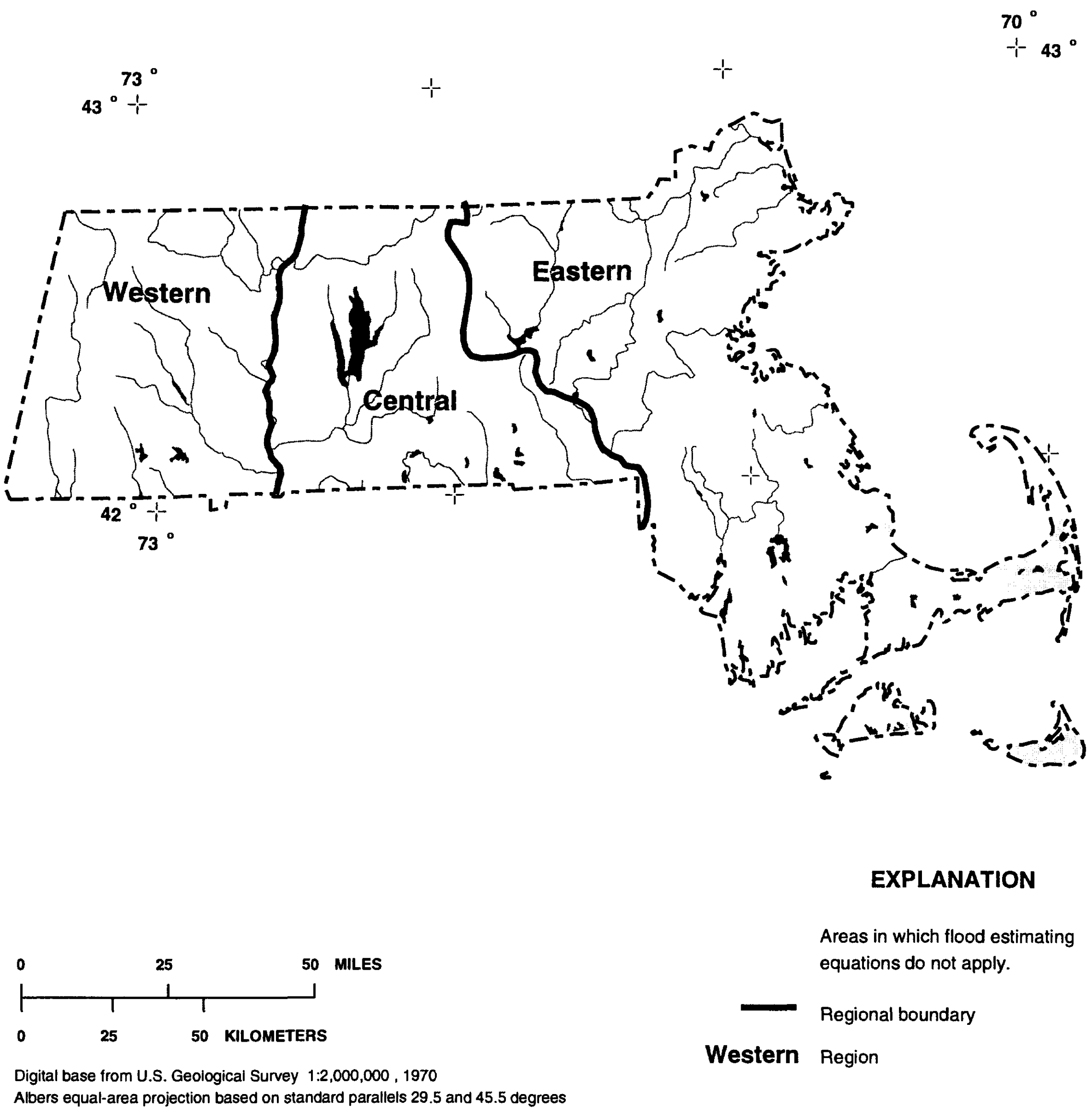


Figure 1. Flood-frequency region map for Massachusetts.

STATEWIDE RURAL

Summary

Michigan is divided into five hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals that range from 5 to 100 years. The explanatory basin variables used in the equations are contributing drainage area (CONDA), in square miles; main-channel slope (SLOPE), in feet per mile; main-channel swamp (CHSWAMP) which is the percentage of main-channel length that passes through swamp, lake, or pond; slenderness ratio (SLENRAT) which is the square of channel length divided by the contributing drainage area; the 100-year 24-hour rainfall (I24-100), in inches; 7 characteristics of surficial geologic material and a regional factor (Rf). The surficial geologic variables are CLAY, lacustrine clay and silt, as a percentage of CONTDA; CORGT, coarse-textured glacial till, as a percentage of CONTDA; FINEM, end moraines of fine-textured till, as a percentage of CONTDA; MEDTILL, medium-textured glacial till and end moraines of medium-textured glacial till, as a percentage of CONTDA; MUCK, peat and muck, as a percentage of CONTDA; OUTWASH, postglacial alluvium, glacial outwash sand and gravel and postglacial alluvium, and ice-contact outwash sand and gravel, as a percentage of CONTDA; and TILROCK, thin to discontinuous glacial till over bedrock, as a percentage of CONTDA. The constant 1 is added to all the surficial geology variables in the computer application of the regression equations. The user should enter the actual values of these variables.. The first four variables can be measured from topographic maps, I24-100 is determined from figure 2 and the regional factor (Rf) is determined from figure 1. The surficial geologic variables can be determined from geologic maps by Farrand and Bell (1984). The regression equations were developed from peak-discharge records available through 1982 from 185 stations with 10 or more years of record and are applicable to unregulated and unurbanized streams draining less than 1,000 square miles. The standard errors of estimate of the regression equations range from 30 to 39 percent. The report by Holtschlag and Croskey (1984) includes procedures for estimating mean and mean monthly flows, 5 points on the flow-duration curve, and 7-day and 30-day, 10-year low flows. The report also includes computed and estimated mean and mean monthly flow values, flow duration and low flow values, peak flow and flood volume values, physical, climatological and surficial geologic basin characteristics for all gaging stations in the analysis.

Procedure

Topographic maps, the hydrologic regions map (fig. 2), the 100-year 24-hour precipitation (fig. 2) and the geologic characteristics from the maps in the report by Farrand and Bell (1984), and the following equations are used to estimate the needed peak discharge QT, in cubic feet per second, having the selected recurrence intervals T.

$$Q5 = 0.6869\ CONTDA^{0.893}\ SLOPE^{0.216}\ CHSWAMP^{-0.174}\ SLENRAT^{-0.115}\ I24{,}100^{1.046}\ OUTWASH^{-0.152}\ MUCK^{0.167}\ FINEM^{0.102}\ MEDTILL^{0.088}\ CLAY^{0.090}\ TILROCK^{0.096}\ CORGT^{0.040}\ Rf$$

$$Q10 = 0.6688\ CONTDA^{0.890}\ SLOPE^{0.226}\ CHSWAMP^{-0.175}\ SLENRAT^{-0.124}\ I24{,}100^{1.194}\ OUTWASH^{-0.155}\ MUCK^{0.166}\ FINEM^{0.110}\ MEDTILL^{0.100}\ CLAY^{0.100}\ TILROCK^{0.090}\ CORGT^{0.044}\ Rf$$

$$Q25 = 0.6099\ CONTDA^{0.888}\ SLOPE^{0.237}\ CHSWAMP^{-0.174}\ SLENRAT^{-0.135}\ I24{,}100^{1.408}\ OUTWASH^{-0.156}\ MUCK^{0.167}\ FINEM^{0.119}\ MEDTILL^{0.112}\ CLAY^{0.109}\ TILROCK^{0.083}\ CORGT^{0.049}\ Rf$$

$$Q50 = 0.5569\ CONTDA^{0.886}\ SLOPE^{0.246}\ CHSWAMP^{-0.174}\ SLENRAT^{-0.141}\ I24{,}100^{1.566}\ OUTWASH^{-0.157}\ MUCK^{0.168}\ FINEM^{0.125}\ MEDTILL^{0.118}\ CLAY^{0.114}\ TILROCK^{0.078}\ CORGT^{0.052}\ Rf$$

$$Q100 = 0.4936\ CONTDA^{0.885}\ SLOPE^{0.256}\ CHSWAMP^{-0.173}\ SLENRAT^{-0.149}\ I24{,}100^{1.730}\ OUTWASH^{-0.157}\ MUCK^{0.170}\ FINEM^{0.131}\ MEDTILL^{0.124}\ CLAY^{0.118}\ TILROCK^{0.074}\ CORGT^{0.054} \bullet Rf$$

Regional factors (Rf)

	Region				
	1	2	3	4	5
Q5	0.9890	1.0209	0.9986	1.0705	0.9171
Q10	.9840	1.0238	.9940	1.0639	.9303
Q25	.9790	1.0301	.9886	1.0546	.9447
Q50	.9761	1.0354	.9849	1.0479	.9539
Q100	.9741	1.0426	.9820	1.0409	.9605

Reference

Holtschlag, D.J. and Croskey, H.M., 1984, Statistical models for estimating flow characteristics of Michigan streams: U.S. Geological Survey Water-Resources Investigations Report 84-4207, 80 p.

Additional Reference

Farrand, W.R. and Bell, D.L., 1984, Quaternary geology of Michigan with surface water drainage divides: Michigan Department of Natural Resources, Geological Survey Division, 2 maps. (Copies can be obtained from Information and Education Department of Natural Resources, P.O. Box 30028, Lansing, Michigan).

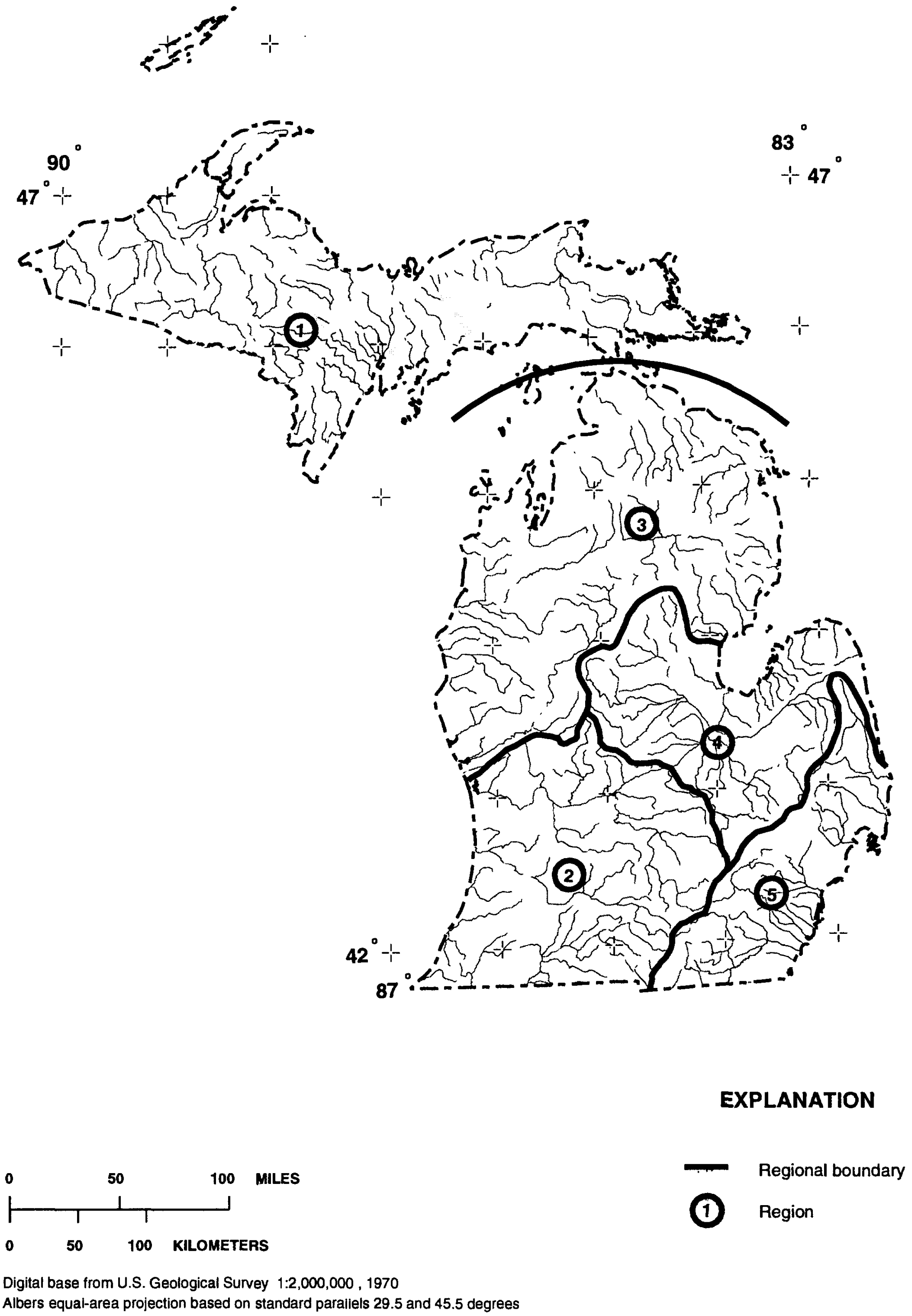


Figure 1. Flood-frequency region map for Michigan.

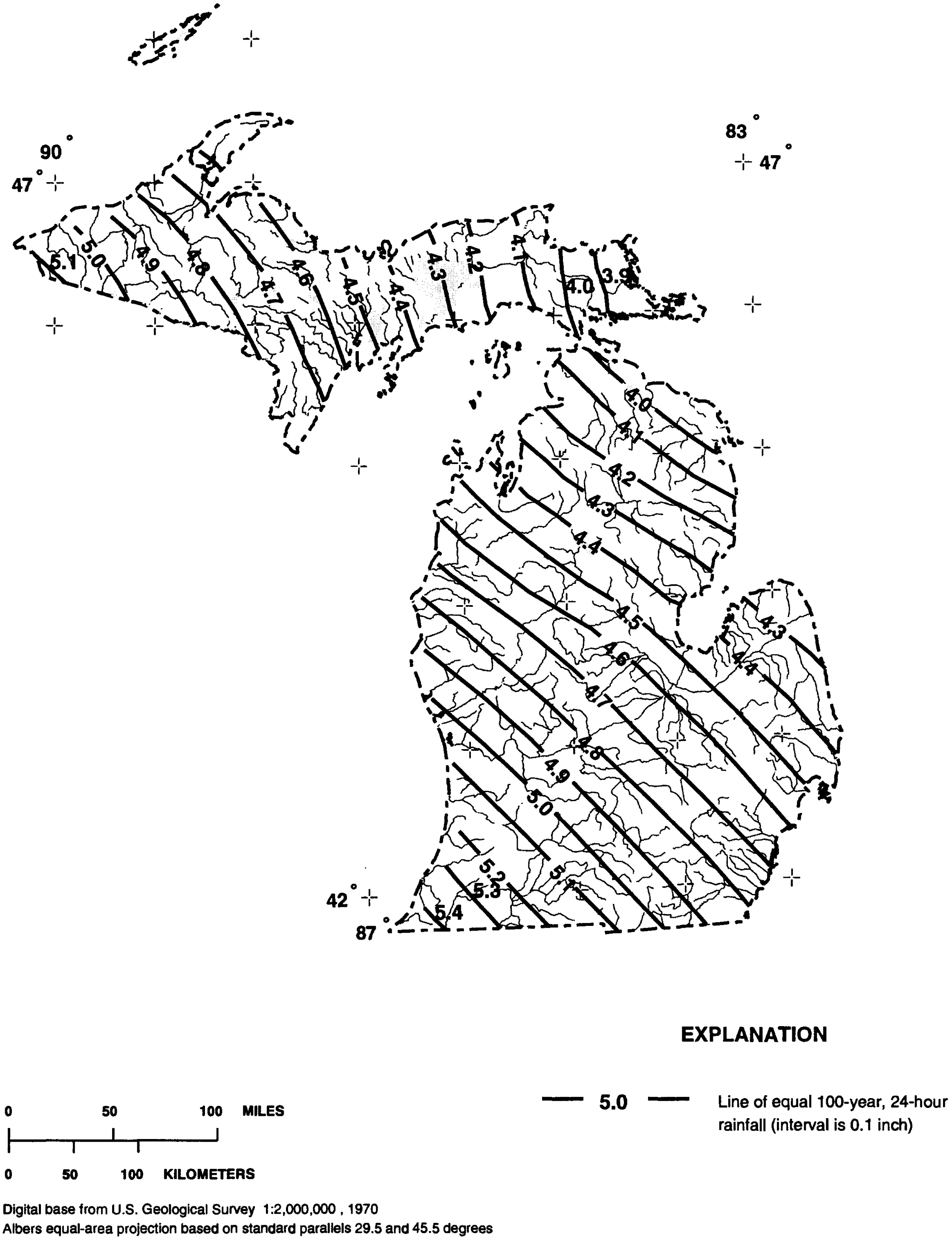


Figure 2. The 100-year 24-hour rainfall in Michigan.

MINNESOTA

STATEWIDE RURAL

Summary

Minnesota is divided into four hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; storage (St) which includes all lakes, ponds, and wetlands in the basin and is expressed as a percentage of the contributing drainage area; mean annual runoff (R), in inches; and main-channel slope (S), in feet per mile. The constant 1 is added to St in the computer application of the regression equations. The user should enter the actual value of St. The variables A, St, and S can be measured from topographic maps and R is mapped (fig. 2). The regression equations were developed from peak-discharge records available as of 1983 from 246 stations, and the equations are applicable to unregulated streams with drainage areas ranging from 0.1 to 2,520 square miles. The report by Jacques and Lorenz (1988) also includes basin and weighted peak-discharge characteristics and surficial geological basin characteristics at gaging stations used in the analysis. The standard errors of estimate of the regression equations are given below for the various regions.

Region	A	B	C	D
SE, in percent	36-53	33-54	49-52	43-60

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual runoff map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region A

$$Q2 = 28.2A^{0.616} (St+1)^{-0.108}$$
$$Q5 = 62.3A^{0.617} (St+1)^{-0.186}$$
$$Q10 = 92.5A^{0.615} (St+1)^{-0.227}$$
$$Q25 = 139\ A^{0.613} (St+1)^{-0.270}$$
$$Q50 = 179\ A^{0.610} (St+1)^{-0.298}$$
$$Q100 = 224\ A^{0.608} (St+1)^{-0.323}$$

Region B

$$Q2 = 2.98\ A^{0.843} (Lk+1)^{-0.531} R^{0.902}$$
$$Q5 = 8.88\ A^{0.836} (Lk+1)^{-0.587} R^{0.654}$$
$$Q10 = 14.8\ A^{0.833} (Lk+1)^{-0.612} R^{0.544}$$
$$Q25 = 24.5\ A^{0.829} (Lk+1)^{-0.636} R^{0.444}$$
$$Q50 = 33.1\ A^{0.827} (Lk+1)^{-0.651} R^{0.387}$$
$$Q100 = 42.7\ A^{0.825} (Lk+1)^{-0.662} R^{0.342}$$

Region C

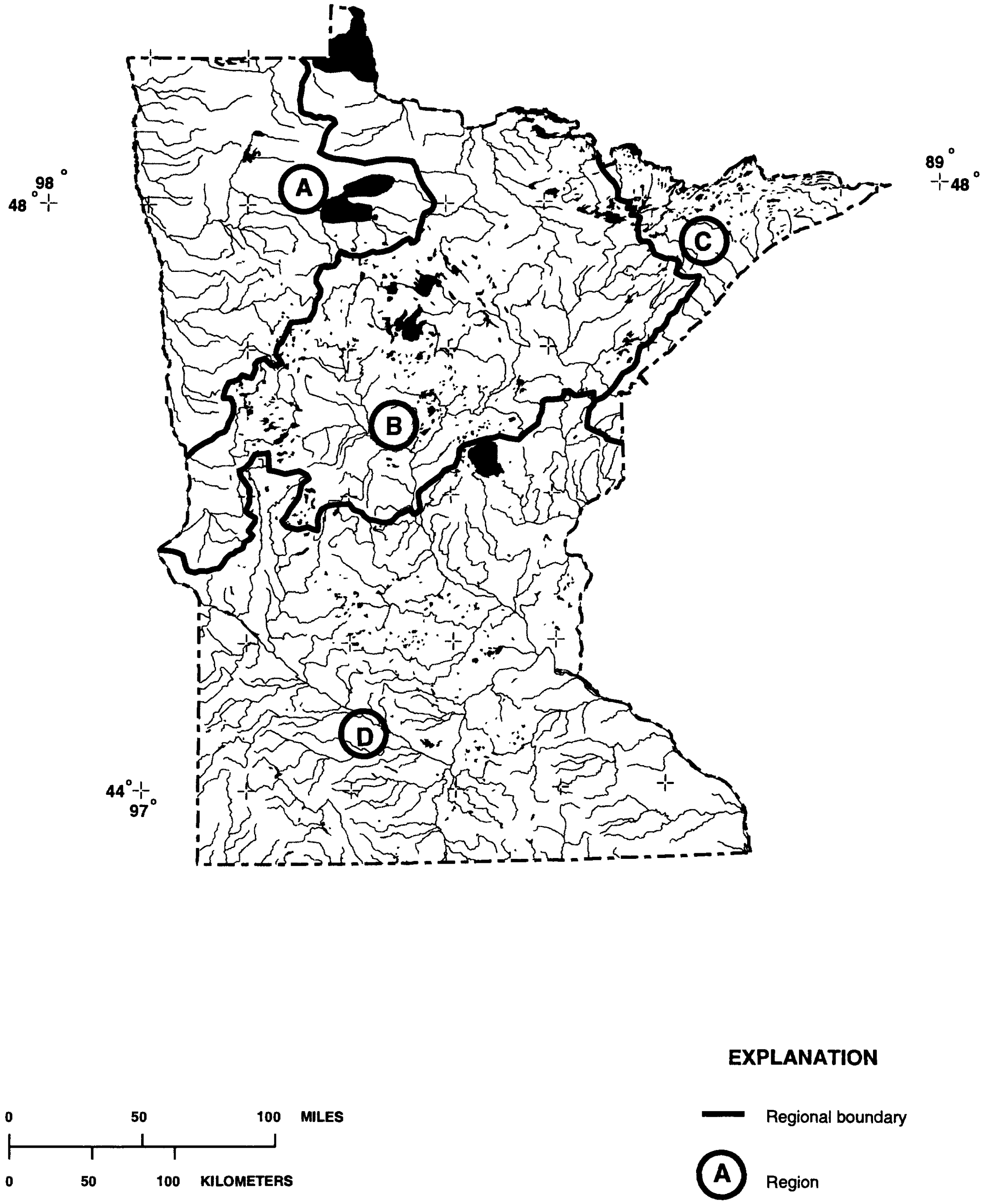
$$Q2 = 20.3\ A^{0.856} (St+1)^{-0.327} S^{0.288}$$
$$Q5 = 24.1\ A^{0.851} (St+1)^{-0.339} S^{0.383}$$
$$Q10 = 24.3\ A^{0.852} (St+1)^{-0.338} S^{0.451}$$
$$Q25 = 23.0\ A^{0.855} (St+1)^{-0.333} S^{0.536}$$
$$Q50 = 21.4\ A^{0.858} (St+1)^{-0.326} S^{0.599}$$
$$Q100 = 19.7\ A^{0.862} (St+1)^{-0.318} S^{0.660}$$

Region D

$$Q2 = 3.24\ A^{0.738} (St+1)^{-0.377} S^{0.302} R^{1.08}$$
$$Q5 = 7.92\ A^{0.732} (St+1)^{-0.392} S^{0.324} R^{0.937}$$
$$Q10 = 12.3\ A^{0.728} (St+1)^{-0.401} S^{0.335} R^{0.869}$$
$$Q25 = 19.5\ A^{0.723} (St+1)^{-0.409} S^{0.347} R^{0.801}$$
$$Q50 = 25.9\ A^{0.720} (St+1)^{-0.415} S^{0.355} R^{0.760}$$
$$Q100 = 33.1\ A^{0.716} (St+1)^{-0.419} S^{0.362} R^{0.724}$$

Reference

Jacques, J.E.,and Lorenz, D.L., 1988, Techniques for estimating the magnitude and frequency of floods in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 87-4170, 48 p.



Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Flood-frequency region map for Minnesota.

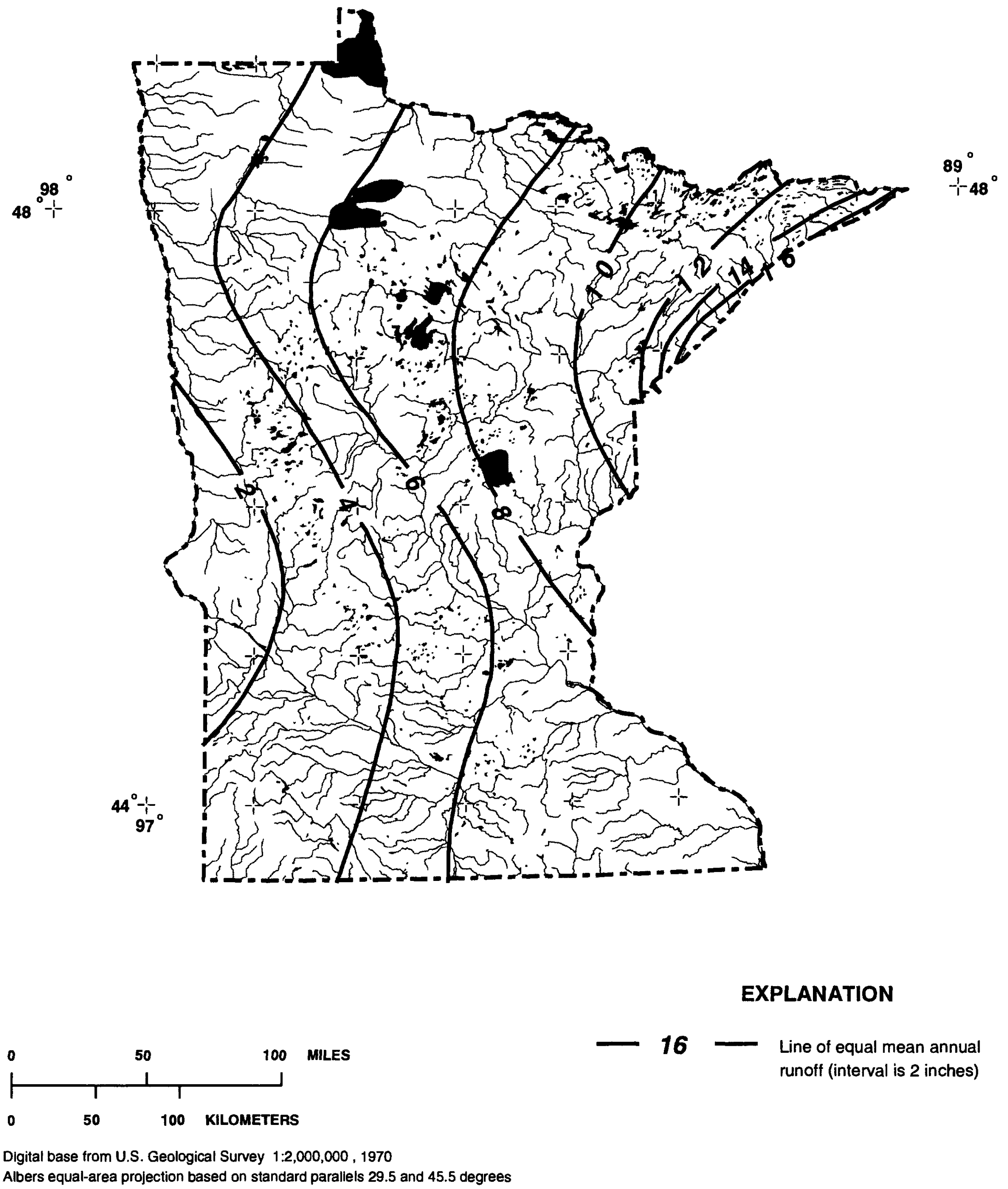


Figure 2. Mean annual runoff in Minnesota.

MISSISSIPPI

STATEWIDE RURAL

Summary

Mississippi is divided into four regions (fig. 1). Three of these regions are defined by geographic boundaries and one by drainage area magnitude (streams outside the Mississippi River Delta having drainage areas greater than 800 square miles). The regression equations developed for these subgroups are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile, defined as the difference in altitude between points located at 10 and 85 percent of the main-channel length divided by the channel length between the two points; and main-channel length (L), in miles, from the point of discharge to the drainage divide as measured in 0.1 mile increments on topographic maps. At a stream junction, the branch draining the largest area is considered the main channel. The regression equations were developed from peak-discharge records available at 312 stations with 10 or more years of record. The standard errors of prediction of the equations range from 15 to 45 percent and the equations are applicable to floods for all natural drainage basins in Mississippi, except for the Pearl River main stem. A graphical relation of flood-frequency discharge to drainage area, with an adjustment for basin shape, is presented in the report for the Pearl River main stem. The report by Landers and Wilson (1991) includes flood-frequency discharges and basin characteristics for 330 gaged streams.

Procedure

A user would select: (1) the Mississippi River Delta equations, if the stream is in the Delta; (2) the GT800 equations, if the stream is outside the Delta with drainage area greater than 800 square miles (GT800); or (3) the East or West equations, based on stream-site location (fig. 1), regions 1, 2, and 3 are the East, West, and Delta regions, respectively. The Delta and West boundary is crossed by stream basins sloping westward down the abrupt, dissected escarpment. For ungaged sites located in the Delta part of these basins, it is suggested that two discharges be estimated for each frequency by assuming all of the basin lies in each region and then averaging the discharges by areal weighting.

Topographic maps, the hydrologic regions map (fig. 1) and the following equations are used to estimate peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Peak discharges for drainage basins affected by urbanization should be estimated using the equations from Sauer and others (1983), with the rural peak discharge estimated from the appropriate equation as shown below.

DELTA

$$Q2 = 171(A)^{0.87}(S)^{0.25}(L)^{-0.52}$$
$$Q5 = 192(A)^{0.93}(S)^{0.37}(L)^{-0.54}$$
$$Q10 = 205(A)^{0.96}(S)^{0.42}(L)^{-0.56}$$
$$Q25 = 224(A)^{0.99}(S)^{0.48}(L)^{-0.58}$$
$$Q50 = 232(A)^{1.00}(S)^{0.52}(L)^{-0.57}$$
$$Q100 = 236(A)^{1.00}(S)^{0.57}(L)^{-0.55}$$
$$Q200 = 243(A)^{1.00}(S)^{0.60}(L)^{-0.54}$$
$$Q500 = 249(A)^{1.00}(S)^{0.64}(L)^{-0.52}$$

GT800

$$Q2 = 131(A)^{0.97}(S)^{0.21}(L)^{-0.47}$$
$$Q5 = 382(A)^{0.90}(S)^{0.22}(L)^{-0.48}$$
$$Q10 = 668(A)^{0.87}(S)^{0.21}(L)^{-0.49}$$
$$Q25 = 1{,}260(A)^{0.84}(S)^{0.18}(L)^{-0.52}$$
$$Q50 = 1{,}950(A)^{0.83}(S)^{0.15}(L)^{-0.55}$$
$$Q100 = 2{,}890(A)^{0.83}(S)^{0.12}(L)^{-0.59}$$
$$Q200 = 4{,}050(A)^{0.82}(S)^{0.09}(L)^{-0.63}$$
$$Q500 = 6{,}070(A)^{0.83}(S)^{0.06}(L)^{-0.68}$$

EAST

$Q2 = 296(A)^{0.81}(S)^{0.03}(L)^{-0.36}$
$Q5 = 406(A)^{0.84}(S)^{0.07}(L)^{-0.35}$
$Q10 = 482(A)^{0.85}(S)^{0.09}(L)^{-0.34}$
$Q25 = 577(A)^{0.85}(S)^{0.10}(L)^{-0.32}$
$Q50 = 648(A)^{0.85}(S)^{0.11}(L)^{-0.31}$
$Q100 = 716(A)^{0.85}(S)^{0.11}(L)^{-0.30}$
$Q200 = 786(A)^{0.85}(S)^{0.12}(L)^{-0.29}$
$Q500 = 874(A)^{0.85}(S)^{0.12}(L)^{-0.28}$

WEST

$Q2 = 66.2(A)^{0.88}(S)^{0.51}(L)^{-0.11}$
$Q5 = 94.7(A)^{0.93}(S)^{0.51}(L)^{-0.15}$
$Q10 = 122(A)^{0.96}(S)^{0.49}(L)^{-0.19}$
$Q25 = 164(A)^{0.99}(S)^{0.47}(L)^{-0.24}$
$Q50 = 197(A)^{1.00}(S)^{0.45}(L)^{-0.26}$
$Q100 = 230(A)^{1.00}(S)^{0.44}(L)^{-0.25}$
$Q200 = 262(A)^{1.00}(S)^{0.42}(L)^{-0.25}$
$Q500 = 305(A)^{1.00}(S)^{0.41}(L)^{-0.25}$

Reference

Landers, M.N., and Wilson, K.V., Jr., 1991, Flood characteristics of Mississippi streams: U.S. Geological Survey Water-Resources Investigations Report 91-4037, 82 p.

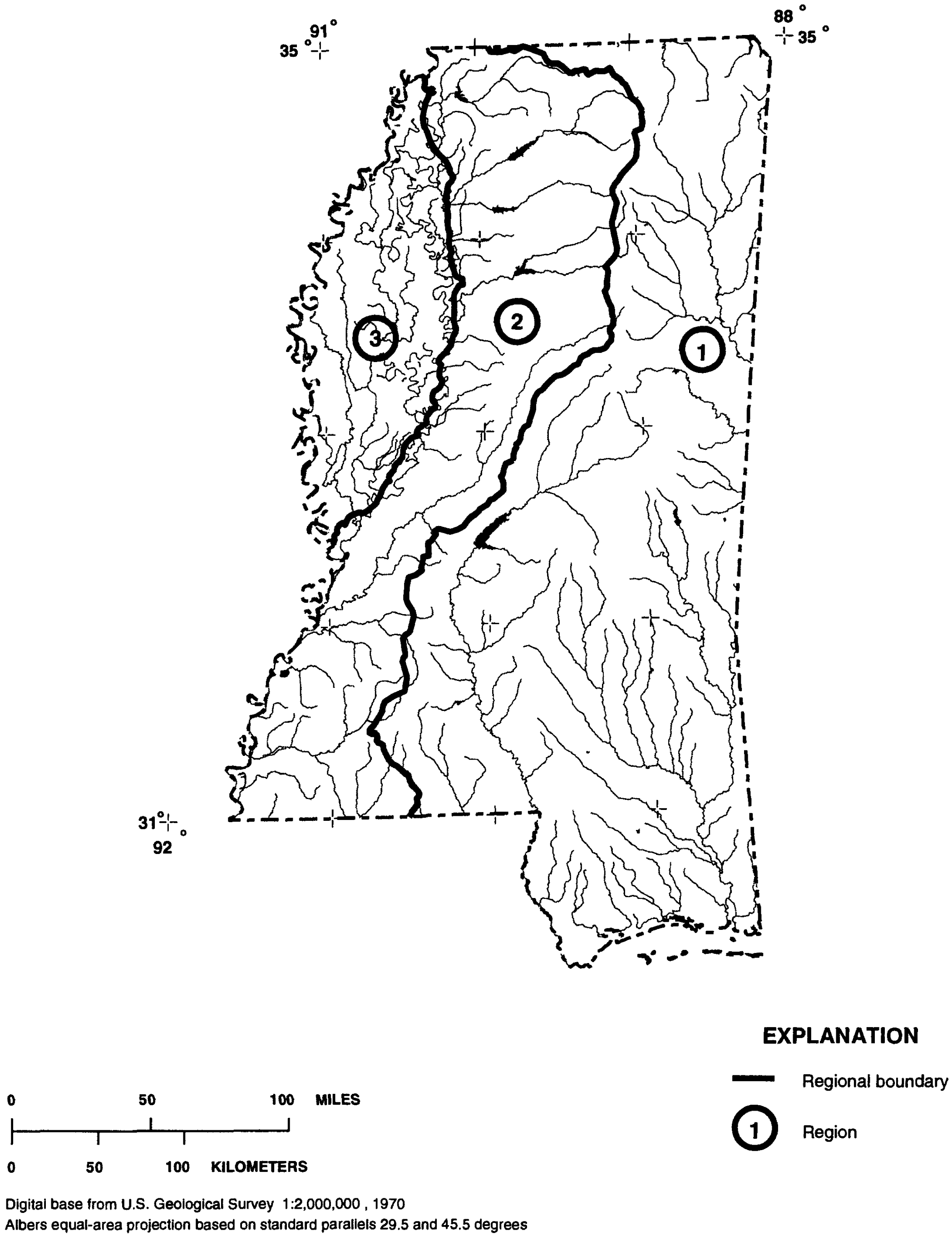


Figure 1. Flood-frequency region map for Mississippi.

MISSOURI

STATEWIDE RURAL

Summary

Missouri is considered to be one hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; and channel slope (S), in feet per mile. The variables A and S can be measured from topographic maps. The regression equations were developed from peak-discharge records for 152 gaging stations with drainage areas ranging from 0.1 to 14,000 mi2 and are only applicable to natural, unaltered streams. The standard errors of estimate of the regression equations range from 33 to 39 percent.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

(Note the nonlinear nature of the equations, i.e., drainage area (A) raised to a power of drainage area (A).)

$$Q2 = 53.5\ A^{0.851A^{**-0.02}}\ S^{0.356}$$
$$Q5 = 64.6\ A^{0.886A^{**-0.02}}\ S^{0.450}$$
$$Q10 = 67.6\ A^{0.905A^{**-0.02}}\ S^{0.500}$$
$$Q25 = 73.7\ A^{0.924A^{**-0.02}}\ S^{0.542}$$
$$Q50 = 79.8\ A^{0.926A^{**-0.02}}\ S^{0.560}$$
$$Q100 = 85.1\ A^{0.934A^{**-0.02}}\ S^{0.576}$$

Reference

Hauth, L.D., 1974, Technique for estimating the magnitude and frequency of Missouri floods: U.S. Geological Survey Open-File report, 20 p.

STATEWIDE URBAN

Summary

The regression equations developed for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The equations are applicable for urban streams statewide and are based on 37 gaged sites. The explanatory basin variables used in the equations are drainage area (A), in square miles; a basin development factor (BDF); and the percentage of the basin that is impervious (I). The drainage area A can be measured from topographic maps. The method of computing BDF is described earlier in the section entitled Urban Flood-Frequency Techniques. The impervious area I may be obtained from topographic maps or, preferably, from recent aerial photographs. The regression equations are applicable to streams with land-use changes but not streams whose floods are significantly affected by flood-detention structures. The range of applicable drainage areas is from 0.25 to 40 square miles. The standard errors of estimates of the regression equations range from 26 to 33 percent.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Two sets of equations are available; one set uses A and I and the other uses A and BDF. The standard errors of estimate of the two sets of regression equations are nearly the same.

For urban streams:

$$Q2 = 801A^{0.747}\ (13 - BDF)^{-0.400}$$
$$Q5 = 1{,}150A^{0.746}\ (13 - BDF)^{-0.318}$$
$$Q10 = 1{,}440A^{0.755}\ (13 - BDF)^{-0.300}$$
$$Q25 = 1{,}920A^{0.764}\ (13 - BDF)^{-0.307}$$
$$Q50 = 2{,}350A^{0.773}\ (13 - BDF)^{-0.319}$$
$$Q100 = 2{,}820A^{0.783}\ (13 - BDF)^{-0.330}$$

$$Q2 = 224A^{0.793}I^{0.175}$$
$$Q5 = 424A^{0.784}I^{0.131}$$
$$Q10 = 560A^{0.791}I^{0.124}$$
$$Q25 = 729A^{0.800}I^{0.131}$$
$$Q50 = 855A^{0.810}I^{0.137}$$
$$Q100 = 986A^{0.821}I^{0.144}$$

Reference

Becker, L.D., 1986, Techniques for estimating flood-pea discharges from urban basins in Missouri: U.S. Ge logical Survey Water-Resources Investigations Repo 86-4322, 38 p.

MONTANA

STATEWIDE RURAL

Summary

Montana is divided into eight hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches; basin high elevation index (HE+10), which is the percentage of the total basin area above 6000 feet, plus 10; and mean basin elevation (E), in feet, divided by 1000 (E/1000). The constant 10 is added to HE and E is divided by 1000 in the computer application of the regression equation. The user should enter the actual values of HE and E. The variable P is taken from a map developed by the U.S. Soil Conservation Service (1980). The other variables can be measured from topographic maps. The regression equations were developed from peak-discharge records available as of 1988 for 476 stations in Montana and 46 stations in adjacent states and Canada. The regression equations apply to unregulated streams having a drainage area ranging from 0.04 to 2,554 square miles, but are not valid where unique topographic or geologic features affect floods. The standard errors of prediction of the equations range from 22 to 128 percent. The report by Omang (1992) includes graphs of flood characteristics along seven major streams, and a table showing basin and flood characteristics and maximum floods of record at gaging stations.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation map in U.S. Soil Conservation Service (1980), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Northwest-Foothills Region

$$Q2 = 0.653A^{0.49}(E/1000)^{2.60}$$
$$Q5 = 3.70A^{0.48}(E/1000)^{2.22}$$
$$Q10 = 8.30A^{0.47}(E/1000)^{2.10}$$
$$Q25 = 20.3A^{0.46}(E/1000)^{1.95}$$
$$Q50 = 47.7A^{0.47}(E/1000)^{1.62}$$
$$Q100 = 79.8A^{0.48}(E/1000)^{1.40}$$
$$Q500 = 344A^{0.50}(E/1000)^{0.98}$$

Northeast Plains Region

$$Q2 = 15.4A^{0.69}(E/1000)^{-0.39}$$
$$Q5 = 77.0A^{0.65}(E/1000)^{-0.71}$$
$$Q10 = 161A^{0.63}(E/1000)^{-0.84}$$
$$Q25 = 343A^{0.61}(E/1000)^{-1.00}$$
$$Q50 = 543A^{0.60}(E/1000)^{-1.09}$$
$$Q100 = 818A^{0.59}(E/1000)^{-1.19}$$
$$Q500 = 1{,}720A^{0.57}(E/1000)^{-1.37}$$

East-Central Plains Region

$$Q2 = 141A^{0.55}(E/1000)^{-1.88}$$
$$Q5 = 509A^{0.53}(E/1000)^{-1.92}$$
$$Q10 = 911A^{0.52}(E/1000)^{-1.88}$$
$$Q25 = 1{,}545A^{0.50}(E/1000)^{-1.79}$$
$$Q50 = 2{,}100A^{0.49}(E/1000)^{-1.72}$$
$$Q100 = 2{,}260A^{0.49}(E/1000)^{-1.62}$$
$$Q500 = 3{,}930A^{0.47}(E/1000)^{-1.44}$$

Southeast Plains Region

$$Q2 = 537A^{0.55}(E/1000)^{-2.91}$$
$$Q5 = 1{,}350A^{0.53}(E/1000)^{-2.75}$$
$$Q10 = 2{,}050A^{0.52}(E/1000)^{-2.64}$$
$$Q25 = 3{,}240A^{0.51}(E/1000)^{-2.55}$$
$$Q50 = 4{,}140A^{0.50}(E/1000)^{-2.47}$$
$$Q100 = 5{,}850A^{0.50}(E/1000)^{-2.51}$$
$$Q500 = 8{,}250A^{0.49}(E/1000)^{-2.33}$$

West Region

$$Q2 = 0.042A^{0.94}P^{1.49}$$
$$Q5 = 0.140A^{0.90}P^{1.31}$$
$$Q10 = 0.235A^{0.89}P^{1.25}$$
$$Q25 = 0.379A^{0.87}P^{1.19}$$
$$Q50 = 0.496A^{0.86}P^{1.17}$$
$$Q100 = 0.615A^{0.85}P^{1.15}$$
$$Q500 = 0.874A^{0.83}P^{1.14}$$

Northwest Region

$$Q2 = 0.266A^{0.94}P^{1.12}$$
$$Q5 = 2.34A^{0.87}P^{0.75}$$
$$Q10 = 7.84A^{0.84}P^{0.54}$$
$$Q25 = 23.1A^{0.81}P^{0.40}$$
$$Q50 = 25.4A^{0.79}P^{0.46}$$
$$Q100 = 38.9A^{0.74}P^{0.50}$$
$$Q500 = 87.1A^{0.67}P^{0.49}$$

Southwest Region

$$Q2 = 2.48A^{0.87}(HE+10)^{-0.19}$$
$$Q5 = 24.8A^{0.82}(HE+10)^{-0.16}$$
$$Q10 = 81.5A^{0.78}(HE+10)^{-0.32}$$
$$Q25 = 297A^{0.72}(HE+10)^{-0.49}$$
$$Q50 = 695A^{0.70}(HE+10)^{-0.62}$$
$$Q100 = 1{,}523A^{0.68}(HE+10)^{-0.74}$$
$$Q500 = 7{,}460A^{0.64}(HE+10)^{-0.99}$$

Upper Yellowstone-Central Mountain Region

$$Q2 = 0.177A^{0.85}(E/1000)^{3.57}(HE+10)^{-0.57}$$
$$Q5 = 0.960A^{0.79}(E/1000)^{3.44}(HE+10)^{-0.82}$$
$$Q10 = 2.71A^{0.77}(E/1000)^{3.36}(HE+10)^{-0.94}$$
$$Q25 = 8.54A^{0.74}(E/1000)^{3.16}(HE+10)^{-1.03}$$
$$Q50 = 19.0A^{0.72}(E/1000)^{2.95}(HE+10)^{-1.05}$$
$$Q100 = 41.6\,A^{0.70}(E/1000)^{2.72}(HE+10)^{-1.07}$$
$$Q500 = 205A^{0.65}(E/1000)^{2.17}(HE+10)^{-1.07}$$

Reference

Omang, R.J., 1992, Analysis of the magnitude and frequency of floods and the peak-flow gaging network in Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4048, 70 p.

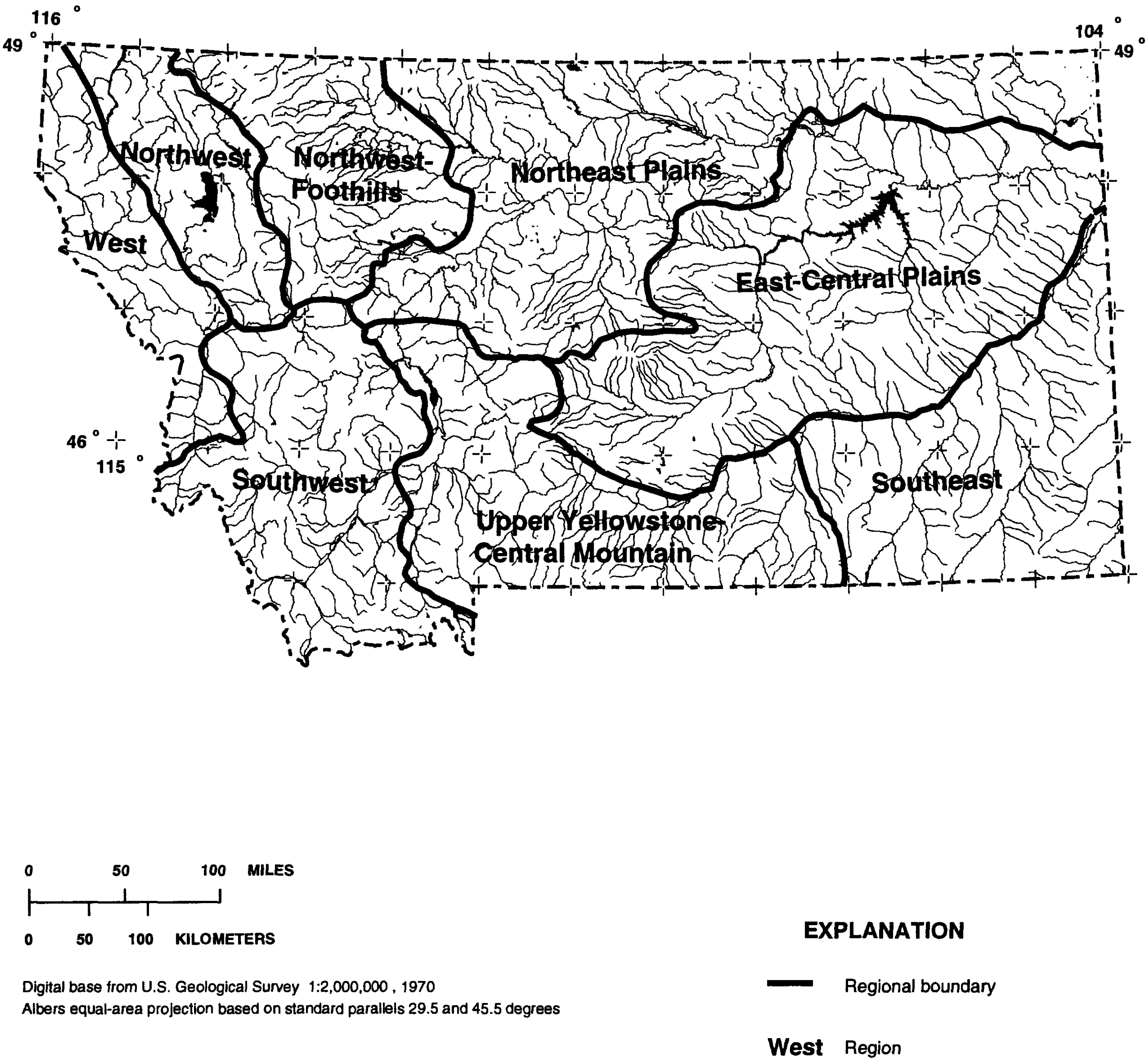


Figure 1. Flood-frequency region map for Montana.

NEBRASKA

STATEWIDE RURAL

Summary

Nebraska is divided into five hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin characteristics used in the equations are total drainage area (A), in square miles; contributing drainage area (Ac), in square miles; mean annual precipitation (P) (fig. 2), in inches; main stream length (L), in miles; main stream slope (S), in feet per mile; normal daily maximum March temperature (T3) (fig. 3), in degrees Fahrenheit; mean minimum January temperature (T1) (fig. 4), in degrees Fahrenheit; and 50-year 24-hour rainfall (I24,50) (fig. 5), in inches. The constants -13, -37, -11 and -3 are added to P, T3, T1 and I24,50 in the computer application of the regression equations. The user should enter the actual values of P, T3, T1 and I24,50 from figures 2-5. The variables A, Ac, L, and S can be measured from topographic maps, and the others can be taken from figures 2-5. The regression equations were developed from peak-discharge records available through 1972 at 258 sites. The equations are applicable to streams unaffected by regulation or urbanization, and to drainage areas greater than 0.1 square miles except for those of region 2 which apply to basins greater than 10 square miles. Some other limitations are given by Beckman (1976). The range of standard errors of estimate of the regression equations by region are:

Region	1	2	3	4	5
SE, percent	98-102	60-84	37-52	43-65	22-37

The report by Beckman (1976) includes graphs showing flood characteristics along the reaches of North Platte, South Platte, Platte, and Republican Rivers. Also included are flood-frequency characteristics and drainage-basin and climate characteristics at gaging stations. Maximum observed peak discharges at gaging stations and miscellaneous sites are also listed.

Procedure

Topographic maps, figures 1-5 and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1

$$Q2 = 1.56Ac^{0.997} (P-13)^{1.952} L^{-0.794}$$
$$Q5 = 20.18Ac^{0.787} (P-13)^{1.396} L^{-0.631}$$
$$Q10 = 67.19Ac^{0.737} (P-13)^{1.149} L^{-0.608}$$
$$Q25 = 222.93Ac^{0.690} (P-13)^{0.905} L^{-0.573}$$
$$Q50 = 490.86Ac^{0.656} (P-13)^{0.742} L^{-0.543}$$
$$Q100 = 996.78Ac^{0.624} (P-13)^{0.588} L^{-0.512}$$

Region 2

$$Q2 = 0.63Ac^{0.797} S^{0.427} (I24,50-3)^{2.863}$$
$$Q5 = 0.51Ac^{0.824} S^{0.696} (I24,50-3)^{3.155}$$
$$Q10 = 0.49Ac^{0.839} S^{0.814} (I24,50-3)^{3.320}$$
$$Q25 = 0.50Ac^{0.854} S^{0.928} (I24,50-3)^{3.501}$$
$$Q50 = 0.51Ac^{0.864} S^{1.008} (I24,50-3)^{3.632}$$
$$Q100 = 0.55Ac^{0.872} S^{1.063} (I24,50-3)^{3.731}$$

Region 3

$$Q2 = 103Ac^{1.231} (T3-37)^{0.798} L^{-1.230}$$
$$Q5 = 266Ac^{1.095} (T3-37)^{0.760} L^{-1.050}$$
$$Q10 = 412Ac^{1.026} (T3-37)^{0.741} L^{-0.948}$$
$$Q25 = 646Ac^{0.952} (T3-37)^{0.727} L^{-0.838}$$
$$Q50 = 887Ac^{0.891} (T3-37)^{0.703} L^{-0.745}$$
$$Q100 = 1{,}162Ac^{0.843} (T3-37)^{0.686} L^{-0.671}$$

Region 4

$$Q2 = 1{,}774\, A^{1.226} (I24{,}50\text{-}5)^{1.831} L^{-1.380}$$
$$Q5 = 5{,}408\, A^{1.376} (I24{,}50\text{-}5)^{1.602} L^{-1.669}$$
$$Q10 = 8{,}475\, A^{1.451} (I24{,}50\text{-}5)^{1.491} L^{-1.783}$$
$$Q25 = 15{,}288\, A^{1.561} (I24{,}50\text{-}5)^{1.426} L^{-1.953}$$
$$Q50 = 22{,}301\, A^{1.650} (I24{,}50\text{-}5)^{1.382} L^{-2.081}$$
$$Q100 = 31{,}454\, A^{1.724} (I24{,}50\text{-}5)^{1.365} L^{-2.184}$$

Region 5

$$Q2 = 0.94\, Ac^{0.831} (T1\text{-}11)^{1.606} S^{0.501}$$
$$Q5 = 6.10\, Ac^{0.747} (T1\text{-}11)^{1.280} S^{0.430}$$
$$Q10 = 13.25\, Ac^{0.721} (T1\text{-}11)^{1.114} S^{0.443}$$
$$Q25 = 27.51\, Ac^{0.701} (T1\text{-}11)^{0.955} S^{0.482}$$
$$Q50 = 44.07\, Ac^{0.687} (T1\text{-}11)^{0.845} S^{0.521}$$
$$Q100 = 63.87\, Ac^{0.680} (T1\text{-}11)^{0.741} S^{0.572}$$

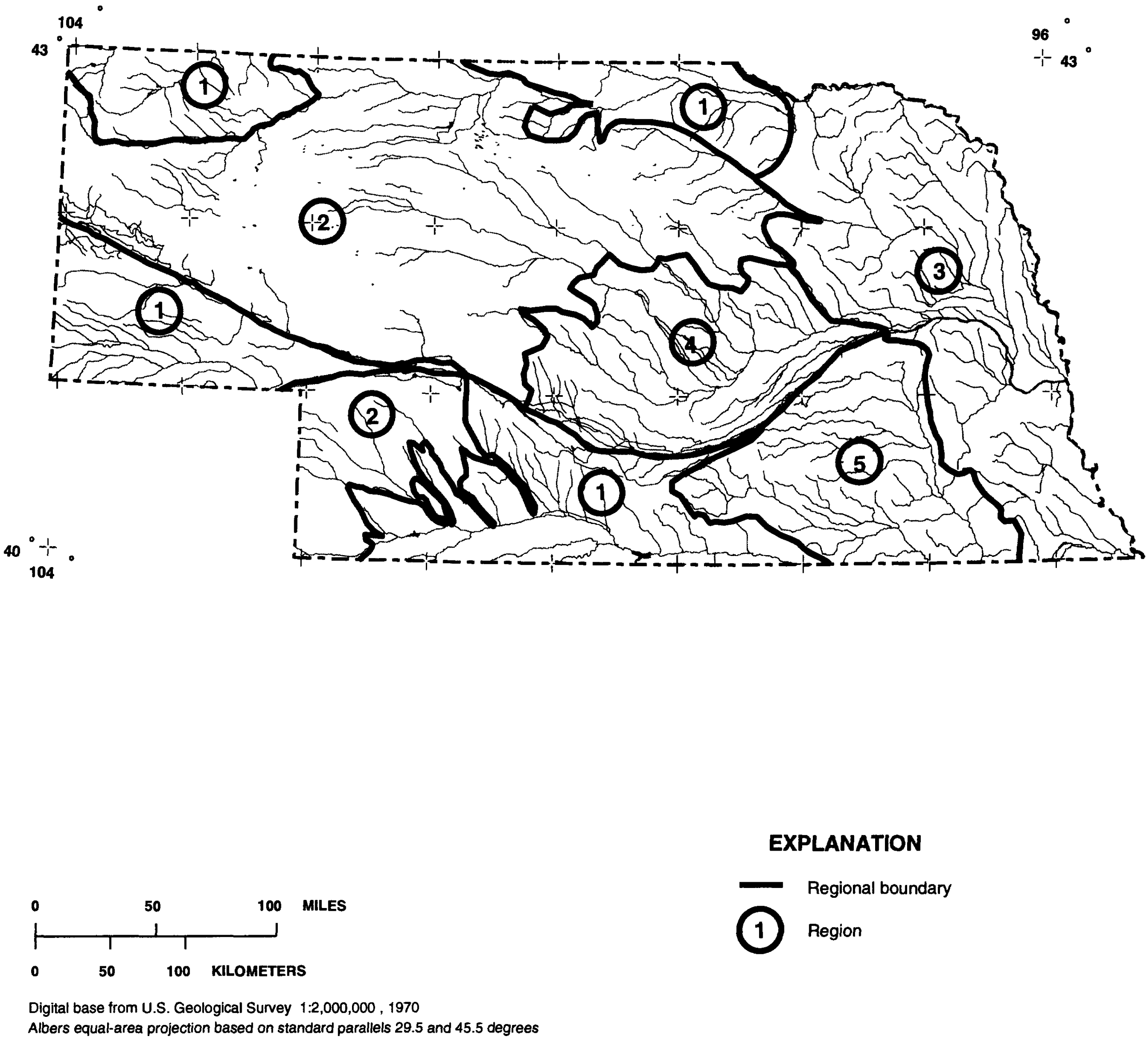


Figure 1. Flood-frequency region map for Nebraska.

Reference

Beckman, E.W., 1976, Magnitude and frequency of floods in Nebraska: U.S. Geological Survey Water-Resources Investigations Report 76-109, 128 p.

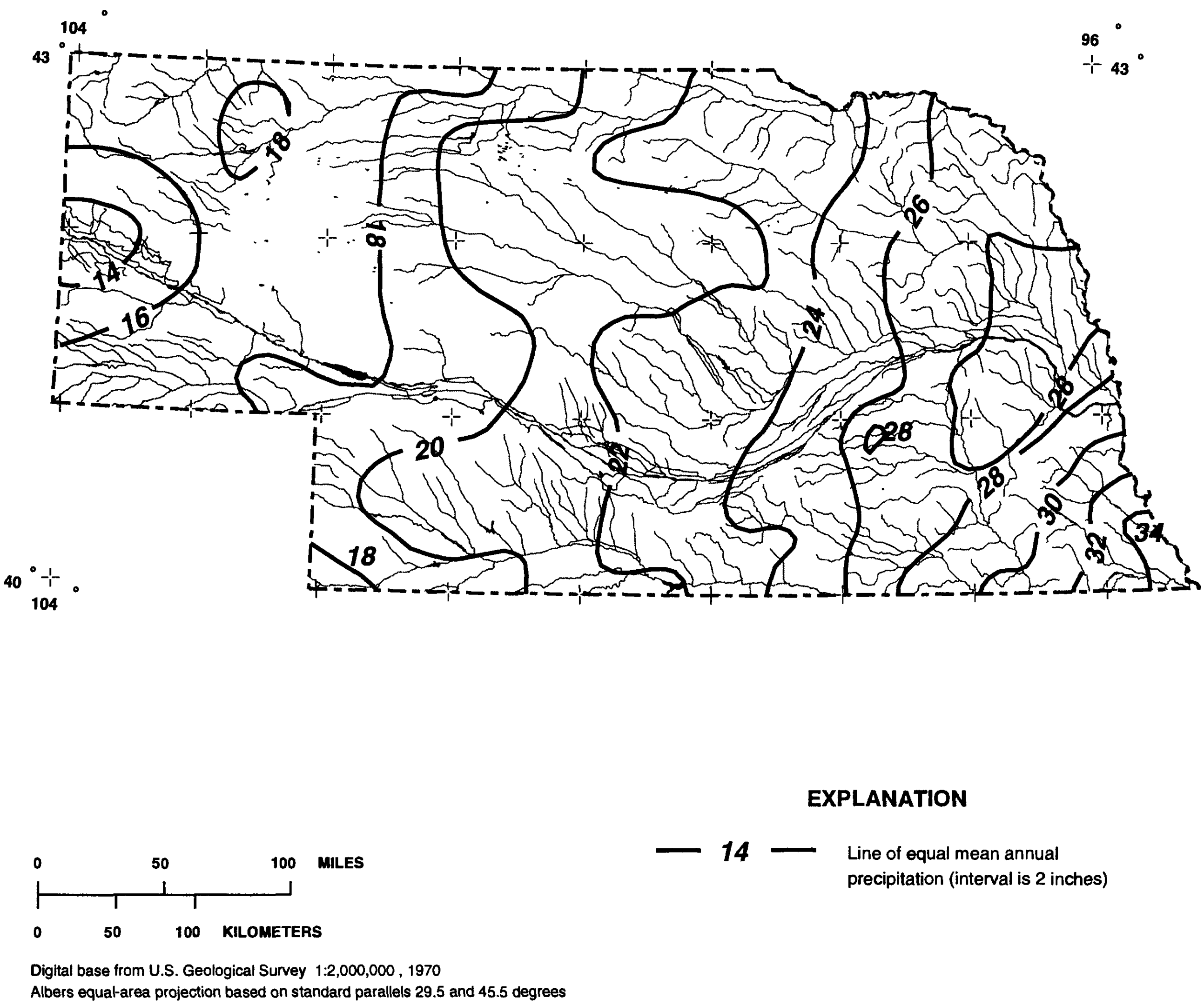
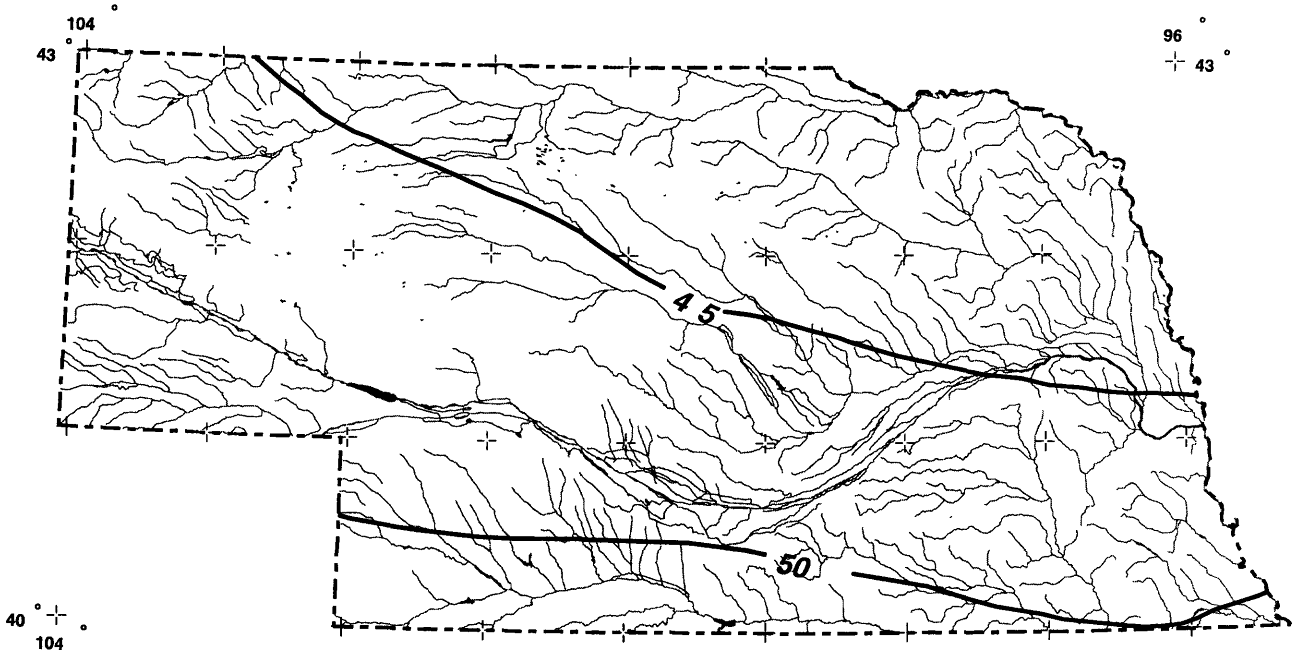


Figure 2. Mean annual precipitation in Nebraska.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albars equal-area projection based on standard parallels 29.5 and 45.5 degreas

EXPLANATION

— 45 — Line of equal normal daily maximum March temperature, in degrees Fahrenheit.

Figure 3. The normal daily maximum March temperature for Nebraska.

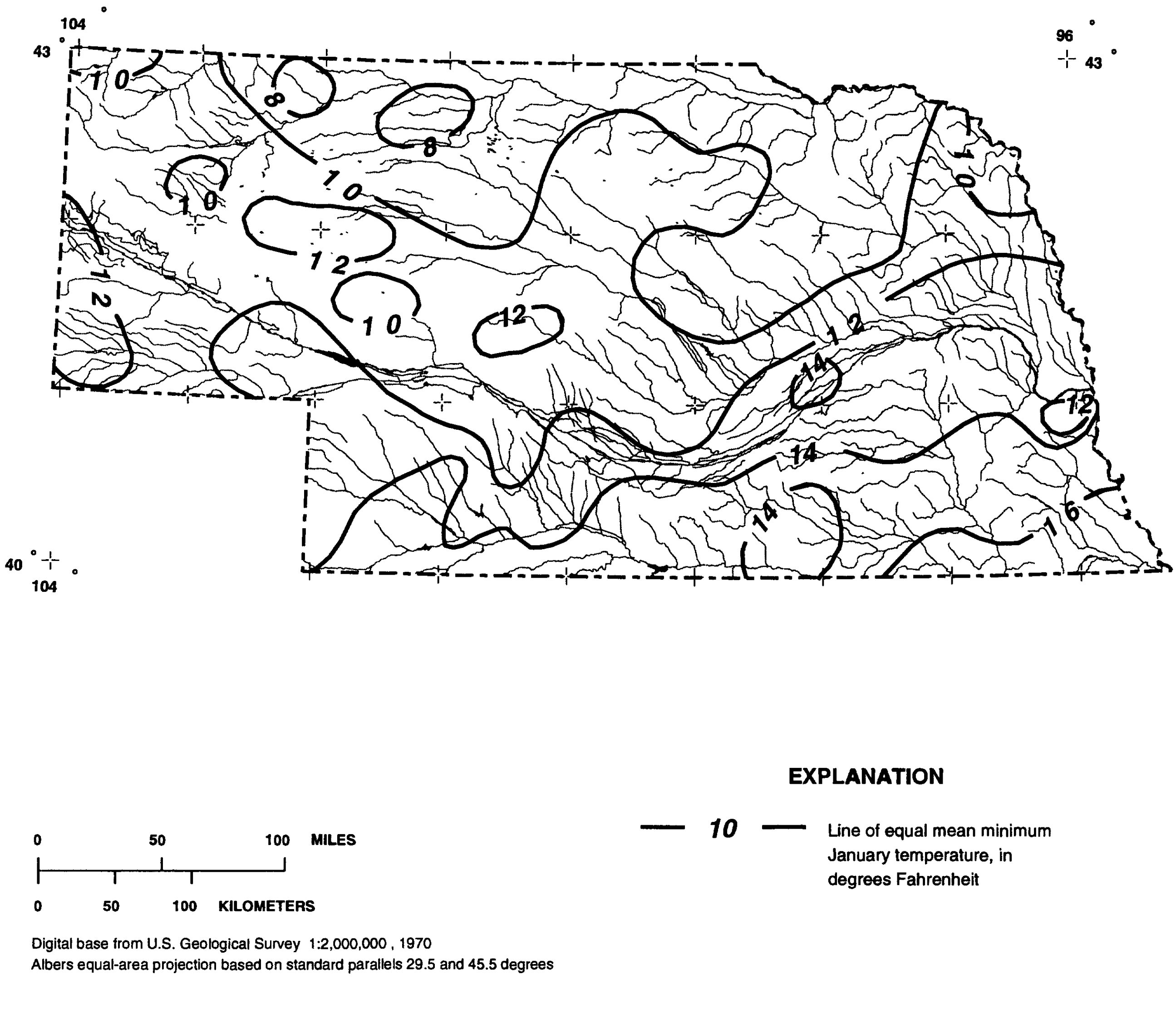
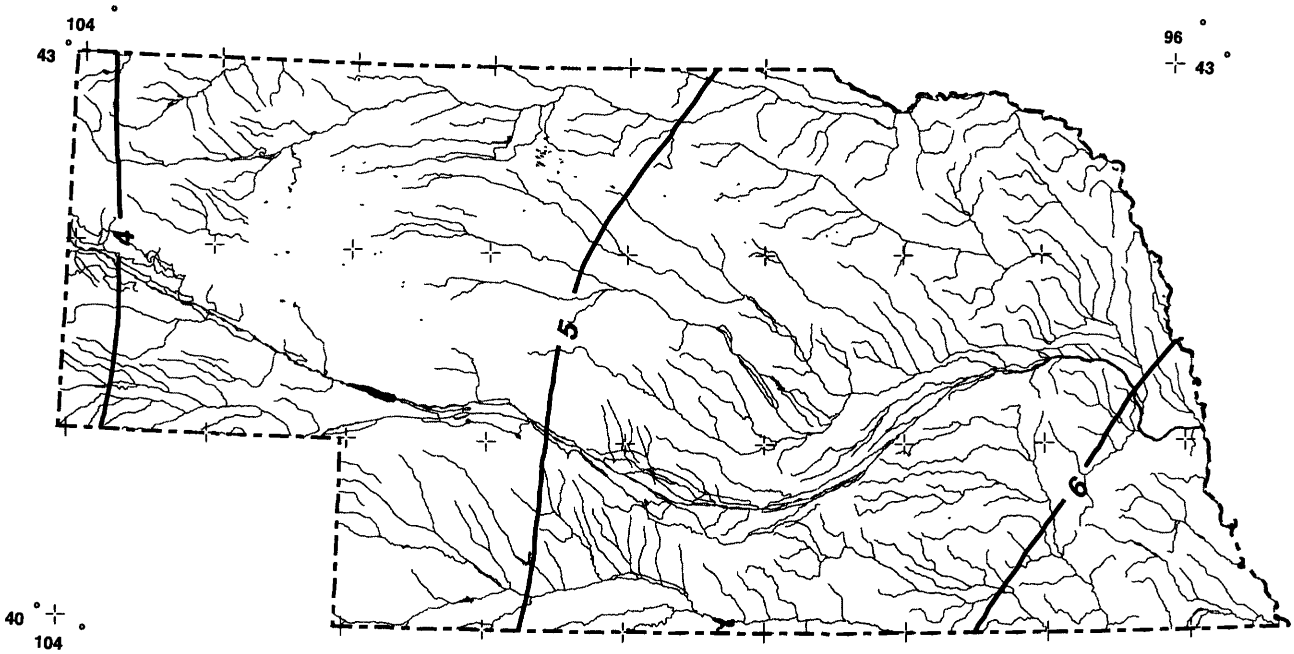


Figure 4. The mean minimum January temperature for Nebraska.



EXPLANATION

— 4 — Line of equal maximum 50 year, 24-hour precipitation (interval is 1 inch)

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 5. The 50-year 24-hour rainfall in Nebraska.

NEVADA

Summary

Christensen and Spahr (1980) evaluate the flood potential of streams in a small area in southern Nevada, but include regression equations for the 10-, 25-, 50-, and 100-year floods that are applicable statewide. The explanatory basin characteristics used in the equations are drainage area (A), in square miles; mean basin altitude (E), in thousands of feet; and latitude of basin (L), in degrees minus 35. The constant 35 is subtracted from L in the computer application of the regression equations. The user should enter the actual value of L. All these variables can be measured from topographic maps. Limits of applicability of the regression equations are $0.2<A<100$, $2<E<10$, and $36<L<42$.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q10 = 392A^{0.66}E^{-1.02}L^{-0.33}$$
$$Q25 = 1{,}810A^{0.61}E^{-1.14}L^{-0.70}$$
$$Q50 = 4{,}860A^{0.58}E^{-1.21}L^{-0.94}$$
$$Q100 = 11{,}900A^{0.55}E^{-1.28}L^{-1.16}$$

Reference

Christensen, R.C. and Spahr, N.E., 1980, Flood potential of Topopah Wash and tributaries, eastern part of Jackass Flats, Nevada Test Site, southern Nevada: U.S. Geological Survey Water-Resources Investigations Report 80-963, 22 p.

NEW HAMPSHIRE

STATEWIDE RURAL

Summary

New Hampshire is considered to be one hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; and the 2-year 24-hour precipitation (I2,24), in inches. The variables A and S can be measured from topographic maps, and I2,24 taken from the U.S. Weather Bureau Technical Paper (TP) 29 is shown (fig. 1).

The regression equations were developed from peak-discharge records for 59 stations. The equations are applicable to streams whose flows are not significantly affected by regulation, diversion or urbanization, and whose drainage areas are between 0.27 and 622 square miles. The standard errors of estimate of the regression equations range from 35 to 58 percent. The report by LeBlanc (1978) also includes selected basin and flood characteristics for gaging stations.

Procedure

Topographic maps, the 2-year 24-hour precipitation map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 1.34A^{1.06}S^{0.37}(I2,24)^{1.24}$$

$$Q5 = 1.00A^{1.06}S^{0.44}(I2,24)^{1.69}$$

$$Q10 = 0.84A^{1.06}S^{0.46}(I2,24)^{1.98}$$

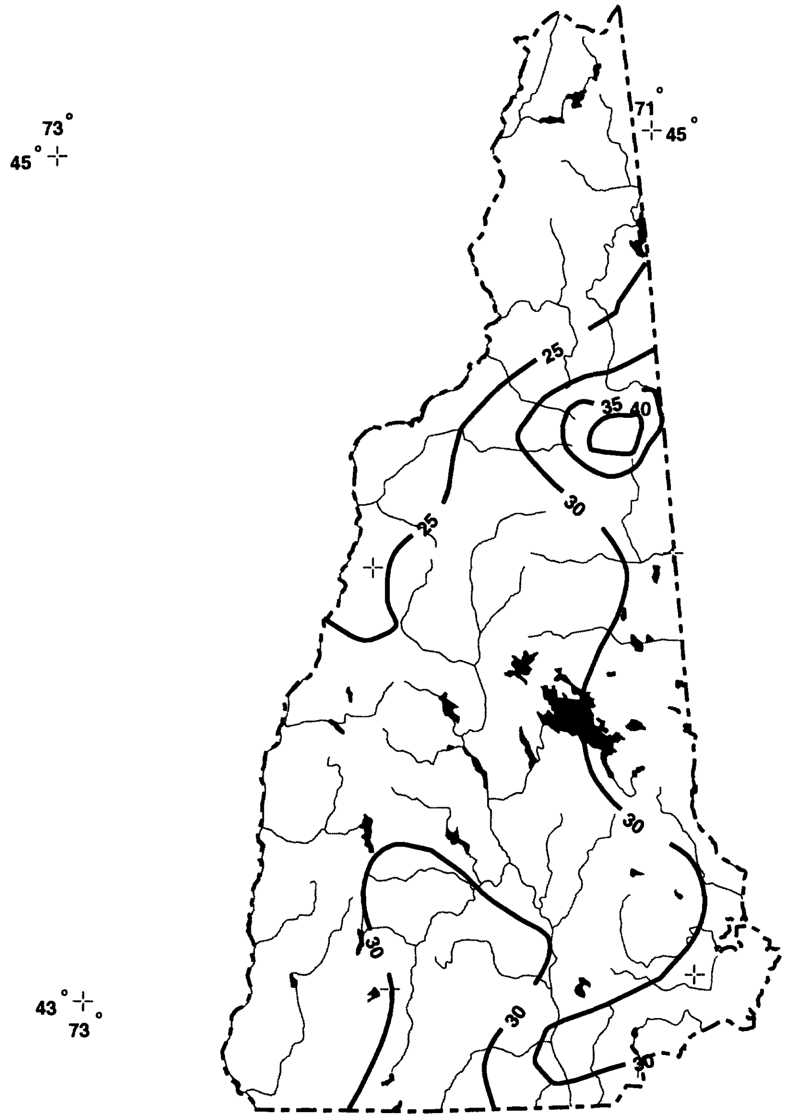
$$Q25 = 0.70A^{1.05}S^{0.52}(I2,24)^{2.29}$$

$$Q50 = 0.62A^{1.05}S^{0.54}(I2,24)^{2.50}$$

$$Q100 = 0.55A^{1.05}S^{0.56}(I2,24)^{2.72}$$

References

LeBlanc, D.R., 1978, Progress report on hydrologic investigations of small drainage areas in New Hampshire-Preliminary relations for estimating peak discharges on rural, unregulated streams: U.S. Geological Survey Water-Resources Investigations Report 78-47, 10 p.



0 25 50 MILES

0 25 50 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

—— 40 —— Line of equal 2-year, 24-hour precipitation (interval in tenths of inches).

Figure 1. The 2-year 24-hour precipitation in New Hampshire.

NEW JERSEY

STATEWIDE RURAL AND URBAN

Summary

New Jersey is treated as a single hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; storage area in basin (St) which is the percentage of the basin occupied by lakes and swamps; and impervious cover (I), in percent, which is a function of population density. The constant 1 is added to St and I in the computer application of the regression equations. The user should enter the actual values of St and I. The variables A, S, and St can be measured from topographic maps; the latter variable I requires data from census reports. The regression equations were developed from peak-discharge records through 1972 for 103 gaging stations where record lengths ranged from 6 to 74 years. The equations are applicable to non-tidal streams whose flow is not significantly affected by regulation or diversion and whose drainage areas are between 1 and 1,000 square miles. The regression equations do apply to urbanized areas. The standard errors of estimate of the regression equations range from 48 to 54 percent. The report by Stankowski (1974) includes the basin characteristics for the stations used in developing the relations, and a discussion of the effects of urbanization.

Procedure

Topographic maps, census data, and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Census data are available from regional, state, and local planning agencies.

$$Q2 = 25.6A^{0.89} S^{0.25} St^{-0.56} I^{0.25}$$
$$Q5 = 39.7A^{0.88} S^{0.26} St^{-0.54} I^{0.22}$$
$$Q10 = 54.0A^{0.88} S^{0.27} St^{-0.53} I^{0.20}$$
$$Q25 = 78.2A^{0.86} S^{0.27} St^{-0.52} I^{0.18}$$
$$Q50 = 104A^{0.85} S^{0.26} St^{-0.51} I^{0.16}$$
$$Q100 = 136A^{0.84} S^{0.26} St^{-0.51} I^{0.14}$$

$$I = 0.117D^{0.792 - 0.039 \log D};$$

where D = basin population density in persons per square mile.

Reference

Stankowski, S.J., 1974, Magnitude and frequency of floods in New Jersey with affects of urbanization: New Jersey Department of Environmental Protection, Division of Water Resources, Special Report 38, 46 p.

NEW MEXICO

STATEWIDE RURAL

Summary

New Mexico is divided into eight hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean basin elevation (E), in feet; 24-hour rainfall (I24), in inches, for recurrence intervals of 10-, 25-, 50- and 100-years; average of channel elevation (Ec), in feet, which is the average of elevations at points 10 and 85 percent of stream length upstream from site; and mean minimum January temperature (T), in degrees Fahrenheit (fig. 2). The variables E and Ec are divided by 1000 in the computer application of the regression equations. The user should enter the actual values of E and Ec. The 24-hour rainfall (I24) for various recurrence intervals can be obtained from National Oceanic and Atmospheric Administration (NOAA) Atlas 2 (Miller and others, 1973) and T can be taken from figure 2. The rest of the variables can be measured from topographic maps. The regression equations were developed from peak-discharge records for 219 stations with 10 or more years of record as of 1982 and are applicable to unregulated streams, except those with unusual topographic or geologic characteristics. The standard errors of estimate of the regression equations range from 44 to 81 percent for the 100-year flood. The report by Waltemeyer (1986) also lists basin characteristics at gaging stations.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean minimum January temperature (fig. 2), the 24-hour rainfall for various recurrence intervals from NOAA Atlas 2 for New Mexico, and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Northeast plains region (1)

$$Q2 = 110A^{0.56}$$
$$Q5 = 282A^{0.55}$$
$$Q10 = 446A^{0.55}$$
$$Q25 = 714A^{0.55}$$
$$Q50 = 956A^{0.55}$$
$$Q100 = 1{,}230A^{0.56}$$

Northwest plateau region (2)

$$Q2 = 80.3A^{0.52}$$
$$Q5 = 205A^{0.47}$$
$$Q10 = 336A^{0.44}$$
$$Q25 = 570A^{0.41}$$
$$Q50 = 803A^{0.39}$$
$$Q100 = 1{,}090A^{0.37}$$

Southeast mountain region (3)

$$Q2 = 35{,}400A^{0.56}(E/1000)^{-2.32}\, I24{,}2^{-3.25}$$
$$Q5 = 14{,}100A^{0.59}(E/1000)^{-2.34}$$
$$Q10 = 34{,}500A^{0.61}(E/1000)^{-2.55}$$
$$Q25 = 86{,}400A^{0.63}(E/1000)^{-2.77}$$
$$Q50 = 154{,}000A^{0.64}(E/1000)^{-2.90}$$
$$Q100 = 257{,}000A^{0.65}(E/1000)^{-3.02}$$

Southwest plains region (4)

$$Q2 = 463A^{0.66}(E/1000)^{2.12}\, I24{,}100^{-4.31}$$
$$Q5 = 676A^{0.58}(E/1000)^{1.65}\, I24{,}100^{-3.13}$$
$$Q10 = 840A^{0.54}(E/1000)^{1.40}\, I24{,}100^{-2.50}$$
$$Q25 = 41.3A^{0.47}(E/1000)^{1.45}$$
$$Q50 = 108A^{0.45}(E/1000)^{1.18}$$
$$Q100 = 1{,}370A^{0.44}$$

Northern mountain region (5)

$$Q2 = 17{,}900A^{0.80}(E/1000)^{-3.37}$$
$$Q5 = 58{,}500A^{0.79}(E/1000)^{-4.00}\ I24{,}100^{0.75}$$
$$Q10 = 162{,}000A^{0.78}(E/1000)^{-4.35}\ I24{,}100^{0.86}$$
$$Q25 = 775{,}000A^{0.78}(E/1000)^{-4.79}\ I24{,}10^{1.03}$$
$$Q50 = 1{,}120{,}000A^{0.78}(E/1000)^{-4.97}\ I24{,}25^{1.12}$$
$$Q100 = 1{,}850{,}000A^{0.77}(E/1000)^{-5.18}\ I24{,}50^{1.21}$$

Central mountain-valley region (6)

$$Q2 = 55{,}200A^{0.47}(Ec/1000)^{-4.05}\ I24{,}10^{1.79}$$
$$Q5 = 170{,}000A^{0.44}(Ec/1000)^{-4.13}\ I24{,}10^{1.67}$$
$$Q10 = 289{,}000A^{0.42}(Ec/1000)^{-4.14}\ I24{,}10^{1.59}$$
$$Q25 = 497{,}000A^{0.40}(Ec/1000)^{-4.13}\ I24{,}10^{1.51}$$
$$Q50 = 685{,}000A^{0.39}(Ec/1000)^{-4.11}\ I24{,}10^{1.45}$$
$$Q100 = 896{,}000A^{0.38}(Ec/1000)^{-4.09}\ I24{,}10^{1.40}$$

Southwest desert region (7)

$$Q2 = 107A^{0.48}$$
$$Q5 = 236A^{0.48}$$
$$Q10 = 355A^{0.48}$$
$$Q25 = 548A^{0.48}$$
$$Q50 = 725A^{0.48}$$
$$Q100 = 932A^{0.48}$$

Southwest mountain region (8)

$$Q2 = 0.72A^{0.24}T^{1.87}$$
$$Q5 = 4.28A^{0.24}T^{1.52}$$
$$Q10 = 11.3A^{0.24}T^{1.33}$$

Q25 = No relation

Q50 = No relation

Q100 = No relation

Reference

Waltemeyer, S.D., 1986, Techniques for estimating flood-flow frequency for unregulated streams in New Mexico: U.S. Geological Survey Water-Resources Investigations Report 86-4104, 56 p.

Additional Reference

Miller, J.F., Frederick, R.H., and Tracey, R.J., 1973, Precipitation-frequency atlas of the western United States: NOAA Atlas 2 Volume IV - New Mexico, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Silver Spring, MD.

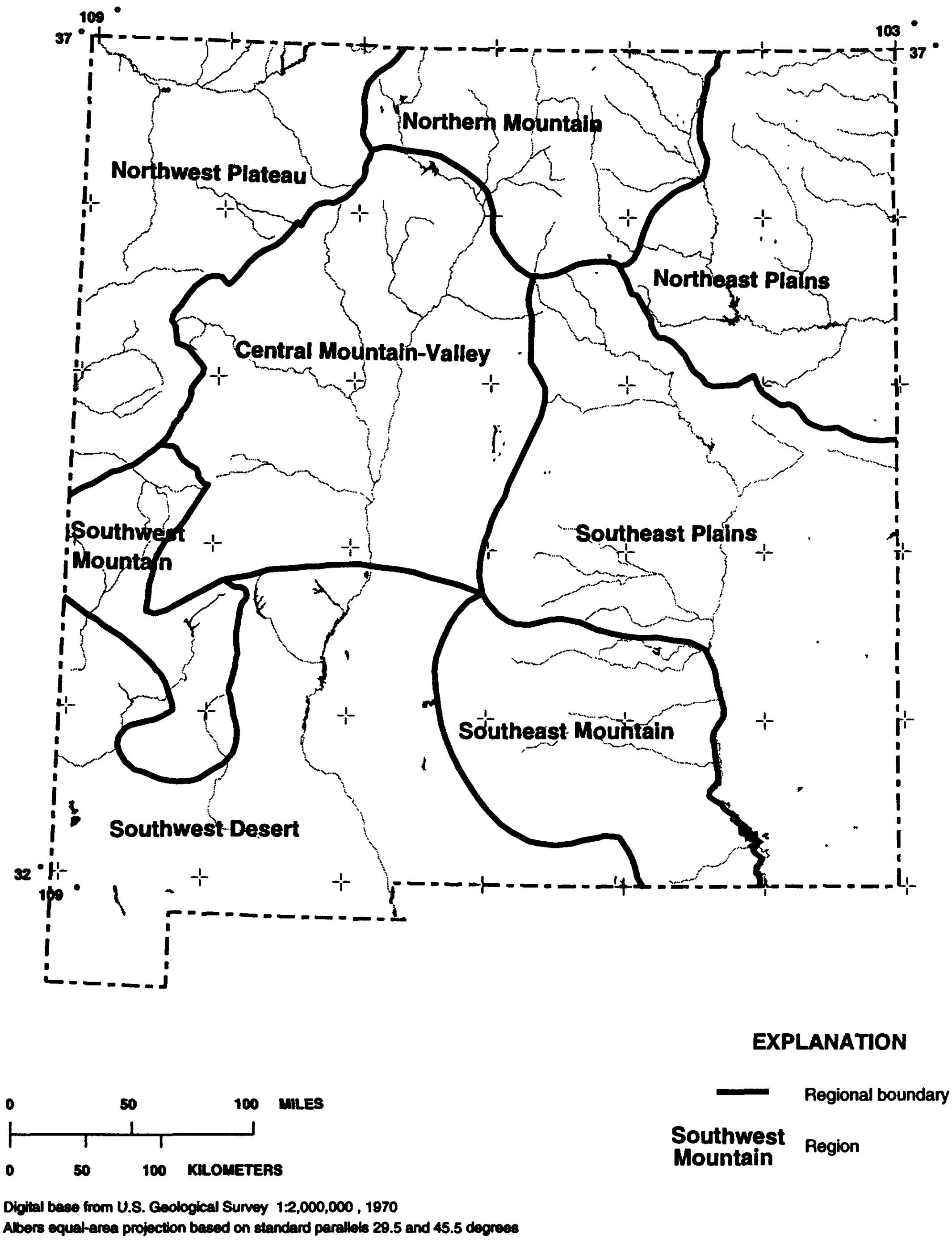
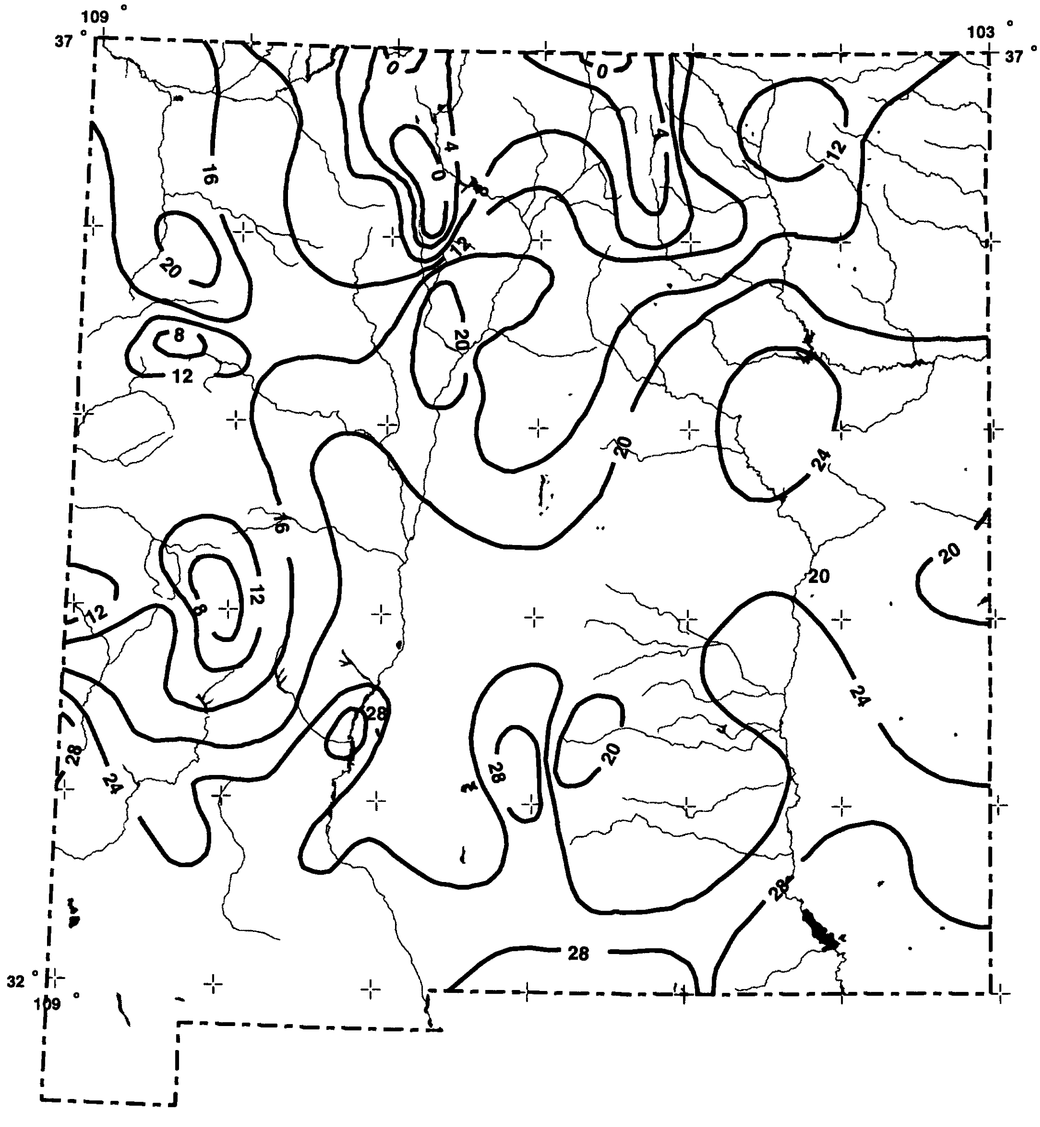


Figure 1. Flood-frequency region map for New Mexico.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— 20 — Line of equal mean minmum January temperature, in degrees Fahrenheit.

Figure 2. Mean minimum January temperature in New Mexico.

NEW YORK

STATEWIDE RURAL, EXCLUDING LONG ISLAND

Summary

New York, exclusive of Long Island, is divided into eight hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; basin storage (ST), the percentage of the drainage area shown as lakes, ponds, or swamps on topographic maps; mean annual precipitation (P), in inches; main-channel slope (SL), in feet per mile; basin forest cover (F), as a percentage of the total drainage area; average main-channel elevation (EL), in feet, computed as the average of the elevations at points located 10 and 85 percent of the channel length upstream from the gage; and basin shape index (SH), computed as the ratio of the square of the main-channel stream length, in miles, to drainage area, in square miles. The constants 5, 1, -20, and 10 are added to St, P and F in the computer application of the regression equations. The user should enter the actual values of St, P and F. All the variables except P can be measured from topographic maps; P can be obtained from figure 2. The regression equations were developed from peak-discharge records available as of 1987 at 313 stations (29 of which were in adjacent States) with the equations applicable only to unregulated, rural streams in New York, excluding Long Island. The standard errors of prediction of the regression equations range from 17 to 51 percent. The report by Lumia (1991) also includes basin and flood-frequency characteristics and maximum known discharges at gaging stations. Alternative regression equations based only on drainage area are also included in Lumia (1991).

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation map (fig. 2) and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1

$$Q2 = 34.9\,(A)^{0.909}\,(ST+5)^{-0.489}\,(P-20)^{1.047}\,(F+10)^{-0.420}$$

$$Q5 = 84.4\,(A)^{0.890}\,(ST+5)^{-0.513}\,(P-20)^{0.984}\,(F+10)**\text{-}0.466$$

$$Q10 = 130\,(A)^{0.881}\,(ST+5)^{-0.526}\,(P-20)^{0.961}\,(F+10)**\text{-}0.490$$

$$Q25 = 197\,(A)^{0.872}\,(ST+5)^{-0.538}\,(P-20)^{0.937}\,(F+10)**\text{-}0.506$$

$$Q50 = 250\,(A)^{0.868}\,(ST+5)^{-0.544}\,(P-20)^{0.919}\,(F+10)^{-0.510}$$

$$Q100 = 306\,(A)^{0.864}\,(ST+5)^{-0.548}\,(P-20)^{0.899}\,(F+10)^{-0.508}$$

$$Q500 = 441\,(A)^{0.858}\,(ST+5)^{-0.553}\,(P-20)^{0.853}\,(F+10)^{-0.496}$$

Region 2

$$Q2 = 3.87\,(A)^{0.905}\,(SL)^{0.260}\,(ST+1)^{-0.160}\,(P-20)^{0.976}\,(EL)^{-0.219}$$

$$Q5 = 7.09\,(A)^{0.896}\,(SL)^{0.257}\,(ST+1)^{-0.189}\,(P-20)^{1.000}\,(EL)^{-0.255}$$

$$Q10 = 9.77\,(A)^{0.891}\,(SL)^{0.251}\,(ST+1)^{-0.209}\,(P-20)^{1.019}\,(EL)^{-0.273}$$

$$Q25 = 13.5\,(A)^{0.888}\,(SL)^{0.242}\,(ST+1)^{-0.236}\,(P-20)^{1.046}\,(EL)^{-0.291}$$

$$Q50 = 16.3\,(A)^{0.887}\,(SL)^{0.236}\,(ST+1)^{-0.256}\,(P-20)^{1.066}\,(EL)^{-0.302}$$

$$Q100 = 19.1\,(A)^{0.887}\,(SL)^{0.230}\,(ST+1)^{-0.275}\,(P-20)^{1.086}\,(EL)^{-0.311}$$

$$Q500 = 25.6\,(A)^{0.889}\,(SL)^{0.218}\,(ST+1)^{-0.318}\,(P-20)^{1.134}\,(EL)^{-0.327}$$

Region 3

$$Q2 = 45.6\,(A)^{0.723}\,(ST+1)^{-0.390}\,(P-20)^{0.491}\,(SH)^{-0.273}$$

$$Q5 = 33.0\,(A)^{0.718}\,(ST+1)^{-0.405}\,(P-20)^{0.806}\,(SH)^{-0.347}$$

$$Q10 = 29.2\,(A)^{0.717}\,(ST+1)^{-0.424}\,(P-20)^{0.977}\,(SH)^{-0.401}$$

$$Q25 = 27.4\,(A)^{0.717}\,(ST+1)^{-0.452}\,(P-20)^{1.155}\,(SH)^{-0.470}$$

$$Q50 = 27.5\,(A)^{0.717}\,(ST+1)^{-0.475}\,(P-20)^{1.263}\,(SH)^{-0.521}$$

$$Q100 = 28.5\,(A)^{0.718}\,(ST+1)^{-0.499}\,(P-20)^{1.354}\,(SH)^{-0.571}$$

$$Q500 = 33.1\,(A)^{0.722}\,(ST+1)^{-0.557}\,(P-20)^{1.529}\,(SH)^{-0.682}$$

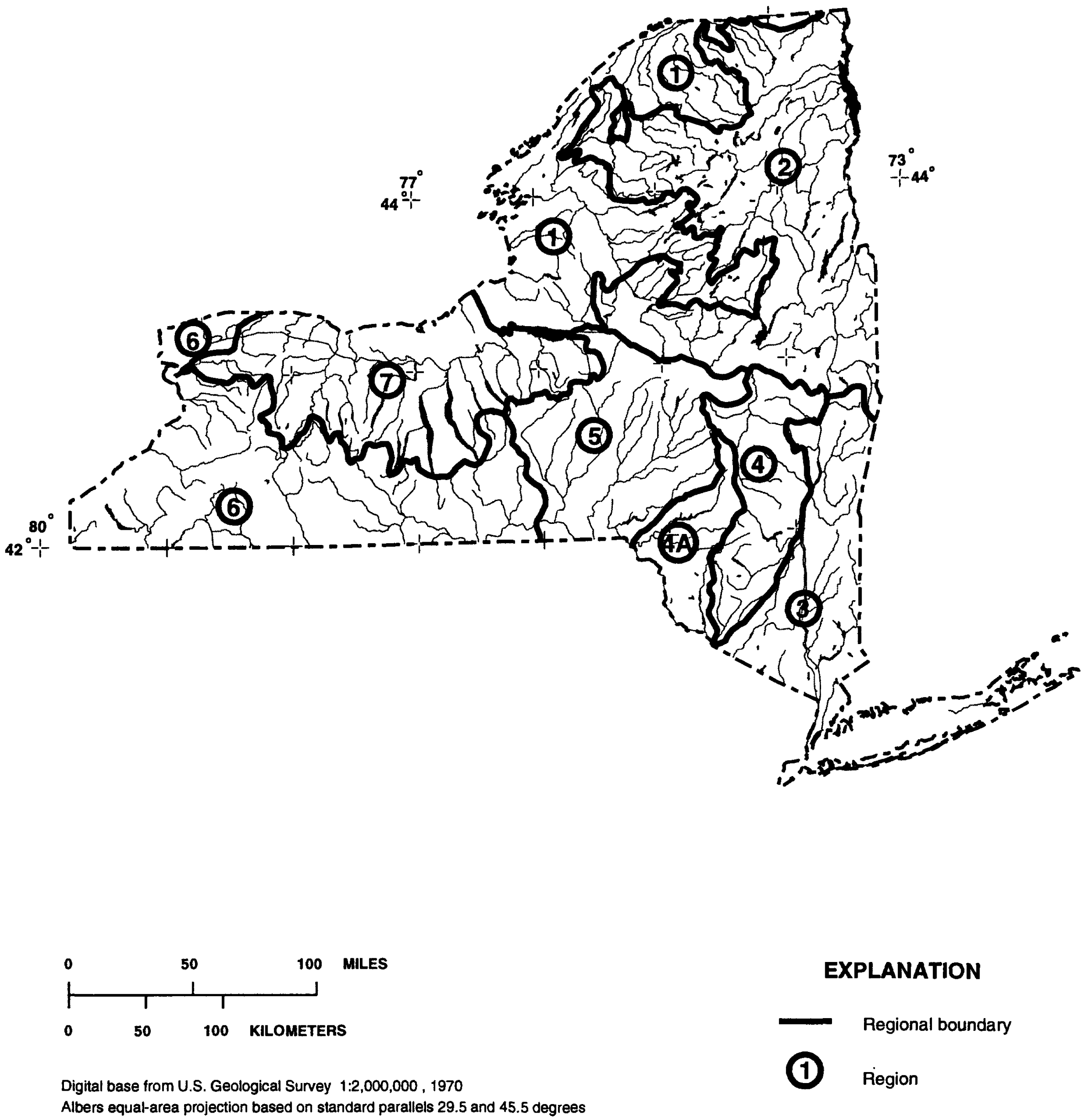


Figure 1. Flood-frequency regional map for New York.

Region 4

$$Q2 = 14.1\,(A)^{0.880}\,(ST+1)^{-0.225}\,(P-20)^{0.614}$$
$$Q5 = 17.2\,(A)^{0.852}\,(ST+1)^{-0.294}\,(P-20)^{0.771}$$
$$Q10 = 19.6\,(A)^{0.835}\,(ST+1)^{-0.335}\,(P-20)^{0.853}$$
$$Q25 = 22.3\,(A)^{0.816}\,(ST+1)^{-0.381}\,(P-20)^{0.948}$$
$$Q50 = 24.0\,(A)^{0.804}\,(ST+1)^{-0.410}\,(P-20)^{1.014}$$
$$Q100 = 25.3\,(A)^{0.794}\,(ST+1)^{-0.435}\,(P-20)^{1.075}$$
$$Q500 = 27.5\,(A)^{0.774}\,(ST+1)^{-0.482}\,(P-20)^{1.205}$$

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

—— 20 —— Line of equal mean annual precipitation, (interval, in inches, is variable)

Figure 2. Mean annual precipitation in New York.

Region 4A

$$Q2 = 2.09\,(A)^{0.904}\,(P\text{-}20)^{1.051}$$
$$Q5 = 2.18\,(A)^{0.879}\,(P\text{-}20)^{1.207}$$
$$Q10 = 2.35\,(A)^{0.865}\,(P\text{-}20)^{1.278}$$
$$Q25 = 2.55\,(A)^{0.850}\,(P\text{-}20)^{1.354}$$
$$Q50 = 2.64\,(A)^{0.841}\,(P\text{-}20)^{1.407}$$
$$Q100 = 2.68\,(A)^{0.833}\,(P\text{-}20)^{1.459}$$
$$Q500 = 2.62\,(A)^{0.821}\,(P\text{-}20)^{1.574}$$

Region 5

$$Q2 = 20.3\,(A)^{0.971}\,(SL)^{0.232}\,(ST+1)^{-0.176}\,(SH)^{-0.093}$$
$$Q5 = 26.4\,(A)^{0.979}\,(SL)^{0.272}\,(ST+1)^{-0.189}\,(SH)^{-0.130}$$
$$Q10 = 30.2\,(A)^{0.981}\,(SL)^{0.295}\,(ST+1)^{-0.196}\,(SH)^{-0.141}$$
$$Q25 = 35.2\,(A)^{0.980}\,(SL)^{0.316}\,(ST+1)^{-0.204}\,(SH)^{-0.147}$$
$$Q50 = 39.2\,(A)^{0.978}\,(SL)^{0.329}\,(ST+1)^{-0.211}\,(SH)^{-0.150}$$
$$Q100 = 43.4\,(A)^{0.976}\,(SL)^{0.339}\,(ST+1)^{-0.217}\,(SH)^{-0.152}$$
$$Q500 = 53.5\,(A)^{0.972}\,(SL)^{0.357}\,(ST+1)^{-0.231}\,(SH)^{-0.158}$$

Region 6

$$Q2 = 8.80\,(A)^{0.870}\,(SL)^{0.233}\,(ST+1)^{-0.217}\,(P\text{-}20)^{0.481}$$
$$Q5 = 13.3\,(A)^{0.869}\,(SL)^{0.302}\,(ST+1)^{-0.216}\,(P\text{-}20)^{0.408}$$
$$Q10 = 16.2\,(A)^{0.869}\,(SL)^{0.334}\,(ST+1)^{-0.217}\,(P\text{-}20)^{0.379}$$
$$Q25 = 19.7\,(A)^{0.869}\,(SL)^{0.360}\,(ST+1)^{-0.220}\,(P\text{-}20)^{0.360}$$
$$Q50 = 22.1\,(A)^{0.869}\,(SL)^{0.374}\,(ST+1)^{-0.224}\,(P\text{-}20)^{0.356}$$
$$Q100 = 24.1\,(A)^{0.870}\,(SL)^{0.385}\,(ST+1)^{-0.228}\,(P\text{-}20)^{0.359}$$
$$Q500 = 27.5\,(A)^{0.872}\,(SL)^{0.406}\,(ST+1)^{-0.244}\,(P\text{-}20)^{0.380}$$

Region 7

$$Q2 = 92.3(A)^{0.998}(SL)^{0.460}(ST+1)^{-0.311}(P\text{-}20)^{0.737}(EL)^{-0.755}(SH)^{0.243}$$
$$Q5 = 98.7(A)^{1.005}(SL)^{0.509}(ST+1)^{-0.311}(P\text{-}20)^{0.829}(EL)^{-0.784}(SH)^{0.267}$$
$$Q10 = 94.5(A)^{1.009}(SL)^{0.528}(ST+1)^{-0.312}(P\text{-}20)^{0.892}(EL)^{-0.788}(SH)^{0.275}$$
$$Q25 = 83.7(A)^{1.014}(SL)^{0.543}(ST+1)^{-0.312}(P\text{-}20)^{0.964}(EL)^{-0.781}(SH)^{0.281}$$
$$Q50 = 74.5(A)^{1.019}(SL)^{0.550}(ST+1)^{-0.313}(P\text{-}20)^{1.011}(EL)^{-0.770}(SH)^{0.828}$$
$$Q100 = 65.6(A)^{1.025}(SL)^{0.555}(ST+1)^{-0.313}(P\text{-}20)^{1.054}(EL)^{-0.758}(SH)^{0.283}$$
$$Q500 = 48.4(A)^{1.038}(SL)^{0.568}(ST+1)^{-0.313}(P\text{-}20)^{1.148}(EL)^{-0.730}(SH)^{0.281}$$

Reference

Lumia, R., 1991, Regionalization of flood discharges for rural, unregulated streams in New York, excluding Long Island: U.S. Geological Survey Water-Resources Investigations Report 90-4197, 119 p.

NEW YORK URBAN

Stedfast (1986) investigated the applicability of six methods of estimating urban flood-frequency characteristics at 11 urban watersheds in New York. The conclusion was that the urban equations described in Sauer and others (1983) yielded the smallest standard errors and bias in relation to flood peaks based on a rainfall-runoff model at the 11 urban watersheds. The method of Sauer and others (1983) is available in the NFF Program.

Reference

Stedfast, D.A., 1986, Evaluation of six methods for estimating magnitude and frequency of peak discharges on urban streams in New York: U.S. Geological Survey Water-Resources Investigations Report 84-4350, 24 p.

NORTH CAROLINA

STATEWIDE RURAL

Summary

North Carolina is divided into three hydrologic regions (fig. 1). The regression equations developed are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. Drainage area (A), in square miles, the only explanatory basin variable used, can be measured from topographic maps. The regression equations were developed from peak-discharge records available through 1984 at 254 gaging stations, and the equations are applicable to rural, unregulated streams. The average standard errors of estimate of the regression equations for the Blue Ridge-Piedmont, Coastal Plain, and Sandhills regions are 44, 39, and 26 percent, respectively. The report by Gunter and others (1987) examines the applicability of methods for estimating flood-frequency characteristics of urban streams as described by Sauer and others (1983), to the Coastal Plain and Piedmont regions of North Carolina. It was concluded that the urban equations described in Sauer and others (1983) were applicable to streams in the Coastal Plain, but that the data were not adequate to determine applicability to the Piedmont region. The report by Gunter and others (1987) includes flood-frequency characteristics at gaging stations used in the analysis.

	Sand Hills	Coastal Plain	Blue Ridge-Piedmont
Q2	$29.7A^{0.733}$	$69.4A^{0.632}$	$144A^{0.691}$
Q5	$48.8A^{0.738}$	$149\ A^{0.582}$	$248A^{0.670}$
Q10	$64.4A^{0.740}$	$225\ A^{0.559}$	$334A^{0.665}$
Q25	$86.2A^{0.751}$	$362\ A^{0.532}$	$467A^{0.655}$
Q50	$105\ A^{0.757}$	$490\ A^{0.514}$	$581A^{0.650}$
Q100	$126\ A^{0.763}$	$653\ A^{0.497}$	$719A^{0.643}$

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Reference

Gunter, H.C., Mason, R.R., and Stamey, T.C., 1987, Magnitude and frequency of floods in rural and urban basins of North Carolina: U.S. Geological Survey Water-Resources Investigations Report 87-4096, 52 p.

NORTH CAROLINA PIEDMONT URBAN

Putnam (1972) provides regression equations for estimating peak discharges with recurrence intervals ranging up to 100 years for urban stream in the Piedmont of North Carolina. The explanatory basin variables used in the equations are drainage area (A), in square miles; length of main watercourse (L), in miles; bed slope of the main watercourse (S) in feet per mile; and ratio of area of basin covered by impervious surfaces (I) to total basin area. The variables A, S and L can be measured from topographic maps; the latter variable I should be determined from the latest aerial photographs. The equations apply to unregulated streams in the Piedmont having drainage areas less than 150 square miles, where the $(L/S^{.50})$ ratio ranges between 0.1 to 0.9 and where impervious cover of less than 30 percent is uniformly distributed over the basin.

Procedure

Topographic maps, aerial photographs and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 221\ A^{0.87}\ T^{-0.60}$$
$$Q5 = 405\ A^{0.80}\ T^{-0.52}$$
$$Q10 = 560\ A^{0.76}\ T^{-0.48}$$
$$Q25 = 790\ A^{0.71}\ T^{-0.42}$$
$$Q50 = 990\ A^{0.67}\ T^{-0.37}$$
$$Q100 = 1{,}200\ A^{0.63}\ T^{-0.33}$$

where

$$T = 0.49\ (L/S^{50})^{0.50}\ I^{-0.57}$$

where T is lag time, in hours, (defined earlier in the section Flood Hydrograph Estimation).

Standard errors of the regression equations for Q2, Q5, Q10 and Q25 range from 30 to 35 percent. Equations for Q50 and Q100 were obtained by extrapolation.

Reference

Putnam, A.L., 1972, Effect of urban development on floods in the Piedmont province of North Carolina: U.S. Geological Survey Open-File Report, 87 p.

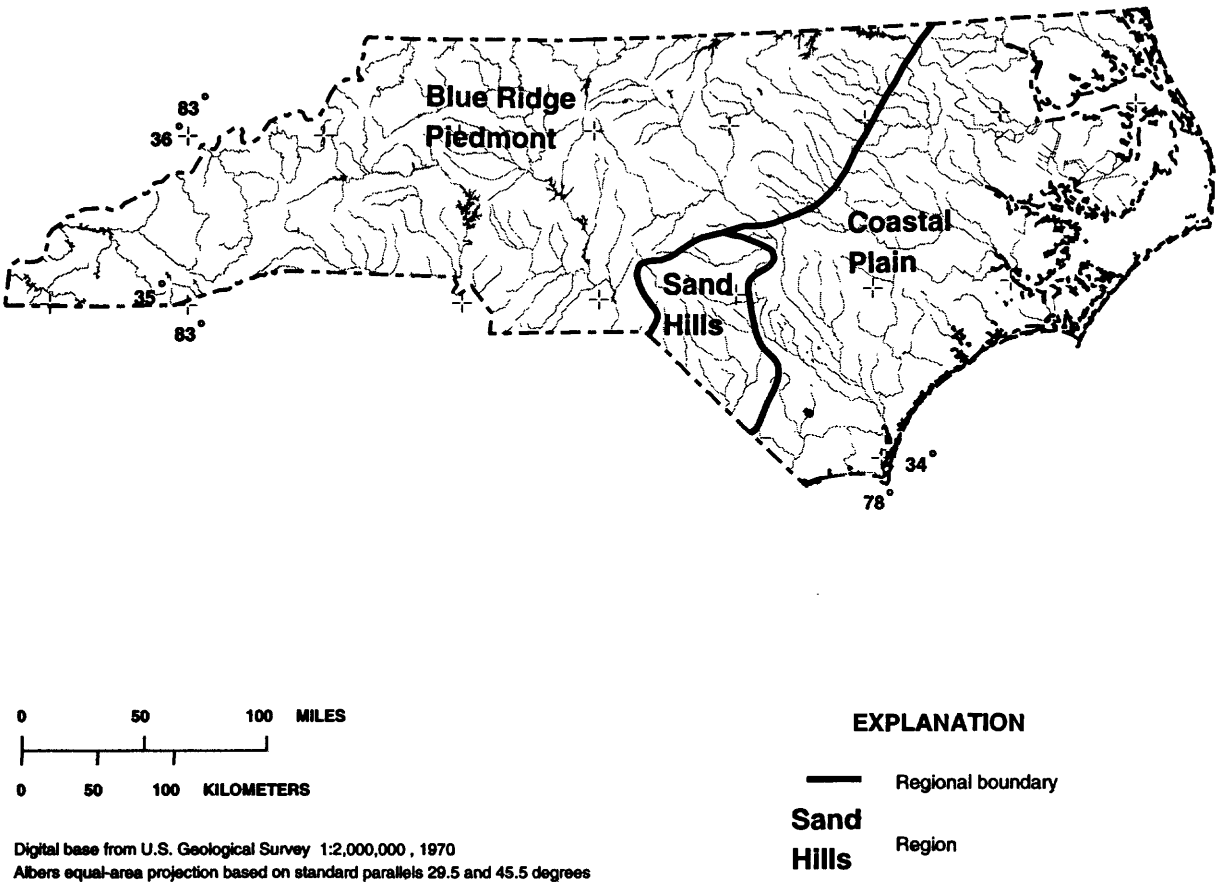


Figure 1. Flood-frequency region map for North Carolina.

NORTH DAKOTA

STATEWIDE RURAL

Summary

North Dakota is divided into three hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are contributing drainage area (CA), in square miles; and main channel slope (S), in feet per mile. The regression equations were developed from peak-discharge records available for 192 continuous- and partial-record streamflow gaging stations and are applicable to rural, unregulated streams draining 1,000 square miles or less. The standard errors of estimate for the regression equations range from 55 to 98 percent. The equivalent years of record range from 2.0 to 12.0 years. The report by Williams-Sether (1992) includes basin and flood-frequency characteristics of the streams used to define the peak-flow relations. The report also includes basin and flood-frequency characteristics of streams with drainage areas over 1,000 square miles and that were not used to define the peak-flow regression relations.

Procedure

Use topographic maps, the hydrologic regions map (fig. 1) and the following regression equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region A				
Q2	$= 24.9\ CA^{0.543}S^{0.094}$	60	64	3.1
Q10	$= 62.2\ CA^{0.600}S^{0.168}$	55	60	5.0
Q15	$= 70.9\ CA^{0.609}S^{0.181}$	56	60	5.6
Q25	$= 81.6\ CA^{0.619}S^{0.197}$	57	61	6.3
Q50	$= 95.9\ CA^{0.631}S^{0.217}$	58	64	7.1
Q100	$= 110\ CA^{0.640}S^{0.234}$	60	66	7.8
Q500	$= 142\ CA^{0.656}S^{0.268}$	67	73	8.7
Region B				
Q2	$= 7.68\ CA^{0.697}S^{0.299}$	83	88	2.3
Q10	$= 32.7\ CA^{0.716}S^{0.294}$	60	64	5.9
Q15	$= 41.6\ CA^{0.717}S^{0.286}$	60	67	6.7
Q25	$= 55.1\ CA^{0.716}S^{0.276}$	61	66	7.5
Q50	$= 76.4\ CA^{0.715}S^{0.262}$	65	70	8.2
Q100	$= 101\ CA^{0.713}S^{0.249}$	70	76	8.5
Q500	$= 171\ CA^{0.708}S^{0.229}$	84	91	8.6
Region C				
Q2	$= 7.08\ CA^{0.638}S^{0.348}$	98	104	2.0
Q10	$= 22.3\ CA^{0.665}S^{0.275}$	66	71	5.2
Q15	$= 29.4\ CA^{0.668}S^{0.263}$	64	77	6.3
Q25	$= 39.7\ CA^{0.670}S^{0.249}$	62	68	7.5
Q50	$= 56.3\ CA^{0.671}S^{0.232}$	62	68	9.0
Q100	$= 75.6\ CA^{0.672}S^{0.219}$	63	69	10.2
Q500	$= 129\ CA^{0.676}S^{0.196}$	67	75	12.0

Reference

Williams-Sether, T., 1992, Techniques for estimating peak-flow frequency relations for North Dakota: U.S. Geological Survey Water-Resources Investigations Report 92-4020, 57 p.

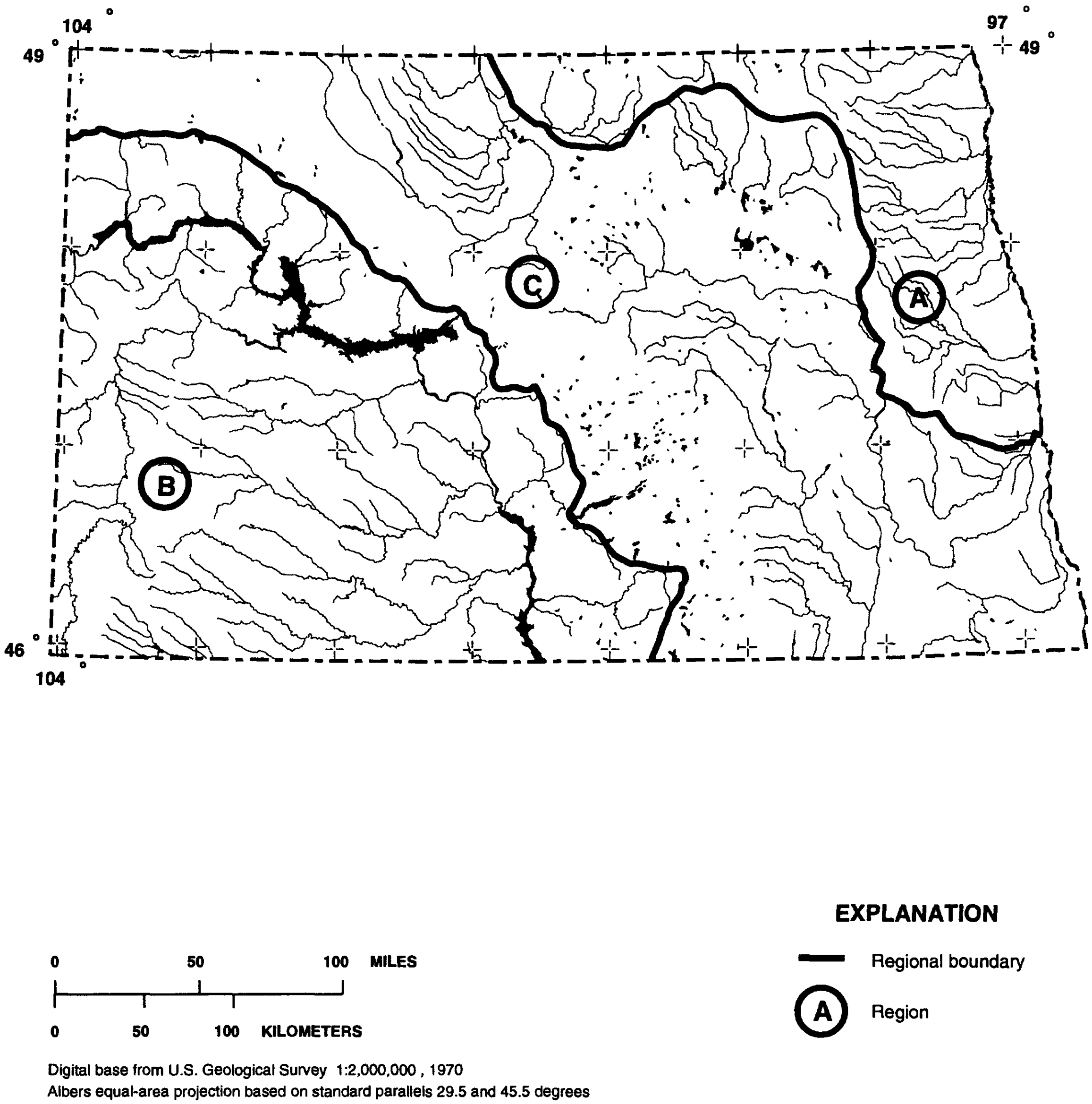


Figure 1. Flood-frequency region map for North Dakota.

OHIO

STATEWIDE RURAL

Summary

Ohio is divided into three regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin characteristics used in the equations are drainage area (A), in square miles; main channel slope (S), in feet per mile; and the percentage of the basin occupied by lakes, ponds, and swamps (St). The constant 1 is added to St in the computer application of the regression equations. The user should enter the actual value to St. These variables can be measured from topographic maps. The regression equations were developed from peak-discharge records for 275 gaging stations and are applicable to rural, unregulated streams having less than 30 percent of the drainage basin strip mined. The standard errors of prediction for the regression equations range from 33 to 41 percent.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = (RC)A^{0.782}\,S^{0.172}\,(St+1)^{-0.297}$$
$$Q5 = (RC)A^{0.769}\,S^{0.221}\,(St+1)^{-0.322}$$
$$Q10 = (RC)A^{0.764}\,S^{0.244}\,(St+1)^{-0.335}$$
$$Q25 = (RC)A^{0.760}\,S^{0.264}\,(St+1)^{-0.347}$$
$$Q50 = (RC)A^{0.757}\,S^{0.276}\,(St+1)^{-0.355}$$
$$Q100 = (RC)A^{0.756}\,S^{0.2859}\,(St+1)^{-0.363}$$

where

RC is the regression constant for a region from the following matrix:

Region	Q2	Q5	Q10	Q25	Q50	Q100
A	56.1	84.5	104	129	148	167
B	40.2	58.4	69.3	82.2	91.2	99.7
C	93.5	133	159	191	214	236

Reference

Koltun, G.F., and Roberts, J.W., 1989, Techniques for estimating flood-peak discharges of rural, unregulated streams in Ohio: U.S. Geological Survey Water-Resources Investigations Report 89-4126, 68 p.

STATEWIDE URBAN

Summary

The regression equations were developed for estimating urban peak discharges (UQT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation minus 30 (P-30), in inches; and a basin development factor (BDF). The constant 30 is subtracted from P in the computer application of the regression equations. The user should enter the actual value of P. The first variable A can be measured from topographic maps, P can be determined from figure 2 and the method of estimating BDF is defined earlier in this report in the section entitled Urban Flood-Frequency Techniques. The equations are based on peak-discharge records of 5-8 years in length at 62 stations in urban and rural areas of Ohio. Record lengths were extended to 66-87 years by use of a rainfall-runoff model. The equations are applicable only to urban streams draining less than 6.5 square miles. The standard errors of prediction range from 34 to 40 percent. The report by Sherwood (1993) also includes procedures for estimating flood volumes and hydrographs.

Procedure

Topographic maps, and the following equations are used to estimate the needed urban peak discharges UQT, in cubic feet per second, having selected recurrence intervals T.

$$UQ2 = 155\ A^{0.68} (P\text{-}30)^{0.50} (13\text{-}BDF)^{-0.45}$$
$$UQ5 = 200\ A^{0.71} (P\text{-}30)^{0.63} (13\text{-}BDF)^{-0.38}$$
$$UQ10 = 228\ A^{0.74} (P\text{-}30)^{0.68} (13\text{-}BDF)^{-0.34}$$
$$UQ25 = 265\ A^{0.76} (P\text{-}30)^{0.72} (13\text{-}BDF)^{-0.29}$$
$$UQ50 = 293\ A^{0.78} (P\text{-}30)^{0.74} (13\text{-}BDF)^{-0.26}$$
$$UQ100 = 321\ A^{0.79} (P\text{-}30)^{0.76} (13\text{-}BDF)^{-0.23}$$

Reference

Sherwood, J.M., 1993, Estimation of peak-frequency relations, flood hydrographs, and volume-duration-frequency relations of ungaged small urban streams in Ohio: U.S. Geological Survey Open-File Report 93-135, 53 p.

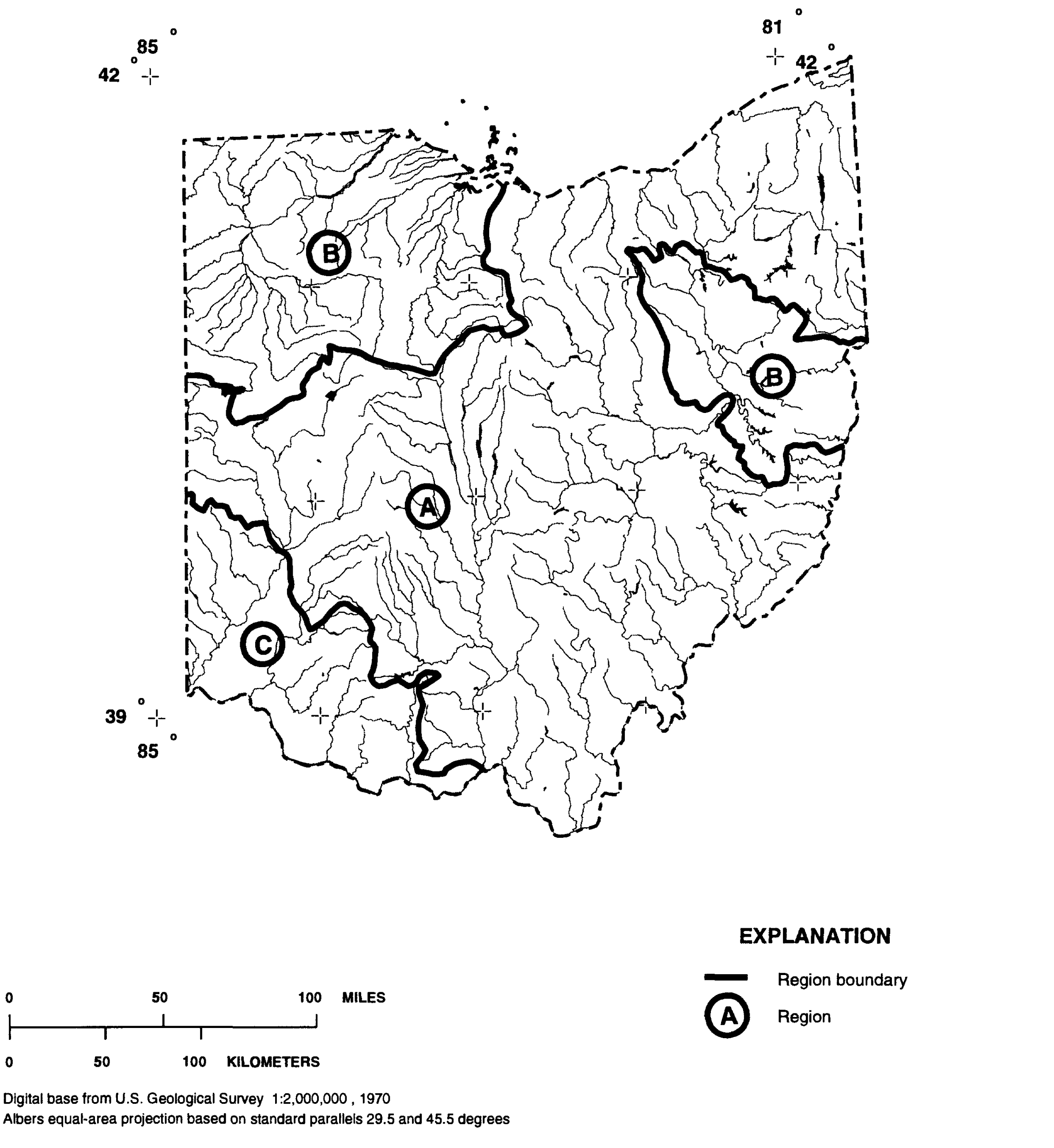


Figure 1. Flood-frequency region map for Ohio.

OKLAHOMA

STATEWIDE RURAL

Summary

Oklahoma is considered to be one hydrologic region. The statewide regression equations are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are contributing drainage area (A), in square miles; and mean annual precipitation (P), in inches. The variable A can be measured from topographic maps and the variable P can obtained from figure 1. The regression equations were developed from peak-discharge records as of 1981 at 226 stations in Oklahoma and adjacent States. The equations apply to unregulated streams with drainage areas less than 2,500 square miles. The standard errors of estimate of the regression equations range from 46 to 66 percent. The report by Tortorelli and Bergman (1985) also presents a method of adjusting for regulation from floodwater-retarding structures. Included in the report are basin and flood-frequency characteristics for unregulated gaged streams and selected gaged streams regulated by floodwater-retarding structures.

Procedure

Topographic maps, the mean annual precipitation map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 0.368A^{0.59} P^{1.84}$$

$$Q5 = 4.00 A^{0.58} P^{1.39}$$

$$Q10 = 13.2 A^{0.57} P^{1.17}$$

$$Q25 = 45.3 A^{0.56} P^{0.94}$$

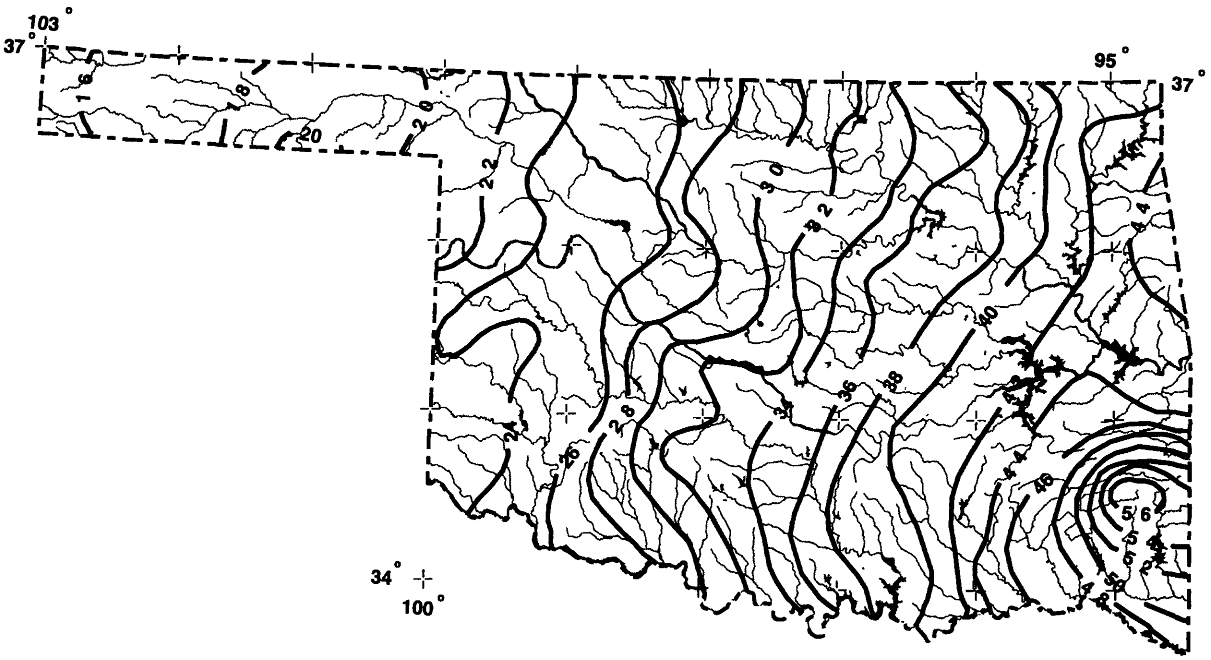
$$Q50 = 98.7 A^{0.56} P^{0.80}$$

$$Q100 = 196 A^{0.56} P^{0.68}$$

$$Q500 = 751 A^{0.55} P^{0.44}$$

Reference

Tortorelli, R.L., and Bergman, D.L., 1985, Techniques for estimating flood peak discharges for unregulated streams and streams regulated by small floodwater-retarding structures in Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 84-4358, 85 p.



EXPLANATION

—— 20 —— Line of equal mean annual precipitation, (interval is 2 inches)

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Mean annual precipitation in Oklahoma.

OREGON

WESTERN OREGON

Summary

Western Oregon is divided into four hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; percentage of basin area in lakes or ponds (St); precipitation (I), in inches, defined as the annual maximum 24-hour rainfall with a recurrence interval of 2 years (fig. 2); and forest cover (F), the percentage of the drainage area covered by forest as indicated on recent topographic maps. The constant 1 is added to St in the computer application of the regression equations. The user should enter the actual value of St. The precipitation variable can be obtained from NOAA Atlas 2 for Oregon (Miller and others, 1973); other variables can be measured from topographic maps. The regression equations were developed from peak-discharge records for 230 stations in Oregon and 9 in adjacent States and are applicable to all streams whose flows from 90 percent or more of the drainage area are uncontrolled. The standard errors of estimate of the regression equations by region range from 34 to 60 percent. The report by Harris and others (1979) includes maximum discharges and flood characteristics at gaging stations used in the analysis.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the 2-year 24-hour precipitation from NOAA Atlas 2 for Oregon and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Coast Region

$$Q2 = 4.59A^{0.96}(ST+1)^{-0.45}\, I^{1.91}$$
$$Q5 = 6.27A^{0.95}(ST+1)^{-0.45}\, I^{1.95}$$
$$Q10 = 7.32A^{0.94}(ST+1)^{-0.45}\, I^{1.97}$$
$$Q25 = 8.71A^{0.93}(ST+1)^{-0.45}\, I^{1.99}$$
$$Q50 = 9.73A^{0.93}(ST+1)^{-0.44}\, I^{2.01}$$
$$Q100 = 10.7A^{0.92}(ST+1)^{-0.44}\, I^{2.02}$$

Willamette Region

$$Q2 = 8.70A^{0.87}\, I^{1.71}$$
$$Q5 = 15.6A^{0.88}\, I^{1.55}$$
$$Q10 = 21.5A^{0.88}\, I^{1.46}$$
$$Q25 = 30.3A^{0.88}\, I^{1.37}$$
$$Q50 = 38.0A^{0.88}\, I^{1.31}$$
$$Q100 = 46.9A^{0.88}\, I^{1.25}$$

Rogue-Umpqua Region

$$Q2 = 24.2A^{0.86}(ST+1)^{-1.16}\, I^{1.15}$$
$$Q5 = 36.0A^{0.88}(ST+1)^{-1.25}\, I^{1.15}$$
$$Q10 = 44.8A^{0.88}(ST+1)^{-1.28}\, I^{1.14}$$
$$Q25 = 56.9A^{0.89}(ST+1)^{-1.31}\, I^{1.12}$$
$$Q50 = 66.7A^{0.90}(ST+1)^{-1.33}\, I^{1.10}$$
$$Q100 = 773.A^{0.90}(ST+1)^{-1.34}\, I^{1.08}$$

High Cascades Region

$$Q2 = 4.75A^{0.90}(ST+1)^{-0.62}(101\text{-}F)^{0.11}\, I^{1.17}$$
$$Q5 = 8.36A^{0.86}(ST+1)^{-0.81}(101\text{-}F)^{0.08}\, I^{1.30}$$
$$Q10 = 11.3A^{0.85}(ST+1)^{-0.92}(101\text{-}F)^{0.07}\, I^{1.37}$$
$$Q25 = 15.4A^{0.83}(ST+1)^{-1.03}(101\text{-}F)^{0.05}\, I^{1.46}$$
$$Q50 = 18.8A^{0.82}(ST+1)^{-1.10}(101\text{-}F)^{0.04}\, I^{1.52}$$
$$Q100 = 22.6A^{0.81}(ST+1)^{-1.17}(101\text{-}F)^{0.03}\, I^{1.57}$$

Reference

Harris, D.D., Hubbard, L.L., and Hubbard, L.E., 1979, Magnitude and frequency of floods in Western Oregon: U.S. Geological Survey Open-File Report 79-553, 35 p.

Miller, J.F., Frederick, R.H., and Tracey, R.J., 1973, Precipitation-frequency atlas of the western United States: NOAA Atlas 2 Volume IV- Oregon, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Silver Spring, MD.

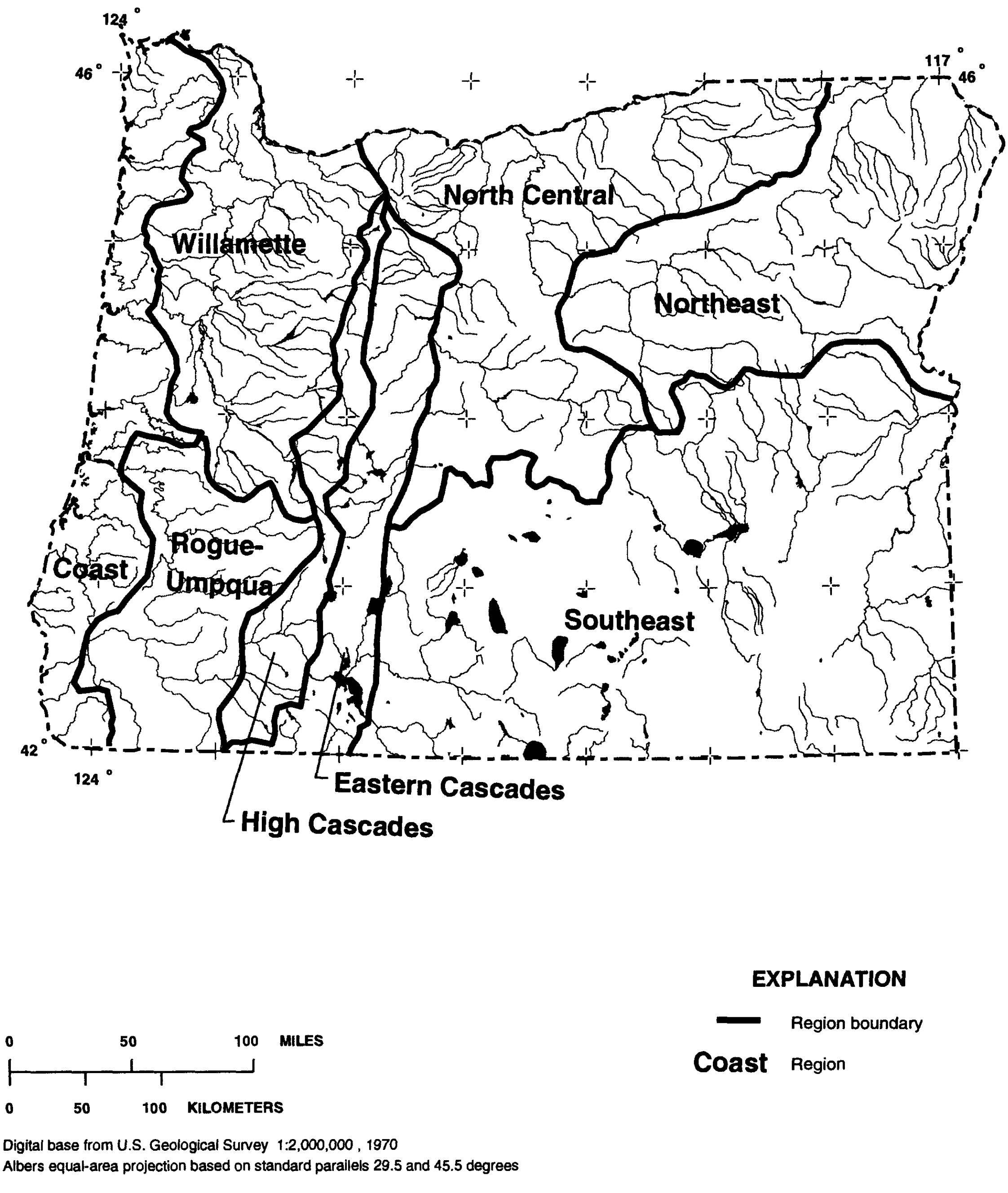
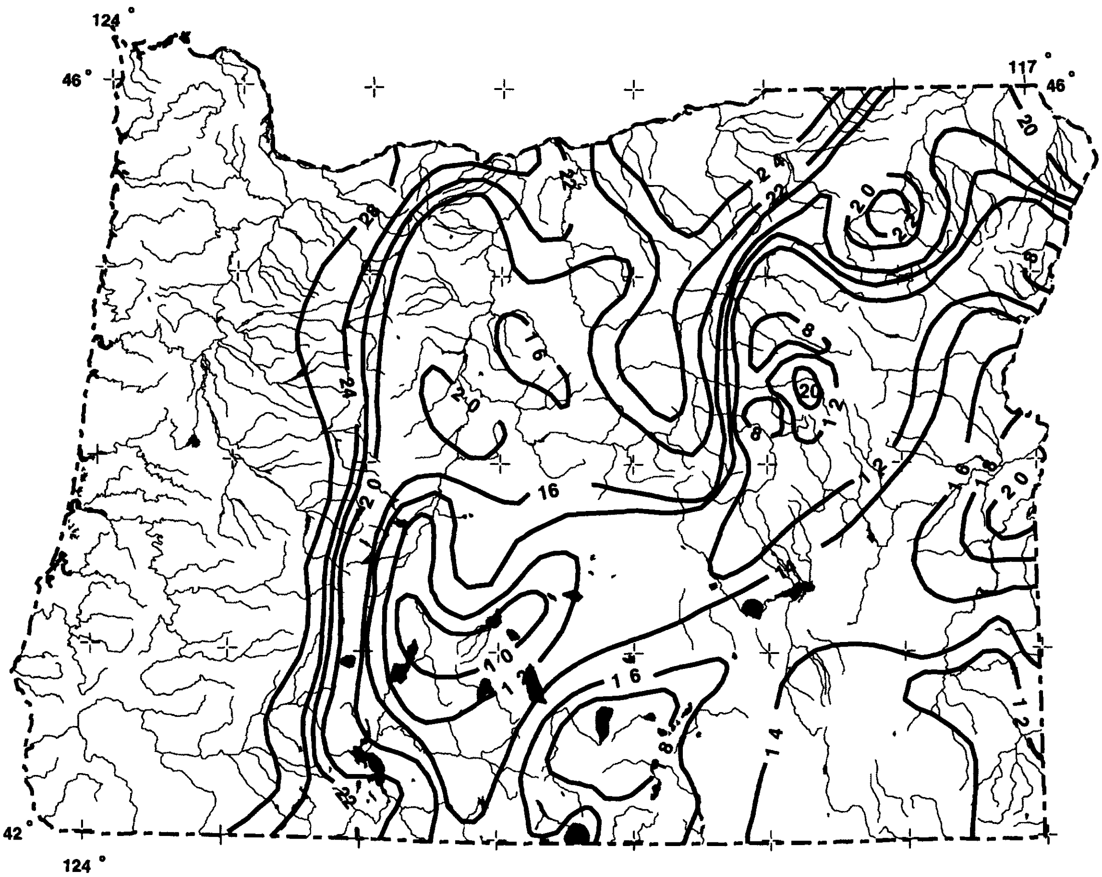


Figure 1. Flood-frequency region map for Oregon.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

—— 20 —— Line of equal minimum January air temperature, in degrees Fahrenheit

Figure 2. The minimum January air temperature in Oregon.

EASTERN OREGON

Summary

Eastern Oregon is divided into four hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals ranging from 2 to 100 years. The explanatory basin characteristics used in the equations are drainage area (A), in square miles; percentage of drainage area covered by forest (F) as shown on recent topographic maps; main channel length (L), in miles; a temperature index (Ti), which is the mean minimum January air temperature, in degrees Fahrenheit (fig. 2) and mean annual precipitation (P), in inches. The constant 1 is added to F in the computer application of the regression equations. The user should enter the actual value of F. The variable Ti can be obtained from figure 2, P can be obtained from U.S. Weather Bureau (1964), and the other variables can be measured from topographic maps. The equations were developed from peak-discharge records available as of 1979 for 148 stations in Oregon and 14 stations in adjacent States. The equations are applicable to ungaged streams whose flow from more than 90 percent of the drainage area is unregulated. The average standard errors of estimate, by region, range from 45 to 51 percent. The report by Harris and Hubbard (1983) includes basin characteristics, flood characteristics, and maximum floods at gaging stations used in the analysis.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the minimum January temperature map (fig. 2), the mean annual precipitation map (fig. 3), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

North Central Region

$$Q2 = 0.00013A^{0.80}P^{1.24}Ti^{2.53}$$
$$Q5 = .00068A^{0.76}P^{0.90}Ti^{2.64}$$
$$Q10 = .00134A^{0.74}P^{0.73}Ti^{2.73}$$
$$Q25 = .00325A^{0.72}P^{0.55}Ti^{2.78}$$
$$Q50 = .00533A^{0.70}P^{0.44}Ti^{2.83}$$
$$Q100 = .00863A^{0.69}P^{0.35}Ti^{2.86}$$

Eastern Cascades Region

$$Q2 = 0.017L^{1.72}P^{1.32}$$
$$Q5 = .118L^{1.59}P^{1.01}$$
$$Q10 = .319L^{1.53}P^{0.85}$$
$$Q25 = .881L^{1.46}P^{0.68}$$
$$Q50 = 1.67L^{1.42}P^{0.58}$$
$$Q100 = 2.92L^{1.39}P^{0.49}$$

Southeast Region

$$Q2 = 0.105A^{0.79}Ti^{1.67}$$
$$Q5 = .328A^{0.77}Ti^{1.52}$$
$$Q10 = .509A^{0.77}Ti^{1.50}$$
$$Q25 = .723A^{0.75}Ti^{1.52}$$
$$Q50 = .872A^{0.76}Ti^{1.52}$$
$$Q100 = .960A^{0.75}Ti^{1.57}$$

Northeast Region

$$Q2 = 0.508A^{0.82}P^{1.36}(1+F)^{-.27}$$
$$Q5 = 2.44A^{0.79}P^{1.09}(1+F)^{-.30}$$
$$Q10 = 5.28A^{0.78}P^{0.96}(1+F)^{-.32}$$
$$Q25 = 11.8A^{0.77}P^{0.83}(1+F)^{-.35}$$
$$Q50 = 19.8A^{0.76}P^{0.75}(1+F)^{-.36}$$
$$Q100 = 30.7A^{0.76}P^{0.68}(1+F)^{-.38}$$

Reference

Harris, D.D., and Hubbard, L.E., 1983, Magnitude and frequency of floods in Eastern Oregon: U.S. Geological Survey Water-Resources Investigations Report 82-4078, 39 p.

U.S. Weather Bureau, 1964, Mean annual precipitation, 1930-57, State of Oregon: U.S. Soil Conservation Service map m-4161, Portland, Oregon.

PORTLAND-VANCOUVER, WASHINGTON URBAN

Summary

The regression equations developed for the Portland area are for estimating urban peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (DA), in square miles; a land-use index (LU12); length of street gutters, in miles per square mile (GUTR); and storage (St), the area where water can be stored during a storm event as a percentage of the total drainage area. The variables DA and St can be measured from topographic maps, but land-use inventory maps are needed to estimate LU12. Information on gutter installation must be obtained locally. The equations were developed from peak-discharge records at 25 gaged sites, derived by synthesizing discharge from historical rainfall data. The average standard error of estimate of the regression equations is about 23 percent.

Procedure

Topographic and land-use maps, information on gutter installation and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 79\ DA^{0.93}\ LU12^{-0.12}\ (GUTR+0.1)^{0.05}\ (ST+0.1)^{-0.27}$$

$$Q5 = 127\ DA^{0.93}\ LU12^{-0.14}\ (GUTR+0.1)^{0.06}\ (ST+0.1)^{-0.26}$$

$$Q10 = 162\ DA^{0.94}\ LU12^{-0.16}\ (GUTR+0.1)^{0.06}\ (ST+0.1)^{-0.25}$$

$$Q25 = 214\ DA^{0.94}\ LU12^{-0.17}\ (GUTR+0.1)^{0.07}\ (ST+0.1)^{-0.24}$$

$$Q50 = 256\ DA^{0.93}\ LU12^{-0.18}\ (GUTR+0.1)^{0.07}\ (ST+0.1)^{-0.23}$$

$$Q100 = 303\ DA^{0.94}\ LU12^{-0.19}\ (GUTR+0.1)^{0.08}\ (ST+0.1)^{-0.22}$$

Reference

Laenen, A., 1980, Storm runoff as related to urbanization in the Portland, Oregon-Vancouver, Washington area: U.S. Geological Survey Open-File Report 80-689, 71 p.

PENNSYLVANIA

STATEWIDE RURAL

Summary

Pennsylvania is divided into eight hydrologic regions (fig. 1), one of which consists of scattered areas underlain by limestone within other regions. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals that range from 2.33 to 100 years. The explanatory basin characteristics used in the equations are drainage area (A), in square miles; main-channel slope (S), in feet per mile; basin storage (St) which is one plus the percentage of drainage area shown to be in lakes, ponds, and swamps on topographic maps; and a precipitation index (Pi), in inches, which is the average annual precipitation minus the estimated annual potential evapotranspiration (fig. 2). A constant of 1 is added to St in the computer application of the equations. The user should enter actual value of St. The variable Pi can be obtained from the two maps in figure 2; other variables can be measured from topographic maps. The regression equations were developed from peak-discharge records available in 1972 at 356 stations. The equations are applicable to unregulated and unurbanized streams that drain more than 2 square miles. Separate equations for drainage areas less than, and for drainage areas more than, 15 square miles are given for regions 6 and 7. The average standard errors of estimate of the regression equations, by region, range from 16 to 33 percent for drainage areas greater than 15 square miles. The report by Flippo (1977) includes basin and flood frequency characteristics at gaging stations and graphs showing flood characteristics along reaches of 11 major streams.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation less potential evapotranspiration map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1 $Q_t = CA^x S^y$

t years	C	x	y
2.33	4.67	1.094	.443
10	8.18	1.070	.459
25	10.5	1.059	.467
50	12.4	1.051	.47
100	14.3	1.045	.477

Region 2 $Q_t = CA^x$

t years	C	x
2.33	103	.822
10	240	.782
25	349	.765
50	448	.754
100	564	.744

Region 3 $Q_t = CA^x St^s$

t years	C	x	s
2.33	70.0	.884	-.419
10	94.4	.955	-.409
25	108	.988	-.404
50	118	1.012	-.401
100	128	1.033	-.398

Region 4 $Q_t = CA^x$

t years	C	x
2.33	73.5	.789
10	118	.778
25	143	.773
50	162	.770
100	181	.766

Region 5 $Q_t = CA^x Pi^p$

t years	C	x	p
2.33	39.4	.827	.222
10	45.4	.789	.445
25	45.3	.772	.566
50	44.5	.759	.656
100	42.2	.751	.744

Region 6A $Q_t = CA^x$ where A>15

t years	C	x
2.33	57.7	.879
10	156	.817
25	244	.788
50	330	.769
100	434	.751

Region 6B $Q_t = CA^x$ where A<15

t years	C	x
2.33	63.2	.943
10	126	1.001
25	173	1.023
50	213	1.037
100	259	1.050

Region 7A $Q_t = CA^xST^s$ where A>15

t years	C	x	s
2.33	201	.707	-.404
10	378	.701	-.402
25	511	.698	-.400
50	628	.695	-.400
100	760	.692	-.400

Region 7B $Q_t = CA^x$ where A<15

t years	C	x
2.33	214	.787
10	469	.806
25	678	.815
50	875	.820
100	1,110	.825

Region 8 $Q_t = CA^x$

t years	C	x
2.33	25.1	.890
10	39.8	.933
25	49.1	.952
50	56.0	.970
100	64.4	.979

Reference

Flippo, H.N., Jr., 1977, Floods in Pennsylvania: Pennsylvania Department of Environmental Resources Bulletin No. 13, 59 p.

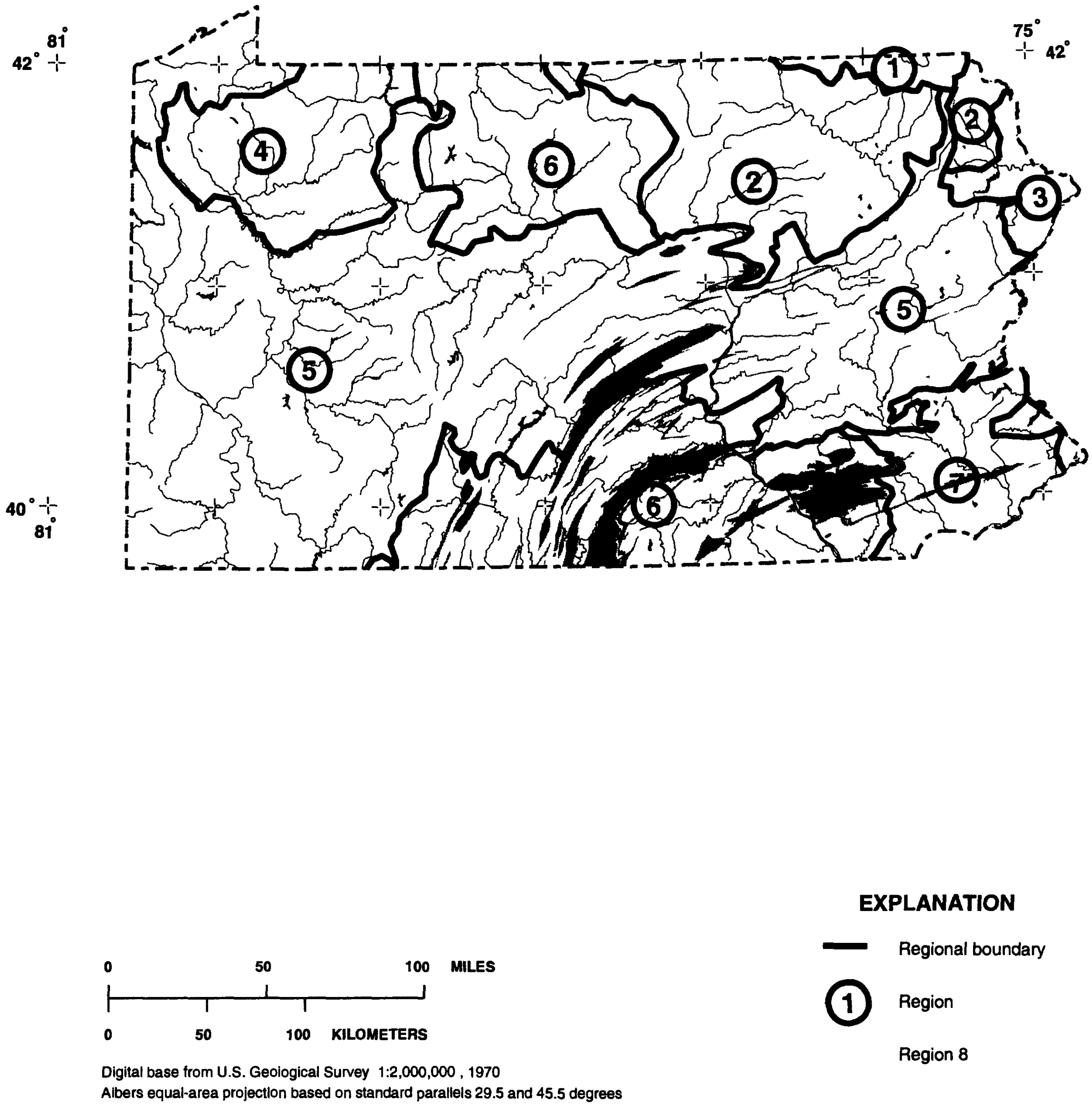
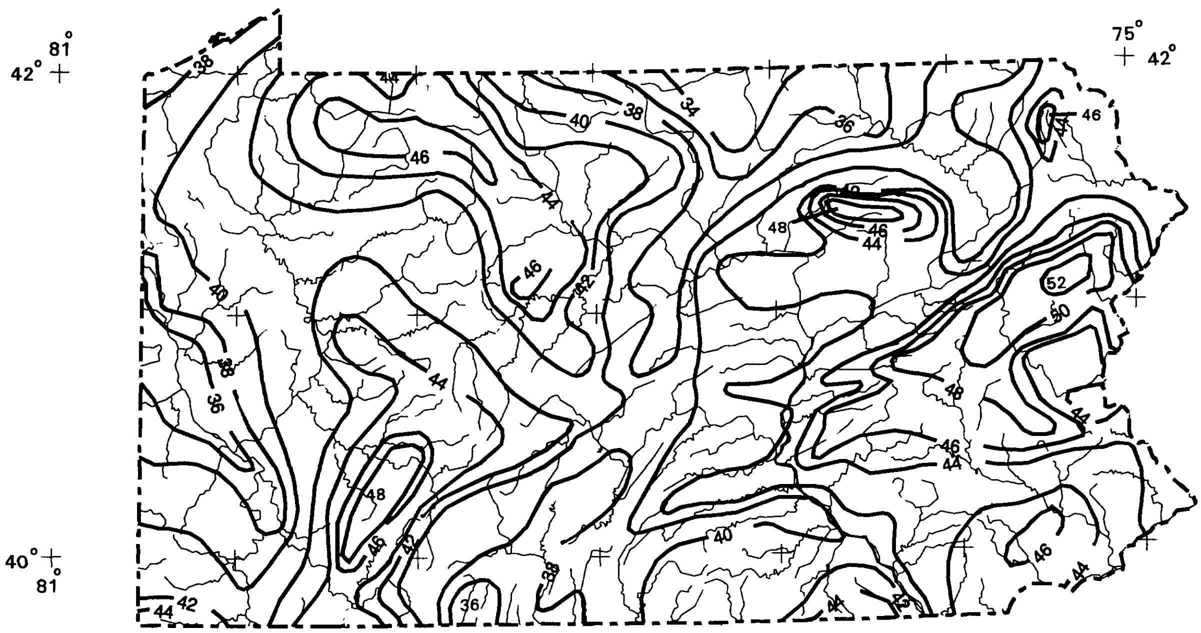
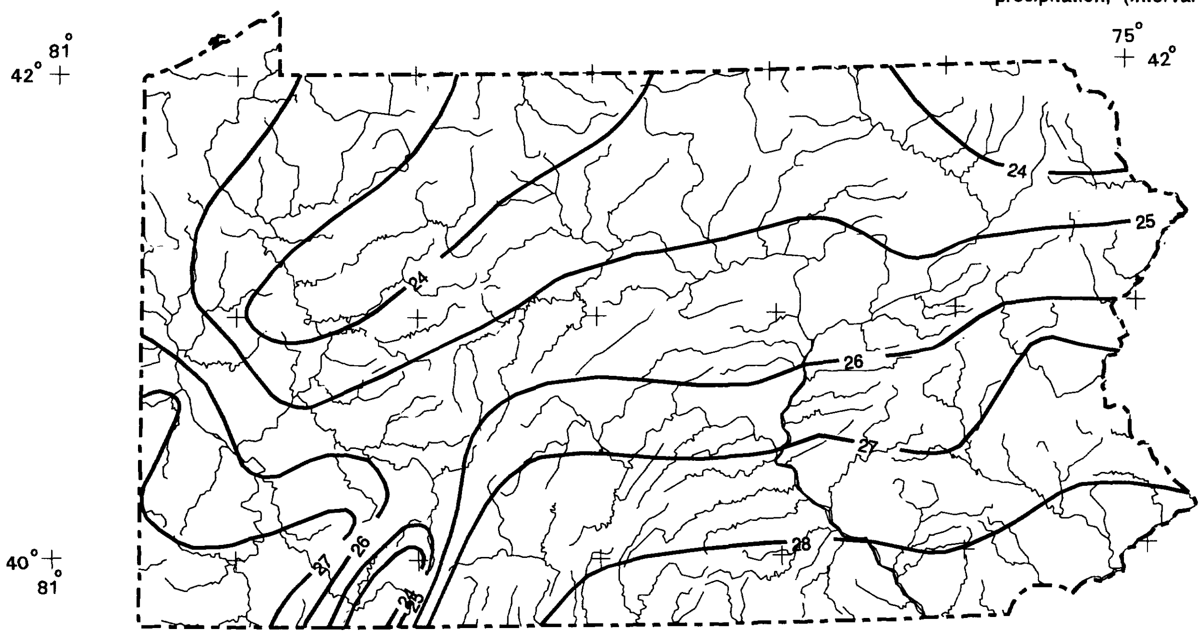


Figure 1. Flood-frequency region map for Pennsylvania.



EXPLANATION

—— 42 —— Line of equal average annual precipitation, (interval is 2 inches)



EXPLANATION

—— 26 —— Line of equal potential annual evapotranspiration, (interval is 1 inch)

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 2. Average annual precipitation and potential annual evapotranspiration in Pennsylvania.

PUERTO RICO

Summary

The whole island is considered to be one hydrologic region. The regression equations developed for the island are for estimating peak discharges (QT) having recurrence intervals that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; and mean annual precipitation (AnnP), in inches. The mean annual precipitation map is shown (fig. 1). The equations are applicable to unregulated, unurbanized streams, and regression equations were developed from peak-discharge records at 37 stations with 10 or more years of record as of 1975. The standard errors of estimate of the regression equations ranged from 38 to 61 percent, but the true errors may be higher because of the short records used.

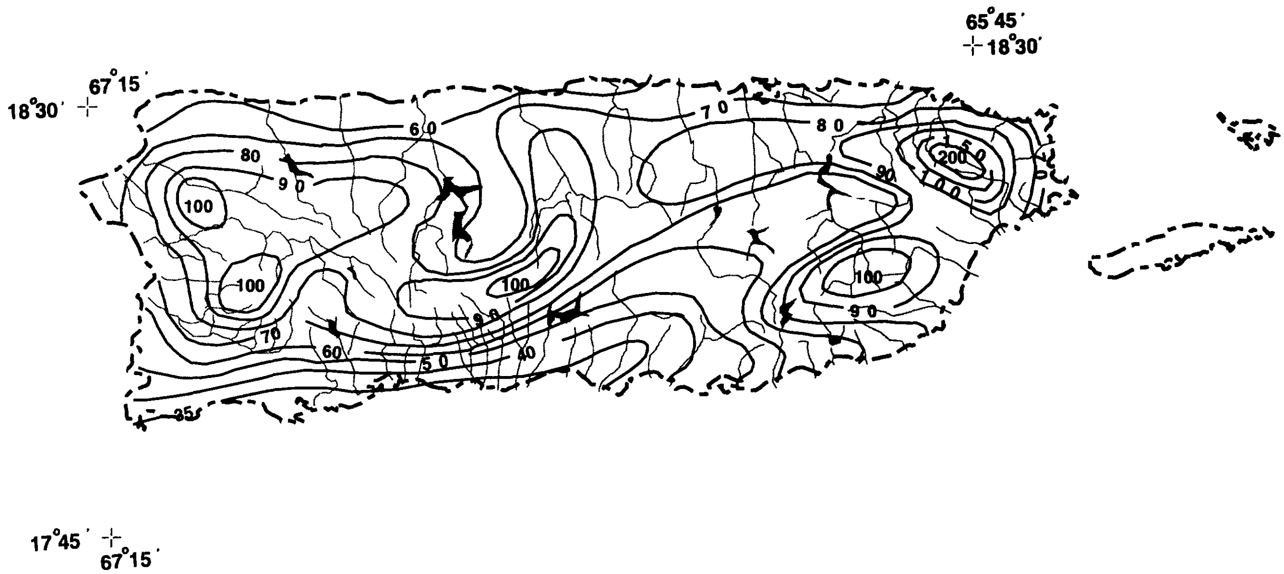
Procedure

Topographic maps, the mean annual precipitation map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 0.033\ A^{.776}(AnnP)^{2.11}$$
$$Q10 = 3.72\ A^{.822}(AnnP)^{1.29}$$
$$Q25 = 25.7\ A^{.826}(AnnP)^{.953}$$
$$Q50 = 89.9\ A^{.830}(AnnP)^{.734}$$
$$Q100 = 286\ A^{.832}(AnnP)^{.531}$$

Reference

Lopez, M.A., Colon-Dieppa, Eloy, and Cobb, E.D., 1979, Floods in Puerto Rico, magnitude and frequency: U.S. Geological Survey Water-Resources Investigations Report 78-141, 68 p.



EXPLANATION

— 60 — Line of equal mean annual precipitation (interval, in inches, is variable)

0 25 50 MILES

0 25 50 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Mean annual precipitation in Puerto Rico.

RHODE ISLAND

STATEWIDE RURAL

Summary

The State of Rhode Island is considered to be one hydrologic region. The regression equations developed for the State are for estimating peak discharges QT with recurrence intervals of 2 and 5 years. The 10-, 25-, and 50-year floods are computed as ratios of the 2-year peak discharge. These ratios are taken from USGS Water-Supply Paper 1671. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean basin elevation (E), in thousands of feet; and forest cover (F) expressed as 0.01 plus the decimal fraction of the drainage area covered by forests. The constant of 0.01 is added to F in the computer application of the equations. The user should enter the actual value of F. All these variables can be measured from topographic maps. The regression equations were developed from peak-discharge records from 1966-1971 for 38 stations and are applicable only to rural streams having no significant storage with drainage areas less than 10 square miles. The standard error of estimate of the regression equation for the 2-year flood is 46 percent, but the results must be considered preliminary because of the short records on which they are based. Comparison of flood records for long-term (1941-1967) and short-term (1966-1971) indicates that the equation derived from the short-term records should include an additional coefficient of 0.79.

Procedure

Topographic maps and the following equations (which should be adjusted for time bias by the factor 0.79) are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 43.5\, A^{0.78}\, E^{0.36}\, F^{-0.56}$$
$$Q5 = 84.5\, A^{0.78}\, E^{0.44}\, F^{-.58}$$
$$Q10 = 1.88\, Q2$$
$$Q25 = 2.75\, Q2$$
$$Q50 = 3.75\, Q2$$

Reference

Johnson, C.G., and Laraway, G.A., 1976, Flood magnitude and frequency of small Rhode Island streams: U.S. Geological Survey Open-File Report 76-883, 22 p.

SOUTH CAROLINA

STATEWIDE RURAL

Summary

South Carolina is divided into four hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The only explanatory basin variable used in the equations is drainage area (A), in square miles, which can be measured from topographic maps. The regression equations were developed from peak-discharge records available as of 1988 at 178 stations in South Carolina and adjacent States; 56 of these stations are in South Carolina. The equations are applicable to unregulated rural streams with drainage areas greater than 0.6, 4.4, 0.1, and 0.6 square miles for the lower Coastal Plain, upper Coastal Plain, Piedmont, and Blue Ridge physiographic regions, respectively. The standard errors of estimate of the regression equations range from about 23 to 53 percent. The report by Guimaraes and Bohman (1991) includes flood-frequency characteristics for stations used in developing the equations, and it also includes flood discharges for selected recurrence intervals on reaches of four large rivers that flow through more than one physiographic province.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Lower Coastal Plain	Upper Coastal Plain	Piedmont	Blue Ridge
$Q2 = 56A^{0.63}$	$25A^{0.74}$	$127A^{0.66}$	$103A^{0.79}$
$Q5 = 111A^{0.61}$	$44A^{0.72}$	$211A^{0.64}$	$196A^{0.76}$
$Q10 = 157A^{0.59}$	$59A^{0.71}$	$267A^{0.64}$	$286A^{0.73}$
$Q25 = 221A^{0.59}$	$80A^{0.70}$	$347A^{0.63}$	$429A^{0.70}$
$Q50 = 275A^{0.58}$	$97A^{0.70}$	$410A^{0.63}$	$558A^{0.69}$
$Q100 = 335A^{0.58}$	$116A^{0.69}$	$474A^{0.63}$	$705A^{0.67}$
$Q500 = 569A^{0.52}$	$179A^{0.66}$	$615A^{0.63}$	$1,146A^{0.63}$

Reference

Guimaraes, W.B., and Bohman, L.R., 1991, Techniques for estimating magnitude and frequency of floods in South Carolina, 1988: U.S. Geological Survey Water-Resources Investigations Report 91-4157, 78 p.

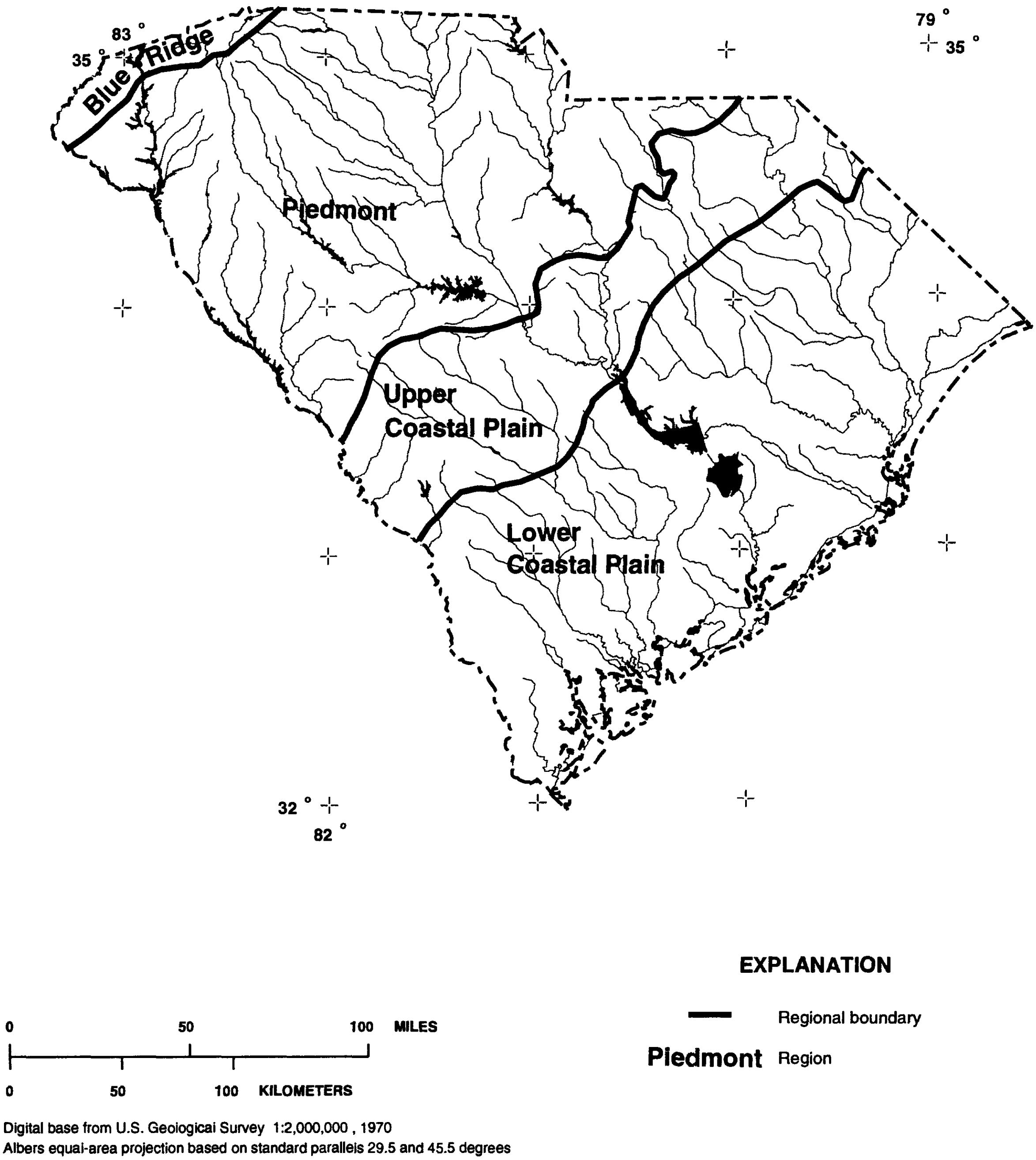


Figure 1. Flood-frequency region map for South Carolina.

SOUTH DAKOTA

STATEWIDE RURAL

Summary

South Dakota is divided into two hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), minus 11 inches; and mean basin elevation (E), in thousands of feet. The constant of 11 is subtracted from P and E is divided by 1000 in the computer application of the equation. The user should enter the actual value of P and E. The variables A and E can be measured from topographic maps and mean annual precipitation can be obtained from figure 2. The regression equations were developed from peak-discharge records for 162 continuous and partial-record stations having 10 or more years of record as of 1972. The equations are generally applicable to unregulated streams varying in drainage area from 0.1 to 4000 square miles in the Eastern region and from 0.1 to 9000 square miles in the Western region. For streams in the Sandhills Area (see fig. 1), use 0.4 times the discharges given by the Western Region equation. The standard errors of estimate of the regression equations range from 65 to 100 percent. The report by Becker (1974) also includes graphs showing flood characteristics along reaches of six major rivers as well as drainage-basin and flood-frequency characteristics at selected gaging stations.

Procedure

Topographic maps, the hydrologic regions map (fig. 1) and the mean annual precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Eastern Region

$Q2 = 0.030A^{0.47}P^{2.93}$
$Q5 = 0.458A^{0.49}P^{2.26}$
$Q10 = 1.78A^{0.50}P^{1.92}$
$Q25 = 7.52A^{0.51}P^{1.54}$
$Q50 = 30.3A^{0.52}P^{1.09}$
$Q100 = 78.4A^{0.52}P^{0.84}$

Western Region

$Q2 = 110A^{0.54}E^{-1.16}$
$Q5 = 320A^{0.49}E^{-0.84}$
$Q10 = 528A^{0.48}E^{-0.79}$
$Q25 = 1{,}020A^{0.48}E^{-0.91}$
$Q50 = 1{,}640A^{0.46}E^{-0.84}$
$Q100 = 2{,}080A^{0.45}E^{-0.74}$

Reference

Becker, L.D., 1974, A method for estimating magnitude and frequency of floods in South Dakota: U.S. Geological Survey Water-Resources Investigations 35-74, 78 p.

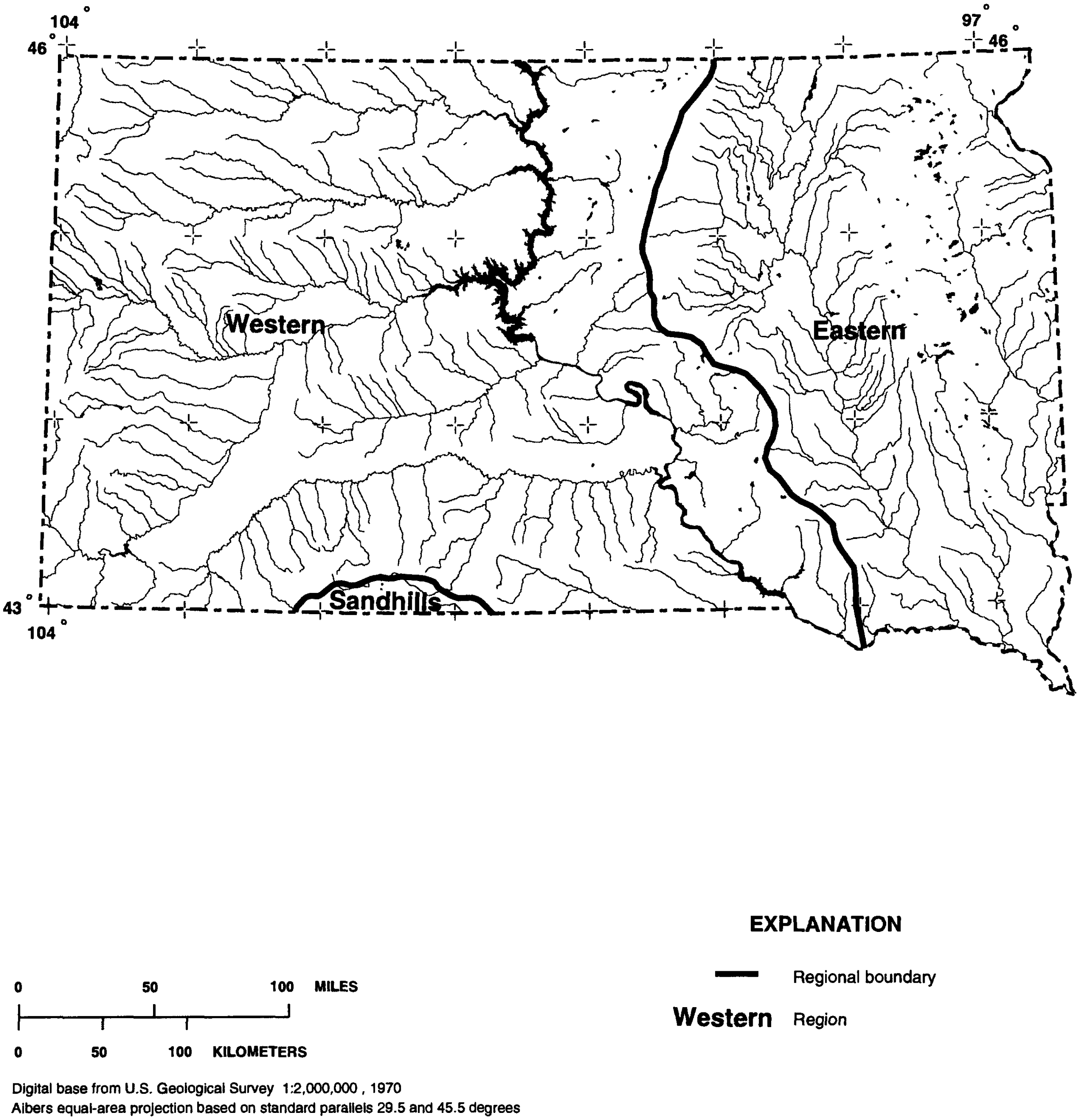
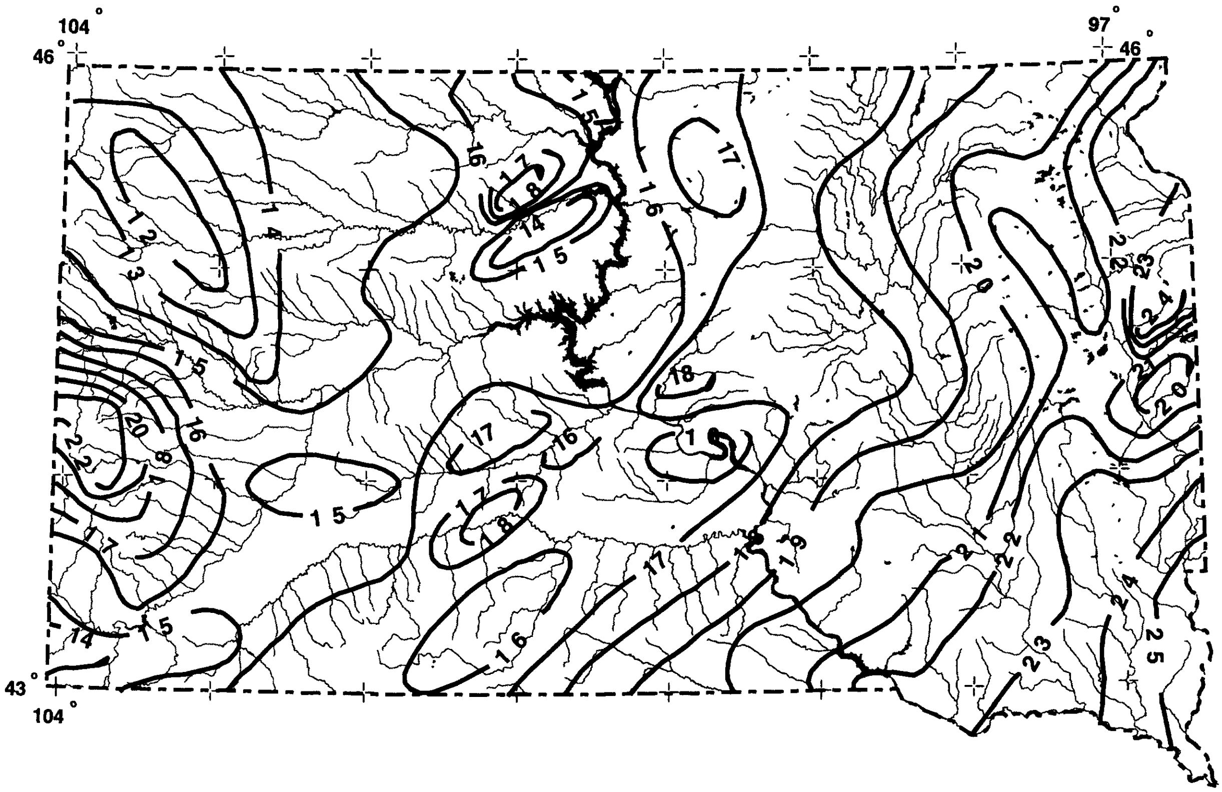


Figure 1. Flood-frequency region map for South Dakota.



EXPLANATION

— 15 — Line of equal mean annual precipitation, 1931 - 55 (interval, in inches, is variable)

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 2. Mean annual precipitation in South Dakota.

TENNESSEE

STATEWIDE RURAL

Summary

Tennessee is divided into four hydrologic areas (fig. 1). The regression equations developed for these areas are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. Drainage area (A), in square miles, the only explanatory basin variable, can be measured from topographic maps. The regression equations were developed from peak-discharge records for 304 gaging stations in Tennessee and adjoining States with each of these stations having 10 or more years of record of unregulated flows as of 1986. The average regional standard errors of prediction of the regression equations range from 32 to 48 percent. The report by Weaver and Gamble (1993) also includes peak discharges for selected recurrence intervals and maximum known discharges at gaging stations and at miscellaneous sites.

Procedure

Topographic maps, the hydrologic area map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Hydrologic Area 1	Hydrologic Area 2
$Q2 = 118A^{0.753}$	$Q2 = 222A^{0.722}$
$Q5 = 198A^{0.736}$	$Q5 = 382A^{0.708}$
$Q10 = 259A^{0.727}$	$Q10 = 502A^{0.703}$
$Q25 = 344A^{0.717}$	$Q25 = 668A^{0.697}$
$Q50 = 413A^{0.711}$	$Q50 = 800A^{0.694}$
$Q100 = 493A^{0.703}$	$Q100 = 938A^{0.690}$
$Q500 = 670A^{0.694}$	$Q500 = 1{,}282A^{0.682}$

Hydrologic Area 3	Hydrologic Area 4
$Q2 = 353A^{0.682}$	$Q2 = 411A^{0.523}$
$Q5 = 562A^{0.678}$	$Q5 = 556A^{0.550}$
$Q10 = 716A^{0.676}$	$Q10 = 648A^{0.563}$
$Q25 = 924A^{0.673}$	$Q25 = 757A^{0.577}$
$Q50 = 1{,}086A^{0.672}$	$Q50 = 833A^{0.586}$
$Q100 = 1{,}253A^{0.670}$	$Q100 = 905A^{0.595}$
$Q500 = 1{,}656A^{0.666}$	$Q500 = 1{,}063A^{0.612}$

Reference

Weaver, J.D. and Gamble, C.R., 1993, Flood frequency of streams in rural basins of Tennessee: U.S. Geological Survey, Water-Resources Investigations Report 92-4165, 38 p.

MEMPHIS URBAN

Summary

The regression equations developed for estimating peak discharges (QT) urban streams in Memphis have recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; and channel condition (P). Channel condition (P) ranges from 1 to 2 and is the average of conditions at 100 percent, 75 percent, 50 percent, and 25 percent of the drainage area. If the channel is paved with concrete, assign a value to 2; if unpaved, assign value of 1. The equations were developed from peak-discharge records for 25 stations, and are recommended for estimating flood magnitudes for ungaged, urban streams in the Memphis area. The standard errors of estimate of the regression equations range from 13 to 18 percent.

Procedure

Topographic maps, knowledge of channel conditions (paved or unpaved), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 488A^{0.81}P^{1.11}$$
$$Q5 = 738A^{0.80}P^{1.09}$$
$$Q10 = 918A^{0.79}P^{1.08}$$
$$Q25 = 1{,}160A^{0.78}P^{1.06}$$
$$Q50 = 1{,}350A^{0.77}P^{1.05}$$
$$Q100 = 1{,}550A^{0.76}P^{1.04}$$

Reference

Neeley, B.L., Jr., 1984, Flood frequency and storm runoff of urban areas of Memphis and Shelby County, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 84-4110, 51 p.

STATEWIDE URBAN (EXCEPT MEMPHIS AREA)

Summary

The regression equations developed for estimating peak discharges (QT) urban streams in Tennessee (except the Memphis area) have recurrence intervals T

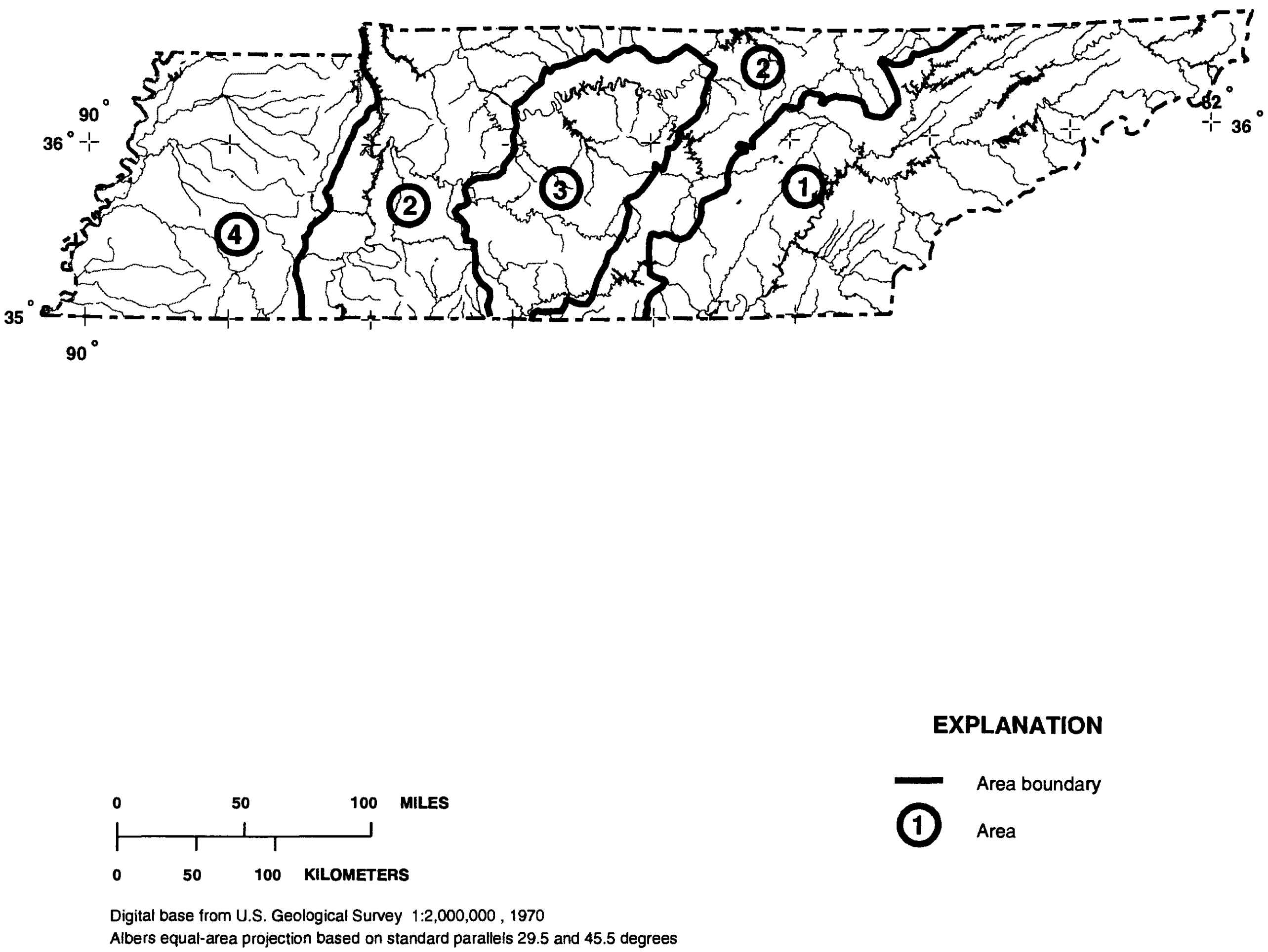


Figure 1. Flood-frequency region map for Tennessee.

that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; the percentage of the contributing drainage area occupied by impervious area (IA); and the 2-year 24-hour rainfall (P2_24), in inches. The variables A and IA can be measured from topographic maps and P2_24 can be determined from figure 2. The regression equations were developed from peak-discharge records for 22 stations having drainage areas of 0.21 to 24.3 square miles in municipalities with populations between 5,000 and 100,000. The peak-discharge records were extended by the use of a rainfall-runoff model. The equations are applicable to urban streams having drainage areas less than 24.3 square miles in Tennessee except for streams in the Memphis area which have the specific equations described above. The standard errors of estimate range from 25 to 32 percent.

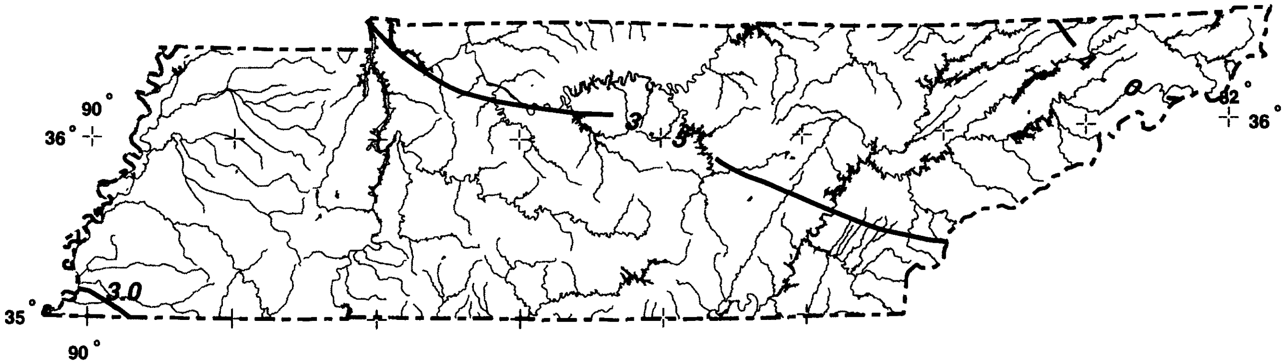
Procedure

Topographic maps, the 2-year 24-hour rainfall map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 1.76A^{0.74}\, IA^{0.48}\, (P2\_24)^{3.01}$$
$$Q5 = 5.55A^{0.75}\, IA^{0.44}\, (P2\_24)^{2.53}$$
$$Q10 = 11.8A^{0.75}\, IA^{0.43}\, (P2\_24)^{2.12}$$
$$Q25 = 21.9A^{0.75}\, IA^{0.39}\, (P2\_24)^{1.89}$$
$$Q50 = 44.9A^{0.75}\, IA^{0.40}\, (P2\_24)^{1.42}$$
$$Q100 = 77.0A^{0.75}\, IA^{0.40}\, (P2\_24)^{1.10}$$

Reference

Robbins, C.H., 1984, Synthesized flood frequency for small urban streams in Tennessee: U.S. Geological Survey Water-Resources Investigations Report 84-4182, 24 p.



EXPLANATION

— 3.5 — Line of equal 2-year 24-hour rainfall (interval is 0.5 inches)

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 2. The 2-year 24-hour rainfall for Tennessee.

TEXAS

STATEWIDE RURAL

Summary

Texas is divided into six hydrologic regions and three additional regions (fig. 1) where regional relations are either undefined or do not apply. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; and mean annual precipitation (P), in inches. The constant of 7 is subtracted from P in the computer application of the equations. The user should enter the actual value of P. The variables A and S can be measured from topographic maps. However, P, which is used only in region 6, may be obtained from figure 2. The regression equations were developed from peak-discharge records at 289 sites; at 40 of these sites, the annual peaks were derived from a rainfall-runoff simulation model. The regression equations are applicable to ungaged, unregulated, and unurbanized streams in the designated regions. The regional average standard errors of estimate of the regression equations for the six defined regions range from about 35 to 50 percent.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Region 1

$$Q2 = 89.9A^{.629}S^{.130}$$
$$Q5 = 117A^{.685}S^{.254}$$
$$Q10 = 131A^{.714}S^{.317}$$
$$Q25 = 144A^{.747}S^{.386}$$
$$Q50 = 152A^{.769}S^{.431}$$
$$Q100 = 157A^{.788}S^{.469}$$

Region 2

$$Q2 = 216A^{.574}S^{.125}$$
$$Q5 = 322A^{.620}S^{.184}$$
$$Q10 = 389A^{.646}S^{.214}$$
$$Q25 = 485A^{.668}S^{.236}$$
$$Q50 = 555A^{.682}S^{.250}$$
$$Q100 = 628A^{.694}S^{.261}$$

Region 3

$$Q2 = 175A^{.540}$$
$$Q5 = 363A^{.580}$$
$$Q10 = 521A^{.599}$$
$$Q25 = 759A^{.616}$$
$$Q50 = 957A^{.627}$$
$$Q100 = 1{,}175A^{.638}$$

Region 4

$$Q2 = 13.3A^{.676}S^{.694}$$
$$Q5 = 42.7A^{.630}A^{.641}$$
$$Q10 = 80.7A^{.604}S^{.596}$$
$$Q25 = 163A^{.576}S^{.535}$$
$$Q50 = 248A^{.562}S^{.497}$$
$$Q100 = 397A^{.540}S^{.442}$$

Region 5

$$Q2 = 4.82A^{.799}S^{.966}$$
$$Q5 = 36.4A^{.776}S^{.706}$$
$$Q10 = 82.6A^{.776}S^{.622}$$
$$Q25 = 180A^{.776}S^{.554}$$
$$Q50 = 278A^{.778}S^{.522}$$
$$Q100 = 399A^{.782}S^{.497}$$

Region 6

$$Q2 = 49.8A^{.602}(P-7)^{.447}$$
$$Q5 = 84.5A^{.643}(P-7)^{.533}$$
$$Q10 = 111A^{.666}(P-7)^{.573}$$
$$Q25 = 150A^{.692}(P-7)^{.608}$$
$$Q50 = 182A^{.709}(P-7)^{.630}$$
$$Q100 = 216A^{.725}(P-7)^{.647}$$

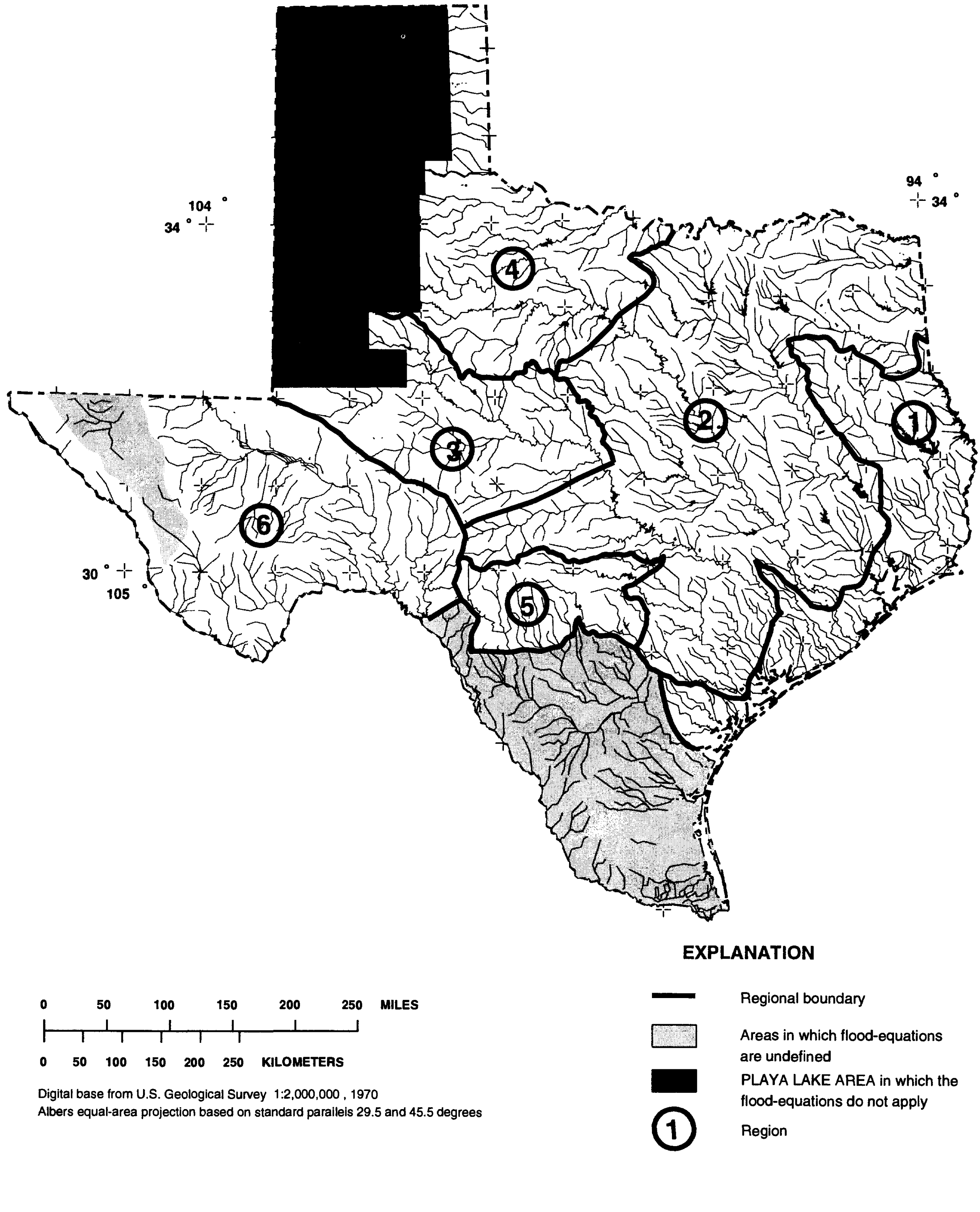
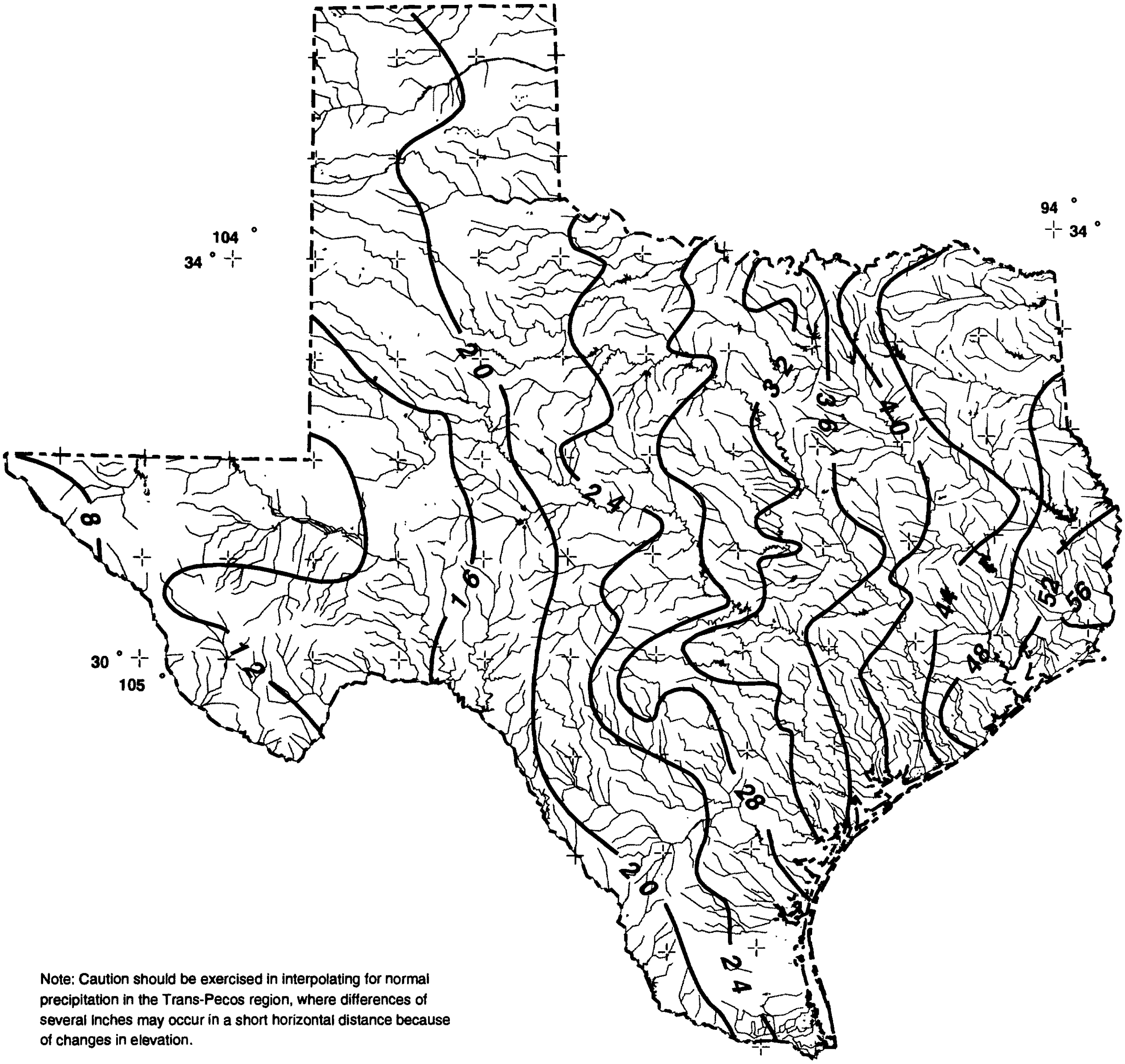


Figure 1. Flood-frequency region map for Texas.



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

— *26* — Line of equal mean annual precipitation (interval is 4 inches)

0 50 100 150 200 250 MILES

0 50 100 150 200 250 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 2. Mean annual precipitation in Texas.

Reference

Schroeder, E.E., and Massey, B.C., 1977, Techniques for estimating the magnitude and frequency of floods in Texas: U.S. Geological Survey Water-Resources Investigations Report 77-110, 22 p.

HOUSTON URBAN

Summary

Regression equations developed for urban streams in Houston are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; the degree of urban development (AD), defined as the percentage of total contributing area within 200 feet of streets, roads, parking lots, and industrial sites that is drained by open street ditches or storm sewers; and the bankfull channel conveyance (K), in cubic feet per second, at the controlling section where $K = (1.49/n)\ AC\ R^{2/3}$ from Mannings equation for open-channel flow (n = Mannings roughness coefficient, AC = channel cross-sectional area at controlling section, in ft^2, and R = hydraulic radius, in feet). The drainage area (A) can be measured from topographic maps, the percentage of urban development (AD) can be obtained from aerial photographs, or field reconnaissance, but bankfull channel conveyance computations will require a field survey. The regression equations were developed from peak-discharge records for 22 stations and are applicable to unregulated streams with drainage areas ranging from 1.33 to 182 square miles, bankfull channel conveyance ranging from 12,000 to 2,800,000 cubic feet per second, and percentage of urban development ranging from 37 to 99. The standard errors of estimate of the regression equations range from 17 to 25 percent.

Procedure

Topographic maps, aerial photographs, field surveys and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Equations are of the following form:

$$QT = a\,A^b\,[K(1.0 + 0.01A_D)]^c.$$

T (years)	Regression constant a	Regression coefficient b A	Regression coefficient c $K(1.0+0.01A_D)$
2	2.028	0.383	0.447
5	2.208	.392	.468
10	2.301	.399	.478
25	2.460	.410	.487
50	2.576	.419	.492
100	2.710	.428	.495
500	3.097	.451	.498

Reference

Liscum, F. and Massey, B.C., 1980, Technique for estimating the magnitude and frequency of floods in the Houston, Texas, metropolitan area: U.S. Geological Survey Water-Resources Investigations Report 80-17, 29 p.

AUSTIN URBAN

Summary

Regression equations developed for urban streams in Austin are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are contributing drainage area (CDA), in square miles; and total percentage of drainage area that is impervious (TIMP). The variable CDA can be measured using topographic maps; TIMP can be estimated from aerial photographs or land-use maps. The regression equations were developed from simulated and recorded peak-discharge records at 13 sites on 7 streams, and the results are applicable to unregulated streams (not regulated by flood-control structures) having drainage areas between 2 and 20 square miles. The standard errors of estimate of the regression equations range from 26 to 30 percent.

Procedure

Topographic maps, aerial photographs or land-use maps and the following equations are used to estimate to the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 332\ (CDA)^{0.607}\ (1 + TIMP/100)\ 1.854$$
$$Q5 = 581\ (CDA)^{0.649}\ (1 + TIMP/100)\ 1.607$$
$$Q10 = 780\ (CDA)^{0.663}\ (1 + TIMP/100)\ 1.526$$
$$Q25 = 1{,}064\ (CDA)^{0.674}\ (1 + TIMP/100)\ 1.476$$
$$Q50 = 1{,}299\ (CDA)^{0.677}\ (1 + TIMP/100)\ 1.475$$
$$Q100 = 1{,}554\ (CDA)^{0.678}\ (1 + TIMP/100)\ 1.474$$

Reference

Veenhuis, J.E., and Gannett, D.G., 1986, The effects of urbanization on floods in the Austin metropolitan area, Texas: U.S. Geological Survey Water-Resources Investigations Report 86-4069, 66 p.

DALLAS-FORT WORTH URBAN

Summary

Regression equations developed for urban streams in Dallas-Fort Worth are for estimating peak discharges (QT) having recurrence intervals (T) that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (DA), in square miles; and an urbanization index (UI), which is evaluated as described in the report by Land and otbers. The regression equations were developed from peak-discharge records from drainage areas in the Dallas-Fort Worth area ranging from 1.25 to 66.4 square miles with results considered applicable to drainage areas between 3 and 40 square miles having urbanization indexes between 12 and 33. The standard errors of estimate of the regression equations are about 30 percent.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 42.83(DA)^{0.704}(UI)\ 0.836$$
$$Q5 = 82.92(DA)^{0.724}(UI)\ 0.751$$
$$Q10 = 120.7\ (DA)^{0.735}(UI)\ 0.697$$
$$Q25 = 184.8\ (DA)^{0.745}(UI)\ 0.632$$
$$Q50 = 246.4\ (DA)^{0.752}(UI)\ 0.587$$
$$Q100 = 362.1\ (DA)^{0.752}(UI)\ 0.510$$

Reference

Land, L.F., Schroeder, E.E., and Hampton, B.B., 1982, Techniques for estimating the magnitude and frequency of floods in the Dallas-Fort Worth metropolitan area, Texas: U.S. Geological Survey Water-Resources Investigations Report 82-18, 55 p.

UTAH

STATEWIDE RURAL

Summary

Utah is divided into seven hydrologic regions (fig. 1). No regression equations were developed for Great Basin Low Elevation subregion, but the equations developed for the other six regions are for estimating peak discharges (QT) having recurrence intervals that range from 2 to 100 years, with the 500-year flood estimated as a ratio to the 100-year flood. The explanatory basin variables used in the equations are drainage area (A), in square miles; and mean basin elevation (E), in thousands of feet, both of which can be measured from topographic maps. Elevation (E) is divided by 1000 in the computer application of the equations. The user should enter the actual value of E. The regression equations are applicable to unurbanized, unregulated streams with negligible storage in their basins. The regression equations are not applicable to low-elevation watersheds in the Great Basin (all sites north of 38 degrees latitude that have a mean basin elevation less than 6,000 feet). The average standard errors of estimate of the regression equations range from 37 to 87 percent. The report by Thomas and Lindskov (1983) includes regional equations for estimating flood-depth at selected recurrence intervals and a table of basin characteristics and flood-discharge and flood-depth frequency characteristics at gaging stations.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Northern Mountains High Elevation Region A

$Q2 = 0.044A^{0.831} E^{2.67}$
$Q5 = 0.064A^{0.822} E^{2.67}$
$Q10 = 0.071A^{0.815} E^{2.70}$
$Q25 = 0.077A^{0.807} E^{2.76}$
$Q50 = 0.079A^{0.801} E^{2.80}$
$Q100 = 0.078A^{0.795} E^{2.86}$
$Q500 = 1.3\ Q100$

Northern Mountains Low Elevation Region B

$Q2 = 562A^{0.755} E^{-2.06}$
$Q5 = 6{,}660A^{0.757} E^{-3.08}$
$Q10 = 30{,}500A^{0.758} E^{-3.74}$
$Q25 = 184{,}000A^{0.758} E^{-4.54}$
$Q50 = 644{,}000A^{0.758} E^{-5.10}$
$Q100 = 2.08 \times 10^{6}A^{0.757} E^{-5.63}$
$Q500 = 1.3\ Q100$

Uinta Basin Region C

$Q2 = 1{,}500A^{0.403} E^{-1.90}$
$Q5 = 143{,}000A^{0.374} E^{-3.66}$
$Q10 = 1.28 \times 10^{6}A^{0.362} E^{-4.50}$
$Q25 = 1.16 \times 10^{7}A^{0.352} E^{-5.32}$
$Q50 = 4.47 \times 10^{7}A^{0.347} E^{-5.85}$
$Q100 = 1.45 \times 10^{8}A^{0.343} E^{-6.29}$
$Q500 = 1.7\ Q100$

High Plateaus Region D

$Q2 = 10.8A^{0.800}$
$Q5 = 25.1A^{0.740}$
$Q10 = 680A^{0.706} E^{-1.30}$
$Q25 = 10{,}300A^{0.672} E^{-2.33}$
$Q50 = 64{,}200A^{0.651} E^{-3.03}$
$Q100 = 347{,}000A^{0.631} E^{-3.68}$
$Q500 = 1.7\ Q100$

Low Plateaus Region E

$Q2 = 3{,}980A^{0.535} E^{-2.21}$
$Q5 = 13{,}300A^{0.467} E^{-2.23}$
$Q10 = 23{,}700A^{0.433} E^{-2.23}$
$Q25 = 42{,}500A^{0.398} E^{-2.21}$
$Q50 = 61{,}000A^{0.375} E^{-2.19}$
$Q100 = 83{,}100A^{0.356} E^{-2.17}$
$Q500 = 1.7\ Q100$

Great Basin High Elevation Subregion F

$$Q2 = 0.004A^{0.786}E^{3.51}$$
$$Q5 = 15.5A^{0.681}$$
$$Q10 = 24.2A^{0.665}$$
$$Q25 = 38.7A^{0.648}$$
$$Q50 = 52.1A^{0.638}$$
$$Q100 = 68.1A^{0.630}$$
$$Q500 = 1.7\ Q100$$

Great Basin Low Elevation Subregion G

No equations developed.

Reference

Thomas, B.E., and Lindskov, K.L., 1983, Methods for estimating peak discharge and flood boundaries of streams in Utah: U.S. Geological Survey Water-Resources Investigations Report 83-4129, 77 p.

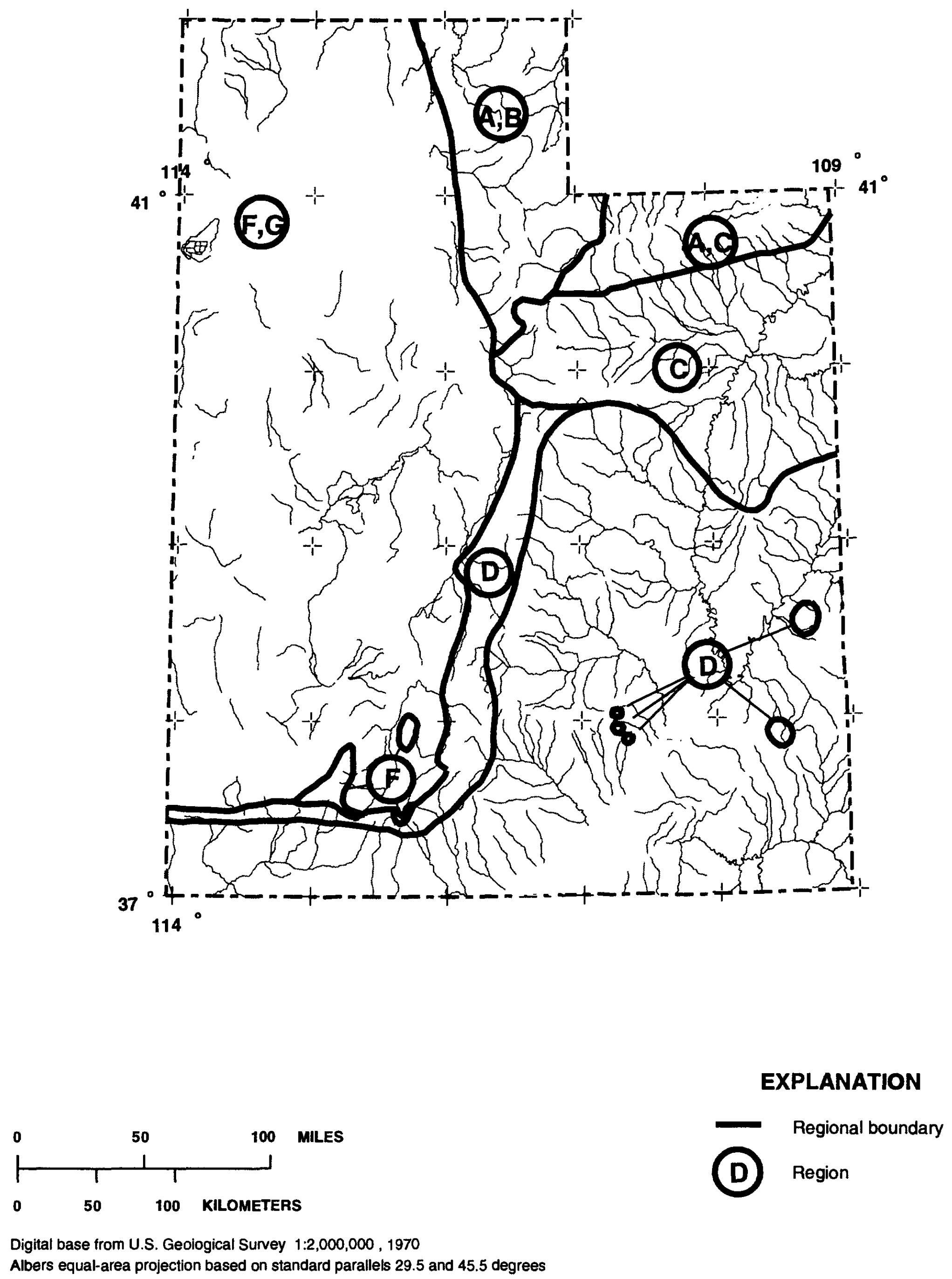


Figure 1. Flood-frequency region map for Utah.

VERMONT

STATEWIDE RURAL

Summary

The State of Vermont is considered a single hydrologic region. The regression equations developed for the State are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; percentage of the drainage area occupied by lakes and ponds plus 0.5 (St); annual maximum 24-hour rainfall for the 2-year recurrence interval (I24,2), in inches (fig. 1); and average seasonal snowfall (Sn), in feet (fig. 2). The constant of 0.5 is added to St in the computer application of the equations. The user should enter the actual value of St. The variables A and St can be measured from topographic maps. The latter two variables, (I24,2) and (Sn), can be determined from maps referenced in U.S. Weather Bureau Technical Paper 29 (1959) and Lautzenheiser (1969) and included in this report as figures 1 and 2, respectively. The regression equations were developed from peak-discharge records for at least seven consecutive years at 82 stations in Vermont and Massachusetts and are applicable to largely rural, unregulated streams. The standard errors of estimate of the regression equations range from 38 to 59 percent.

Procedure:

Topographic maps, the 2-year, 24-hour rainfall map figure 1, the average seasonal snowfall map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 0.380A^{0.925}St^{-0.413}\,I24{,}2^{1.15}Sn^{1.76}$$
$$Q5 = 0.330A^{0.922}St^{-0.458}\,I24{,}2^{1.68}Sn^{1.80}$$
$$Q10 = 0.279A^{0.921}St^{-0.484}\,I24{,}2^{1.99}Sn^{1.86}$$
$$Q25 = 0.189A^{0.919}St^{-0.505}\,I24{,}2^{2.29}Sn^{2.04}$$
$$Q50 = 0.173A^{0.920}St^{-0.532}\,I24{,}2^{2.59}Sn^{2.02}$$
$$Q100 = 0.141A^{0.919}St^{-0.549}\,I24{,}2^{2.82}Sn^{2.10}$$

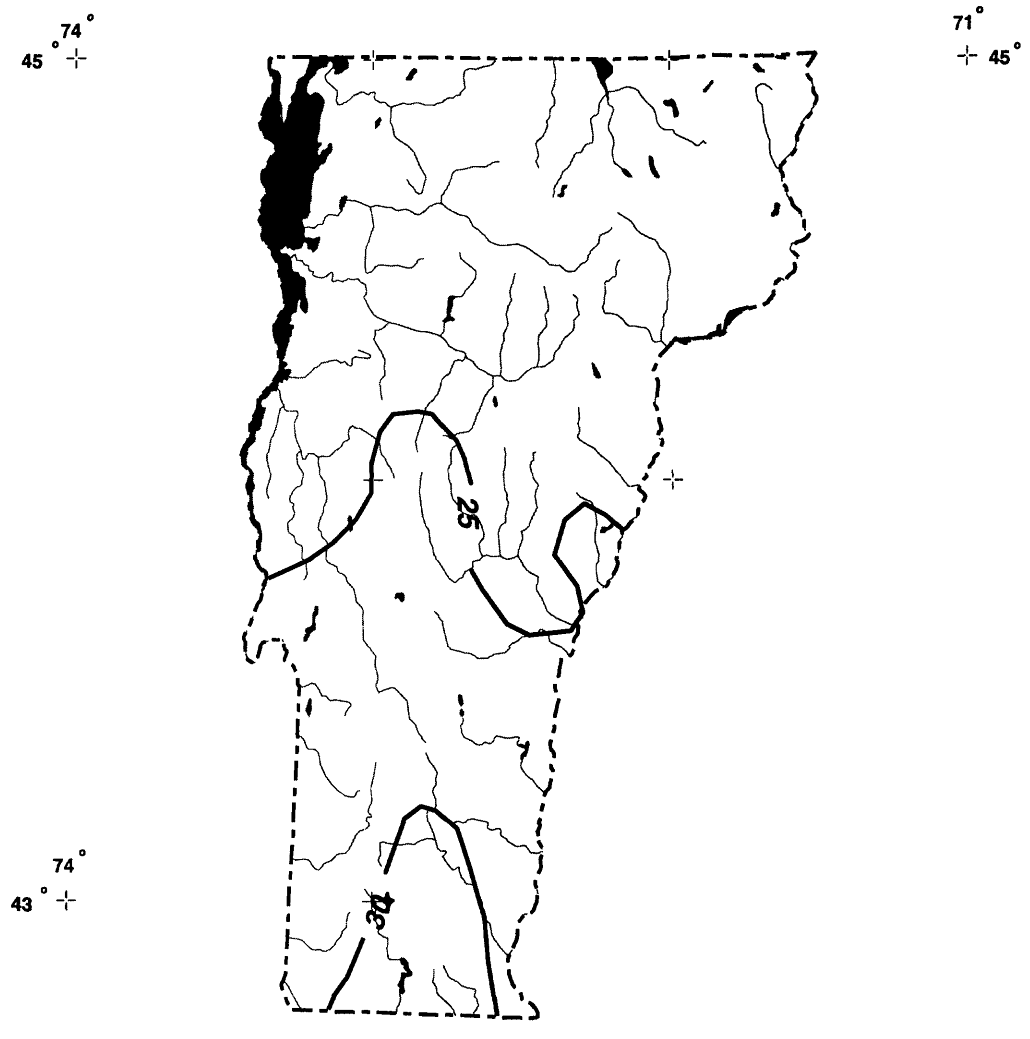
Reference

Johnson, C.G., Tasker, G.D., 1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Additional References

Lautzenheiser, R.E., 1969, Snowfall, snowfall frequencies, and snow-cover data for New England: ESSA Technical Memorandum, EDSTM 12, 15 p.

U.S. Weather Bureau, 1959, Rainfall intensity-frequency regime, northeastern United States: U.S. Weather Bureau Technical Paper, no. 29, 35 p.



0 25 50 MILES

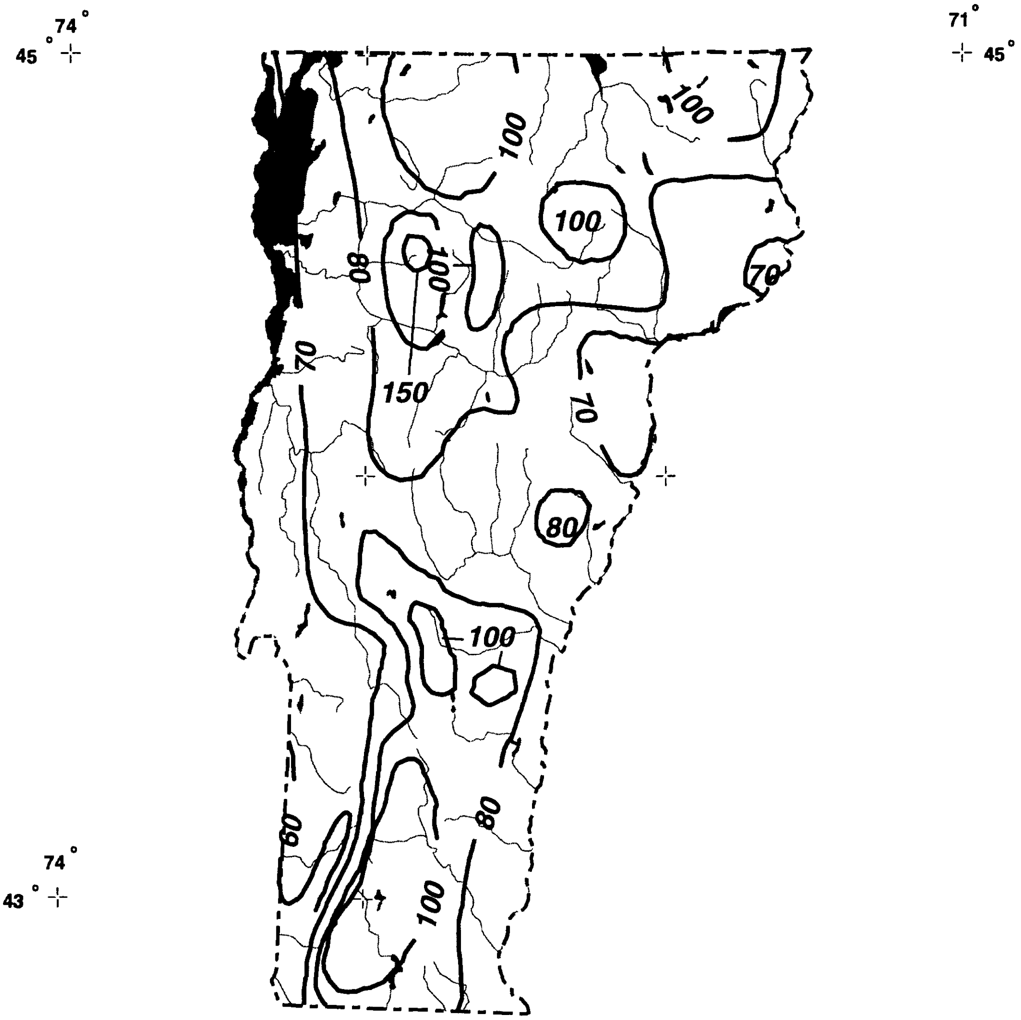
0 25 50 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— 25 — Line of equal 2-year, 24-hour rainfall (interval is tenths of inches)

Figure 1. The 2-year 24-hour rainfall in Vermont.



0 25 50 MILES

0 25 50 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— *25* — Line of equal average seasonal snowfall, (interval, in inches, is variable)

Figure 2. Average seasonal snowfall in Vermont.

VIRGINIA

STATEWIDE RURAL

Summary

Virginia is divided into seven hydrologic areas (fig. 1), each of which is assigned a factor to be applied to the statewide equations. The statewide equations are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; channel slope (S), in feet per mile; and a regional factor (RF). The variables A and S can be measured from topographic maps and the regional factor (RF) can be obtained from figure 1. In the computer application of the equations, the regression constant is multiplied by the regional factor (Rf). The regression equations were developed from peak-discharge records available, as of 1976, for 299 sites and are applicable to natural-flow streams with drainage areas between 0.1 and 8,000 square miles and with channel slopes between 1.6 and 1,320 feet per mile. The standard errors of estimate of the regression equations range from 44 to 60 percent. The report by Miller (1978) also includes a graph showing flood characteristics along the mainstem of the James River, tables of basin characteristics, flood-frequency characteristics and maximum known peak discharges at gaging stations.

Procedure:

Topographic maps, the hydrologic regions map (fig. 1) and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

$$Q2 = 25.2A^{0.83} S^{0.26} RF$$
$$Q5 = 52.2A^{0.80} S^{0.25} RF$$
$$Q10 = 81.3A^{0.78} S^{0.24} RF$$
$$Q25 = 136A^{0.76} S^{0.23} RF$$
$$Q50 = 198A^{0.74} S^{0.22} RF$$
$$Q100 = 269A^{0.73} S^{0.21} RF$$

Reference

Miller, E.M., 1978, Technique for estimating magnitude and frequency of floods in Virginia: U.S. Geological Survey Water-Resources Investigations Report 78-5, 83 p..

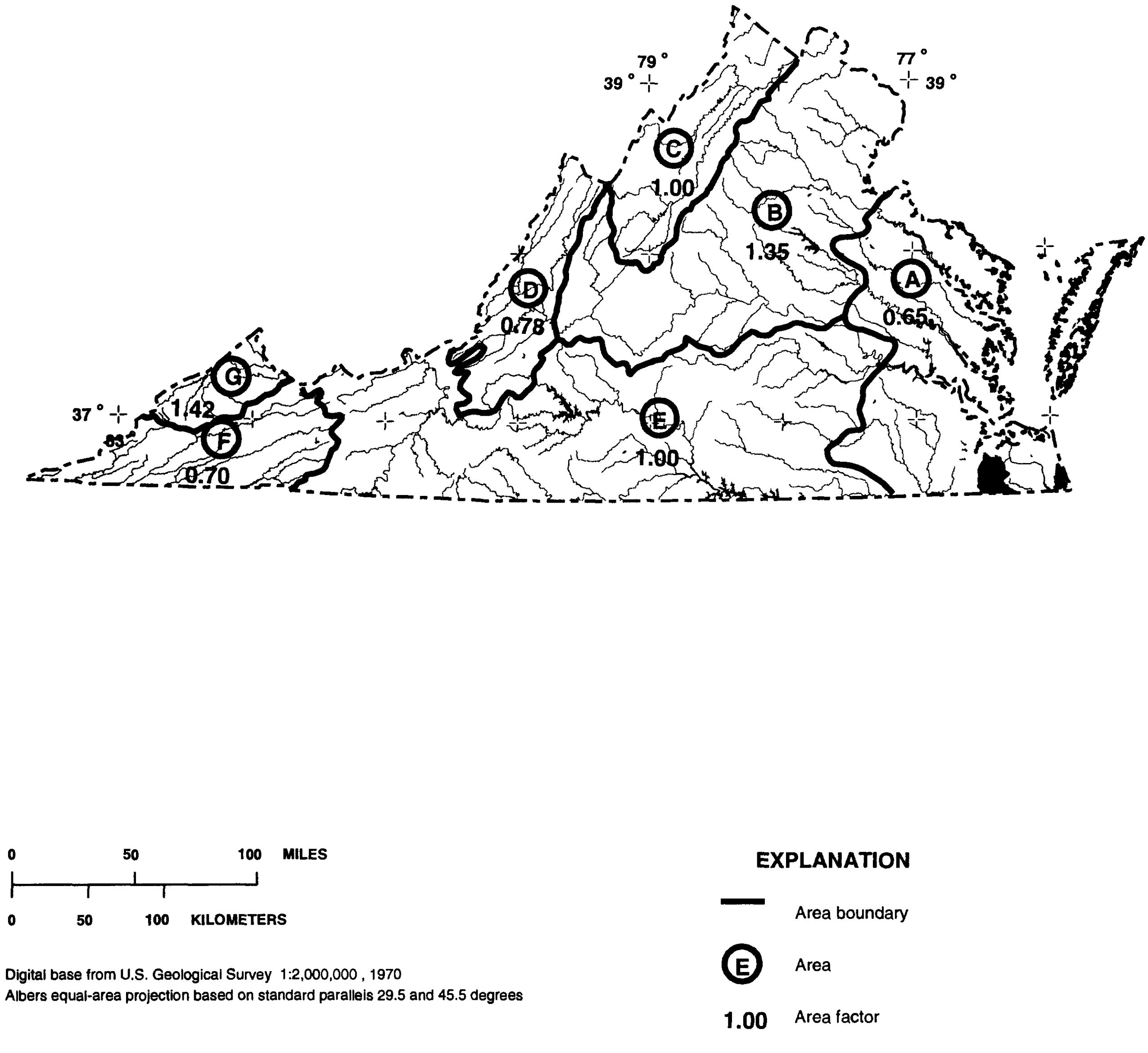


Figure 1. Flood-frequency area map for Virginia.

WASHINGTON

STATEWIDE RURAL

Summary

Western Washington is divided into four hydrologic regions, and eastern Washington is divided into eight hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years in western Washington and 5 to 100 years in eastern Washington. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches (fig. 2); and forest cover (F), in percent of drainage area. The constant of 0.01 is added to F in the computer application of the equations. The user should enter the actual value of F. The regression constant (a) varies for each region and equation and can be obtained from the table below after identifying the region in which the stream is located (fig. 1). The variables A and F can be measured from topographic maps, and P can be obtained from figure 2. The regression equations were developed from peak-discharge records of 10 years or longer, as of 1973, at 450 sites where flood-flows were not significantly altered by upstream regulation or diversion. The standard errors of estimate of the regression equations range from 25 to 60 percent for streams in western Washington and from 42 to 129 percent for those in eastern Washington. The report by Cummans and others (1975) includes basin and climatic characteristics as well as flood-frequency characteristics at gaging stations.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation map (fig. 2), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Form of the equations: $QT = a\ A^{b1}\ P^{b2}\ F^{b3}$

Region I

T	a	b1	b2	
2	0.191	0.86	1.51	--
5	.257	.86	1.53	--
10	.288	.85	1.54	--
25	.317	.85	1.56	--
50	.332	.86	1.58	--
100	.343	.86	1.60	--

Region II

T	a	b1	b2	
2	0.104	0.86	1.51	--
5	.140	.86	1.53	--
10	.158	.85	1.54	--
25	.176	.85	1.56	--
50	.186	.86	1.58	--
100	.194	.86	1.60	--

Region III

T	a	b1	b2	
2	0.054	0.86	1.51	--
5	.073	.86	1.53	--
10	.082	.85	1.54	--
25	.092	.85	1.56	--
50	.098	.86	1.58	--
100	.102	.86	1.60	--

Region IV

T	a	b1	b2	
2	0.059	0.86	1.51	--
5	.081	.86	1.53	--
10	.092	.85	1.54	--
25	.105	.85	1.56	--
50	.112	.86	1.58	--
100	.119	.86	1.60	--

Region V

T	a	b1	b2	b3
5	0.982	0.90	1.35	-0.21
10	2.87	.88	1.16	-.23
25	7.51	.87	1.03	-.25
50	13.6	.86	.95	-.27
100	23.4	.85	.89	-.29

Region VII

T	a	b1	b2	b3
5	0.263	0.90	1.35	-0.21
10	.850	.88	1.16	-.23
25	2.07	.87	1.03	-.25
50	3.46	.86	.95	-.27
100	5.45	.85	.89	-.29

Region VIII

T	a	b1	b2	b3
5	0.508	0.90	1.35	-0.21
10	1.32	.88	1.16	-.23
25	2.95	.87	1.03	-.25
50	4.78	.86	.95	-.27
100	7.36	.85	.89	-.29

Region IX

T	a	b1	b2	b3
5	0.186	0.90	1.35	-0.21
10	.525	.88	1.16	-.23
25	1.29	.87	1.03	-.25
50	2.22	.86	.95	-.27
100	3.60	.85	.89	-.29

Region X

T	a	b1	b2	b3
5	0.449	0.90	1.35	-0.21
10	1.16	.88	1.16	-.23
25	2.54	.87	1.03	-.25
50	4.03	.86	.95	-.27
100	6.05	.85	.89	-.29

Region XI

T	a	b1	b2	b3
5	0.450	0.90	1.35	-0.21
10	1.36	.88	1.16	-.23
25	3.59	.87	1.03	-.25
50	6.61	.86	.95	-.27
100	11.5	.85	.89	-.29

Region VI

T	a	b1	b2	b3
5	0.260	0.90	1.35	-0.21
10	.741	.88	1.16	-.23
25	1.77	.87	1.03	-.25
50	2.97	.86	.95	-.27
100	4.70	.85	.89	-.29

Region XII

T	a	b1	b2	b3
5	0.157	0.90	1.35	-0.21
10	.629	.88	1.16	-.23
25	1.76	.87	1.03	-.25
50	3.05	.86	.95	-.27
100	4.83	.85	.89	-.29

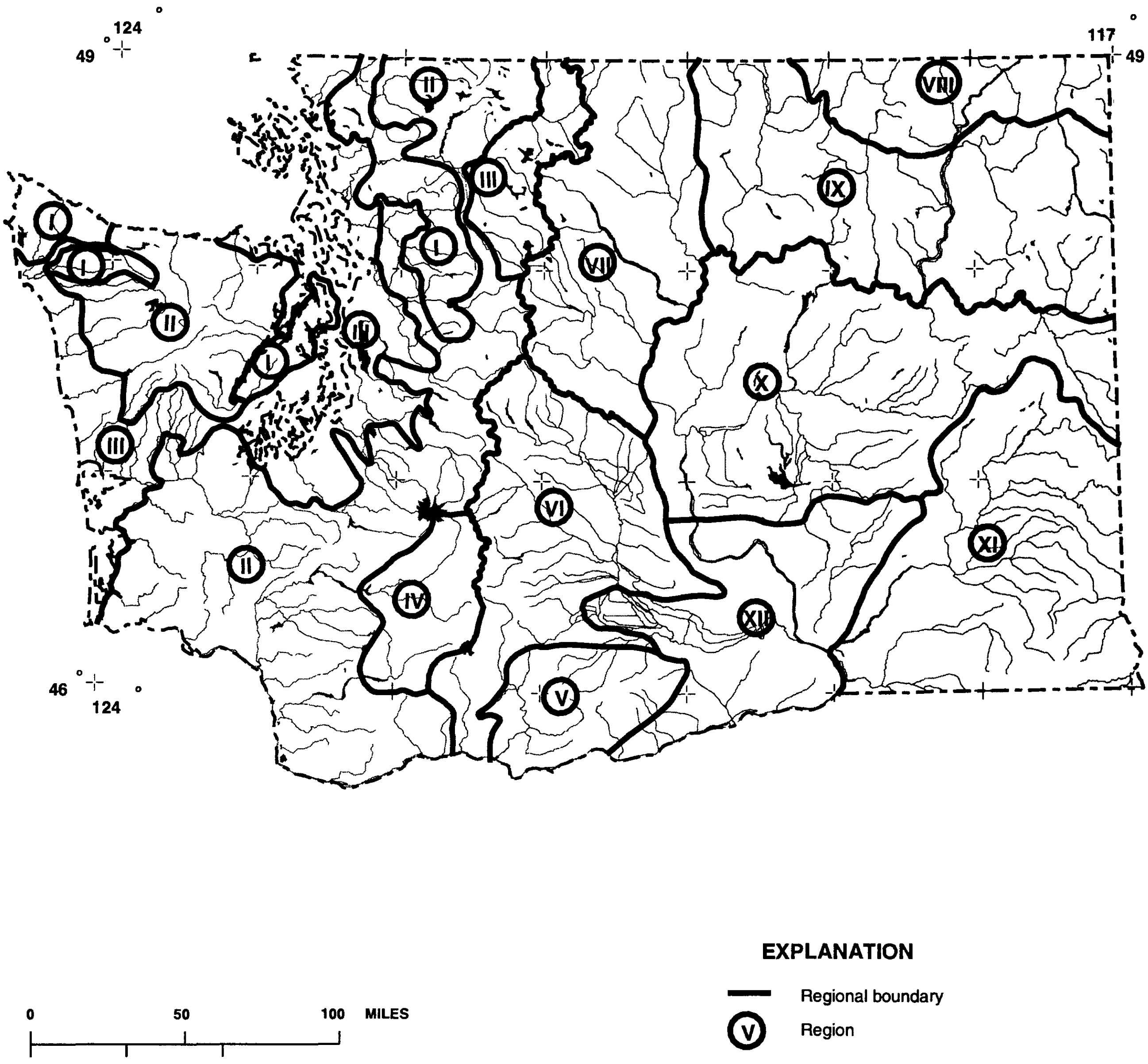
Reference

Cummans, J.E., Collings, M.R., and Nassar, E.G., 1975, Magnitude and frequency of floods in Washington: U.S. Geological Survey Open-File Report 74-336, 46 p.

EASTERN WASHINGTON (SMALL WATERSHEDS)

Summary

Eastern Washington is considered to be a single hydrologic region. The regression equations developed for eastern Washington are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; a longitude index (LI) which is the longitude of the site minus 117 degrees; and forest cover (F) which



Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Flood-frequency region map for Washington.

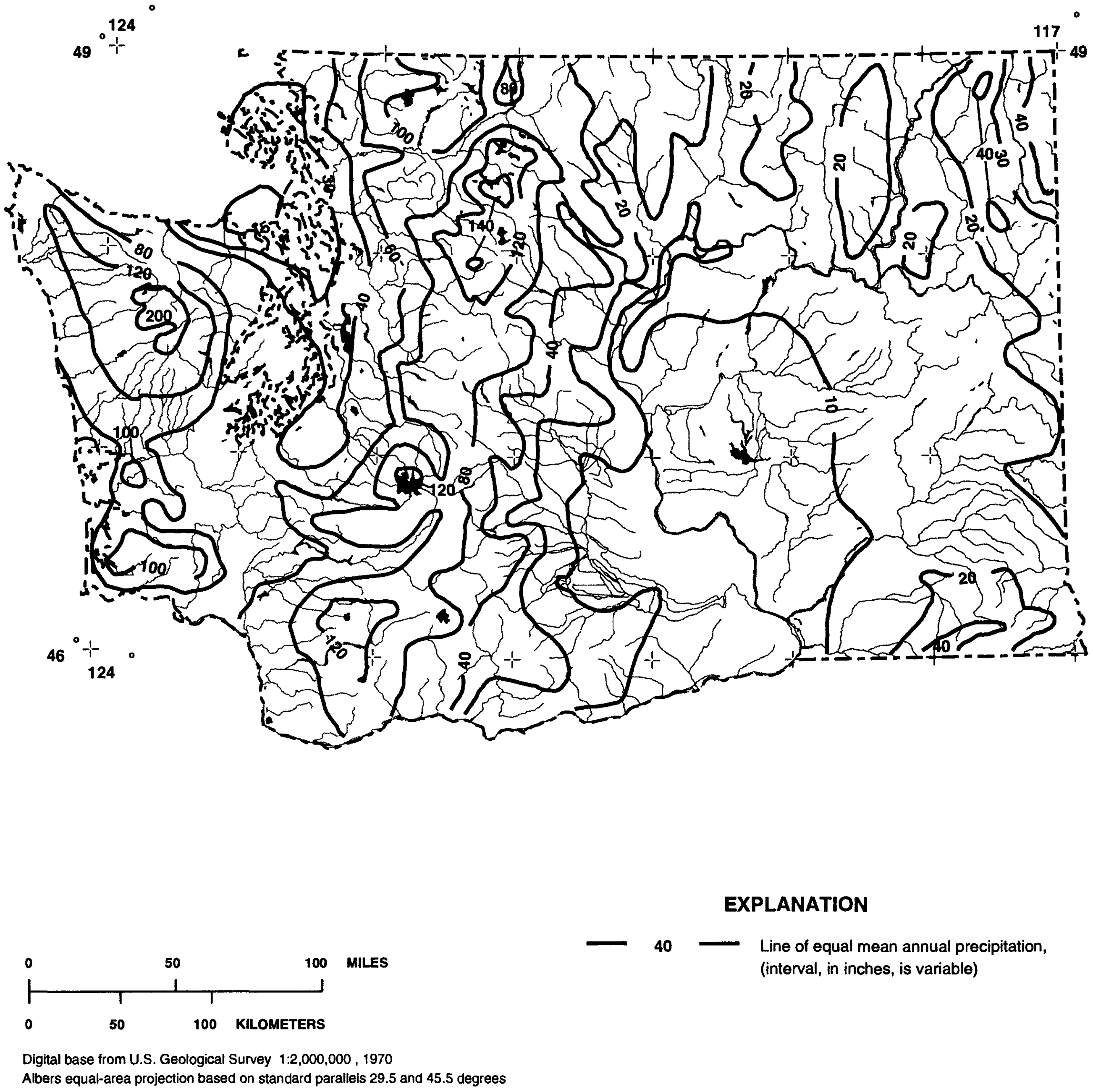


Figure 2. Mean annual precipitation in Washington.

is the percentage of the drainage area covered by forests. The constant of 117 is subtracted from LI in the computer application of the equations. The user should enter the actual value of LI. All of these variables can be measured from topographic maps. The regression equations were developed from peak-discharge records available through 1976 for about 50 sites and apply to unregulated ephemeral streams in eastern Washington with drainage areas (A) less than 40 square miles and with forest covers of less than 30 percent. The standard errors of estimate of the regression equations range from 55 percent for the 25-year flood to 100 percent for the 2-year flood. The report by Haushild (1979) also includes flood-frequency characteristics and maximum observed floods at ephemeral stations in eastern Washington.

Procedure

Topographic maps and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Form of the equations: $QT = a\,A^{b1}\,(LI)^{b2}\,F^{b3}$

T	a	b1	b2	b3
2	13	0.59	-0.63	--
5	38	.60	-.51	--
10	64	.62	-.46	--
25	85	.63	-.46	-0.07
50	110	.64	-.44	-.10
100	139	.66	-.42	-.12

Reference

Haushild, W.L., 1979, Estimation of floods of various frequencies for the small ephemeral streams in eastern Washington: U.S. Geological Survey Open-File Report 79-81, 22 p.

WEST VIRGINIA

STATEWIDE RURAL

Summary

West Virginia is divided into three hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The only explanatory basin variable used in the equations is drainage area (A), in square miles, and that variable can be measured from topographic maps. The regression equations were developed from peak-discharge records available through 1977 at 170 sites and are applicable to natural streams with drainage areas from 0.3 to 2,000 square miles. The standard errors of estimate of the regression equations range from 37 to 54 percent.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. Two sets of regression equations are used for each region--one for small and one for large watersheds. In the equations listed below, the equations on the left should be used for up to the drainage area break point and the equations on the right should be used for watersheds greater than the drainage area break point. In the computer program, the equations for the large watersheds for Regions 1-3 are identified as Regions 4-6, respectively.

	Drainage Area Break Point (square miles)	
Region 1		
$Q2 = 131A^{0.734}$	160	$74\ A^{0.847}$
$Q5 = 235A^{0.683}$	125	$115\ A^{0.831}$
$Q10 = 324A^{0.655}$	116	$149\ A^{0.818}$
$Q25 = 461A^{0.625}$	106	$203\ A^{0.801}$
$Q50 = 583A^{0.604}$	99	$249\ A^{0.789}$
$Q100 = 724A^{0.586}$	95	$303\ A^{0.777}$
$Q500 = 1{,}137A^{0.547}$	84	$462\ A^{0.750}$
Region 2		
$Q2 = 85A^{0.830}$	--	$85\ A^{0.830}$
$Q5 = 148A^{0.792}$	586	$115\ A^{0.831}$
$Q10 = 201A^{0.771}$	549	$149\ A^{0.818}$
$Q25 = 282A^{0.748}$	485	$203\ A^{0.801}$
$Q50 = 354A^{0.733}$	529	$249\ A^{0.789}$
$Q100 = 437A^{0.719}$	330	$303\ A^{0.777}$
$Q500 = 679A^{0.689}$	552	$462\ A^{0.750}$
Region 3		
$Q2 = 74A^{774}$	18.3	$68\ A^{0.803}$
$Q5 = 141A^{0.762}$	77.8	$98\ A^{0.845}$
$Q10 = 203A^{0.754}$	93.2	$122\ A^{0.860}$
$Q25 = 303A^{0.747}$	100	$159\ A^{0.887}$
$Q50 = 397A^{0.743}$	106	$191\ A^{0.899}$
$Q100 = 511A^{0.740}$	116	$228\ A^{0.910}$
$Q500 = 556A^{0.831}$	162	$335\ A^{0.930}$

Reference

Runner, G.S., 1980, Runoff studies on small drainage areas, Techniques for estimating magnitude and frequency of floods in West Virginia: U.S. Geological Survey Open-File Report 80-1218, 44 p.

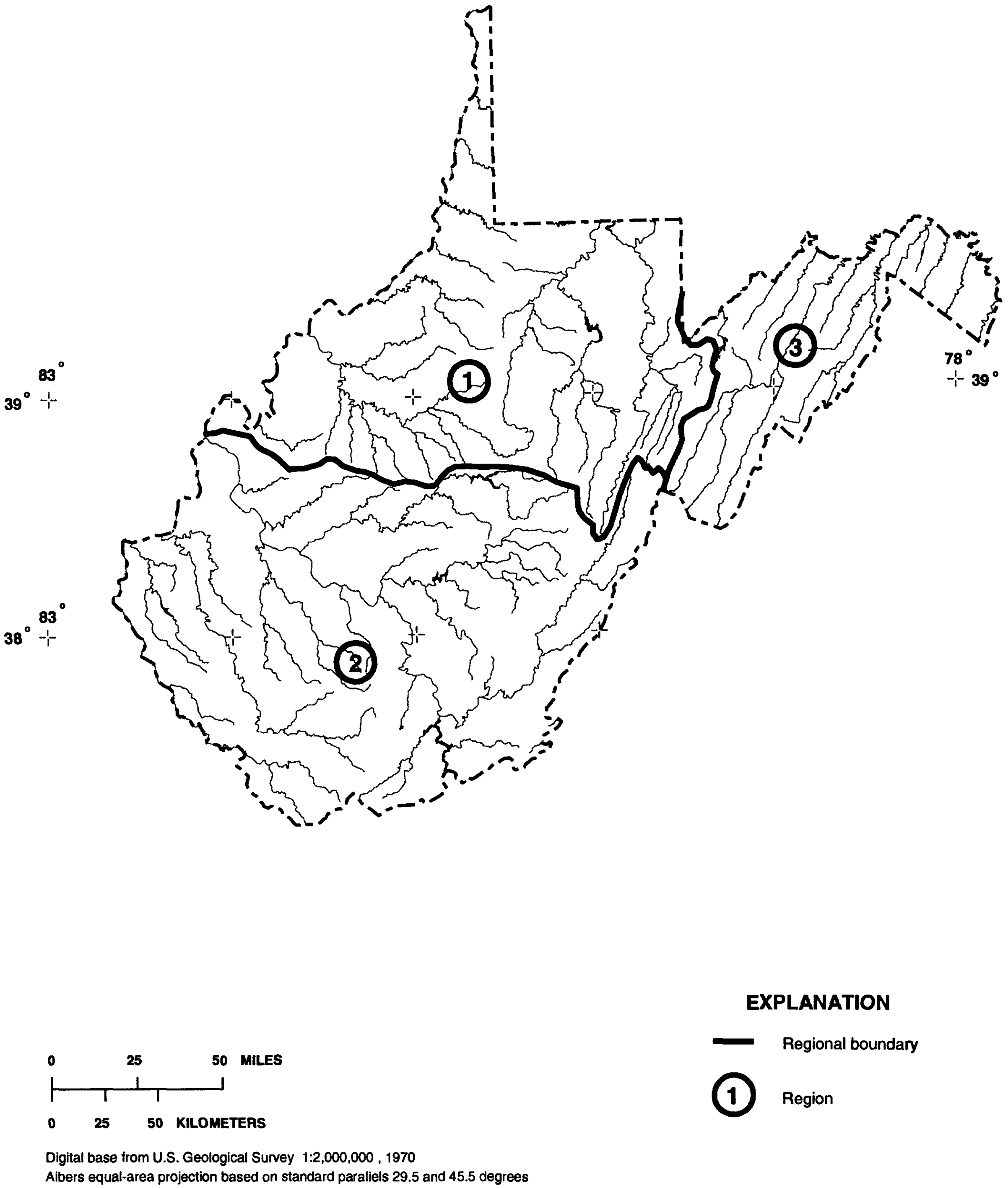


Figure 1. Flood-frequency region map for West Virginia.

WISCONSIN

STATEWIDE RURAL

Summary

Wisconsin is divided into five hydrologic areas (fig. 1). The regression equations developed for these areas are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; main channel slope (S), in feet per mile; storage (ST), the percentage of the drainage area covered by lakes, swamps, and wetlands, plus 1 percent; rainfall (INTENS), the 2-year 24-hour rainfall (fig. 2); mean annual snowfall (SN) for 1951 through 1980, in inches (fig. 3); soil permeability (SP) of the least-permeable soil horizon, in inches per hour; and forest cover (FOR), the percentage of the drainage area covered by forest cover, plus 1 percent. The constants of 1 are added to ST and FOR in the computer application of the equations. The user should enter the actual values of ST and FOR. The variables A, S, ST, and FOR can be measured from topographic maps; INTENS and SN can be determined from figures 2 and 3, respectively, but SP must be determined from a map in Krug and others (1992). The regression equations were developed from peak-discharge records at 269 stations with at least 10 years of records as of 1988. The equations are applicable to unregulated, ungaged streams and the standard errors of prediction of the regression equations range from 23 to 38 percent. The report by Krug and others (1992) also includes graphs relating flood-frequency characteristics to drainage areas for four major streams, flood frequency and drainage-basin characteristics, and annual flood peaks at 142 crest-stage and 184 continuous-record gaging stations.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the 2-year 24-hour rainfall map (fig. 2), the mean annual snowfall map (fig. 3), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

AREA 1 (39 stations)

$$Q2 = 158A^{0.720}\,INTENS^{2.95}\,S^{0.185}$$
$$Q5 = 186A^{0.778}\,INTENS^{3.34}\,S^{0.337}$$
$$Q10 = 226A^{0.798}\,INTENS^{3.58}\,S^{0.396}$$
$$Q25 = 282A^{0.818}\,INTENS^{3.82}\,S^{0.447}$$
$$Q50 = 317A^{0.833}\,INTENS^{3.96}\,S^{0.480}$$
$$Q100 = 342A^{0.848}\,INTENS^{4.06}\,S^{0.512}$$

AREA 2 (36 stations)

$$Q2 = 13.1A^{0.885}\,SP^{-0.562}\,S^{0.338}$$
$$Q5 = 15.1A^{0.907}\,SP^{-0.619}\,S^{0.499}$$
$$Q10 = 16.2A^{0.917}\,SP^{-0.649}\,S^{0.554}$$
$$Q25 = 17.2A^{0.929}\,SP^{-0.679}\,S^{0.610}$$
$$Q50 = 17.6A^{0.938}\,SP^{-0.697}\,S^{0.647}$$
$$Q100 = 17.7A^{0.947}\,SP^{-0.713}\,S^{0.682}$$

AREA 3 (56 stations)

$$Q2 = 22.4A^{0.868}\,SP^{-0.587}\,INTENS^{0.487}\,S^{0.239}$$
$$Q5 = 36.7A^{0.863}\,SP^{-0.665}\,INTENS^{0.523}\,S^{0.250}$$
$$Q10 = 55.9A^{0.865}\,SP^{-0.671}\,INTENS^{0.484}\,S^{0.264}\,FOR^{-0.0853}$$
$$Q25 = 77.3A^{0.864}\,SP^{-0.692}\,INTENS^{0.456}\,S^{0.270}\,FOR^{-0.127}$$
$$Q50 = 92.9A^{0.864}\,SP^{-0.705}\,INTENS^{0.436}\,S^{0.273}\,FOR^{-0.150}$$
$$Q100 = 108A^{0.864}\,SP^{-0.715}\,INTENS^{0.418}\,S^{0.276}\,FOR^{-0.166}$$

AREA 4 (56 stations)

$$Q2 = 1.36A^{0.857}\,S^{0.262}\,ST^{-0.291}\,SP^{-0.251}\,SN^{0.688}$$
$$Q5 = 4.63A^{0.847}\,S^{0.289}\,ST^{-0.272}\,SP^{-0.256}\,SN^{0.486}$$
$$Q10 = 7.94A^{0.844}\,S^{0.309}\,ST^{-0.265}\,SP^{-0.252}\,SN^{0.399}$$
$$Q25 = 13.2A^{0.841}\,S^{0.332}\,ST^{-0.258}\,SP^{-0.244}\,SN^{0.317}$$
$$Q50 = 17.8A^{0.839}\,S^{0.347}\,ST^{-0.253}\,SP^{-0.237}\,SN^{0.271}$$
$$Q100 = 22.7A^{0.838}\,S^{0.361}\,ST^{-0.249}\,SP^{-0.230}\,SN^{0.233}$$

AREA 5 (28 stations)

$Q2 = 8.17A^{0.914} S^{0.454} ST^{-0.264} SP^{-0.195}$

$Q5 = 21.1A^{0.899} S^{0.469} ST^{-0.291} SP^{-0.242} INTENS^{0.486}$

$Q10 = 31.0A^{0.887} S^{0.467} ST^{-0.298} SP^{-0.261} INTENS^{0.611}$

$Q25 = 44.8A^{0.874} S^{0.462} ST^{-0.300} SP^{-0.281} INTENS^{0.716}$

$Q50 = 55.0A^{0.868} S^{0.460} ST^{-0.299} SP^{-0.293} INTENS^{0.769}$

$Q100 = 64.8A^{0.863} S^{0.460} ST^{-0.299} SP^{-0.302} INTENS^{0.808}$

Reference

Krug, W.R., Conger, D.H., and Gebert W.A., 1992, Flood-frequency characteristics of Wisconsin streams: U.S. Geological Survey Water-Resources Report 91-4128, 185 p.

URBAN STREAMS

Summary

Two sets of regression equations were developed for urban streams, one for Milwaukee County, and the other for urban areas in the rest of Wisconsin. The regression equations developed for these areas are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The basin variables used are drainage area (A), in square miles; and percent of drainage area that is impervious (I). The regression equations were developed from peak-discharge records for 32 urban sites and are applicable to urban streams where streamflows are not significantly regulated or subject to diversion. The standard errors of estimate of the regression equations range from 32 to 39 percent.

Procedure

Topographic and land-use maps, and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T. The report by Conger (1986) an alternative method of determining total impervious area.

Wisconsin Urban Areas

$Q2 = 4.18A^{0.786} I^{1.02}$

$Q5 = 9.97A^{0.739} I^{0.910}$

$Q10 = 14.7A^{0.723} I^{0.863}$

$Q25 = 21.5A^{0.712} I^{0.818}$

$Q50 = 27.0A^{0.707} I^{0.792}$

$Q100 = 32.8A^{0.704} I^{0.770}$

Milwaukee County Urban Areas

$Q2 = 3.72A^{0.743} I^{1.11}$

$Q5 = 5.73A^{0.727} I^{1.09}$

$Q10 = 7.05A^{0.724} I^{1.09}$

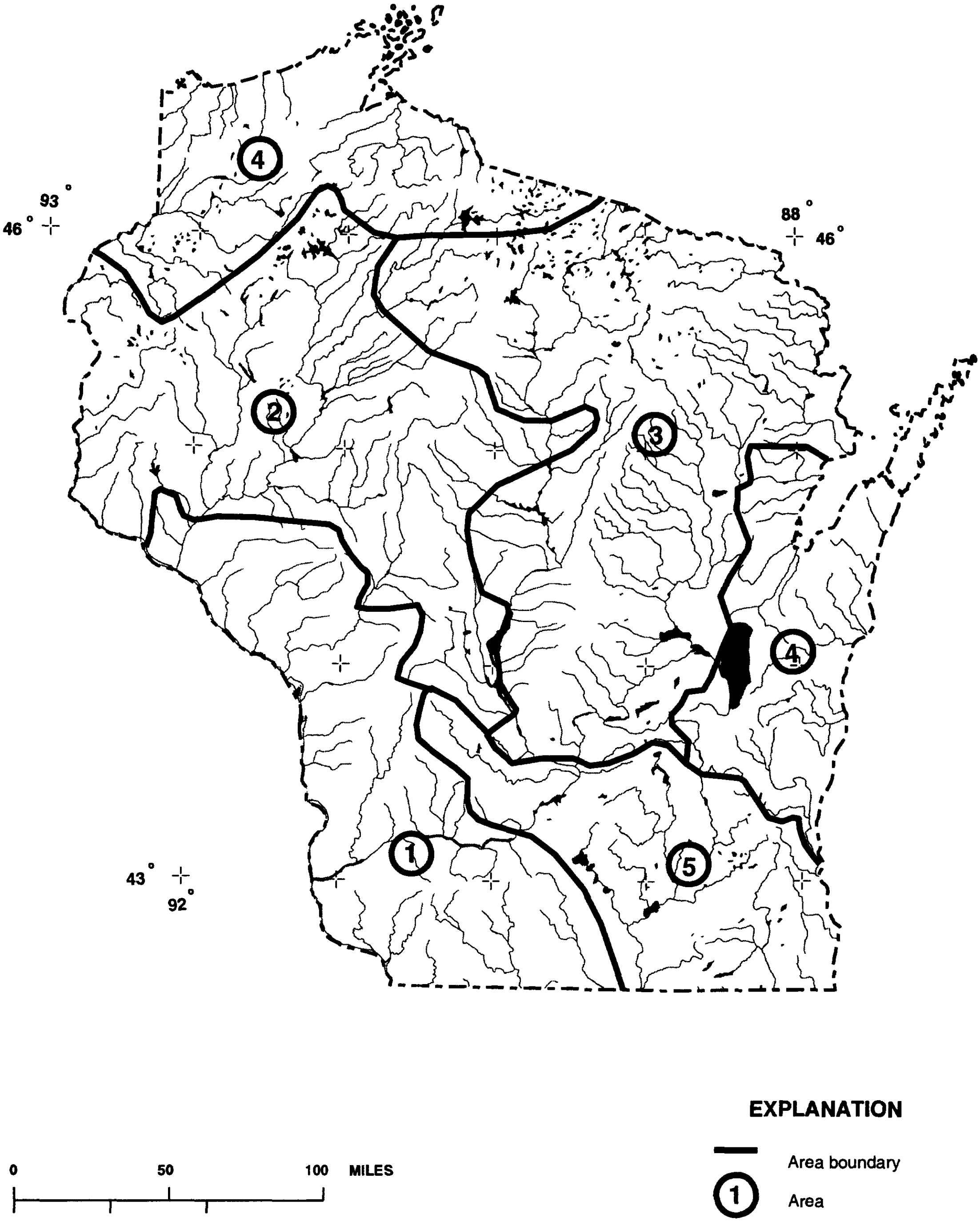
$Q25 = 8.72A^{0.725} I^{1.08}$

$Q50 = 10.0A^{0.727} I^{1.08}$

$Q100 = 11.3A^{0.729} I^{1.07}$

Reference

Conger, D.H., 1986, Estimating magnitude and frequency of floods for Wisconsin urban streams: U.S. Geological Survey Water-Resources Investigations Report 86-4005, 18 p.



Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 1. Flood-frequency area map for Wisconsin.

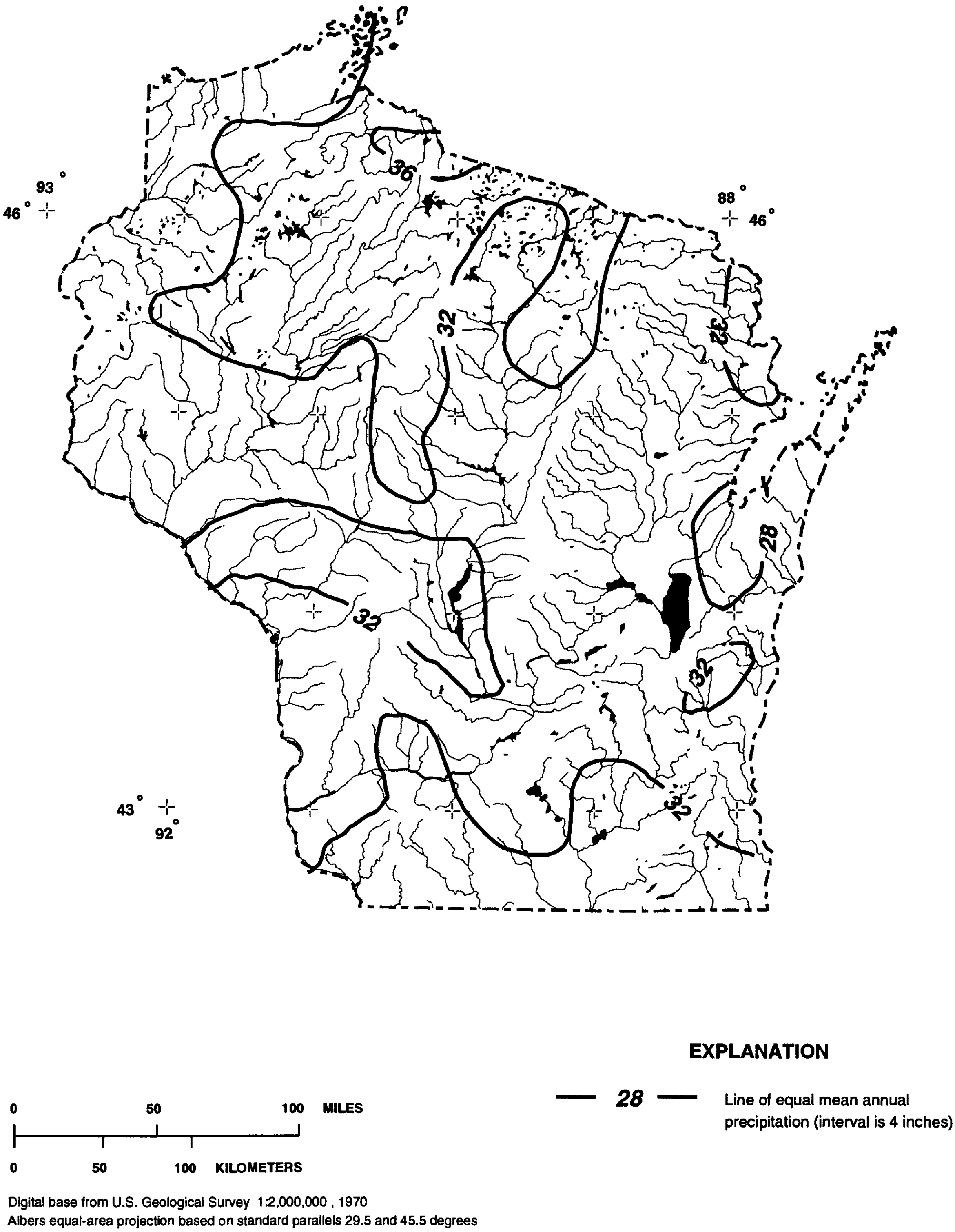
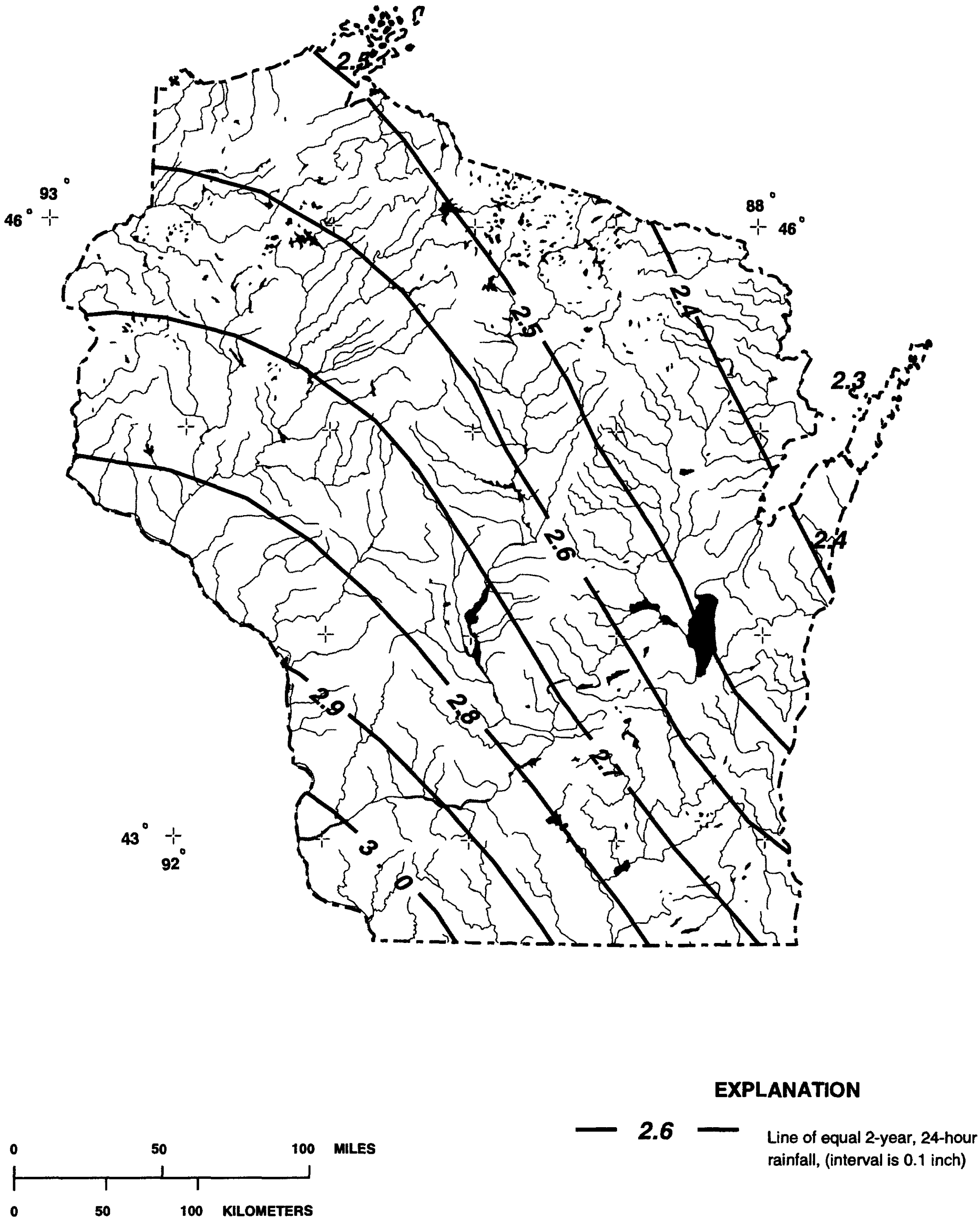


Figure 2. The 2-year 24-hour rainfall in Wisconsin.



Digital base from U.S. Geological Survey 1:2,000,000, 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

Figure 3. Mean annual snowfall in Wisconsin.

WYOMING

STATEWIDE RURAL

Summary

Wyoming is divided into three hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 500 years. The explanatory basin variables used in the equations are contributing drainage area (A), in square miles; mean basin elevation (ELEV) in feet; mean annual precipitation (PR), in inches (fig. 2); and basin slope (Sb), in feet per mile. In the Plains and High Desert regions, a geographic factor (Gf) (fig. 3) is used. The constants of ELEV is divided by 1000 in the computer application of the equations. The user should enter the actual value for ELEV. The variables A, E, and Sb can be measured from topographic maps; the variables PR and Gf are shown in figures 2 and 3, respectively. The regression equations were developed from peak-discharge records available as of December 1986 at 361 stations. The equations are applicable only to natural-flow streams, and the regional average standard errors of estimate of the regression equations range from 50 to 75 percent. The report by Lowham (1988) includes procedures for estimating flood characteristics from channel geometry as well as ones for estimating mean annual and mean monthly flows by various methods. Also included in the report are flood-frequency characteristics, basin characteristics, and channel widths at stations used in the analysis.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation map (fig. 2), the geographic factors map (fig. 3), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

Mountainous Regions

$$Q2 = 0.012A^{0.88} (ELEV/1000)^{3.25}$$
$$Q5 = 0.13A^{0.84} (ELEV/1000)^{2.41}$$
$$Q10 = 0.45A^{0.82} (ELEV/1000)^{1.95}$$
$$Q25 = 1.75A^{0.80} (ELEV/1000)^{1.46}$$
$$Q50 = 4.29A^{0.79} (ELEV/1000)^{1.13}$$
$$Q100 = 9.63A^{0.77} (ELEV/1000)^{0.85}$$
$$Q200 = 25.9A^{0.75} (ELEV/1000)^{0.47}$$
$$Q500 = 63.4A^{0.74} (ELEV/1000)^{0.14}$$

Plains Region

$$Q2 = 41.3A^{0.60}A^{-0.05}\, Gf$$
$$Q5 = 63.7A^{0.60}A^{-0.05}\, SB^{0.09}\, Gf$$
$$Q10 = 76.9A^{0.59}A^{-0.05}\, SB^{0.14}\, Gf$$
$$Q25 = 94.2A^{0.59}A^{-0.05}\, SB^{0.19}\, Gf$$
$$Q50 = 112A^{0.58}A^{-0.05}\, SB^{0.23}\, Gf$$
$$Q100 = 130A^{0.58}A^{-0.05}\, SB^{0.25}\, Gf$$
$$Q200 = 182A^{0.57}A^{-0.05}\, SB^{0.26}\, Gf$$
$$Q500 = 245A^{0.57}A^{-0.05}\, SB^{0.27}\, Gf$$

High Desert Region

$$Q2 = 6.66A^{0.59}\, A^{-0.03}\, PR^{0.60}\, Gf$$
$$Q5 = 10.6\, A^{0.56}\, A^{-0.03}\, PR^{0.81}\, Gf$$
$$Q10 = 13.8A^{0.55}\, A^{-0.03}\, PR^{0.90}\, Gf$$
$$Q25 = 19.4A^{0.53}\, A^{-0.03}\, PR^{0.98}\, Gf$$
$$Q50 = 24.2A^{0.52}\, A^{-0.03}\, PR^{1.02}\, Gf$$
$$Q100 = 30.1A^{0.51}\, A^{-0.03}\, PR^{1.05}\, Gf$$
$$Q200 = 36.0A^{0.51}\, A^{-0.03}\, PR^{1.07}\, Gf$$
$$Q500 = 47.1A^{0.50}\, A^{-0.03}\, PR^{1.09}\, Gf$$

Reference

Lowham, H.W., 1988, Streamflows in Wyoming: U.S. Geological Survey Water-Resources Investigations Report 88-4045, 78 p.

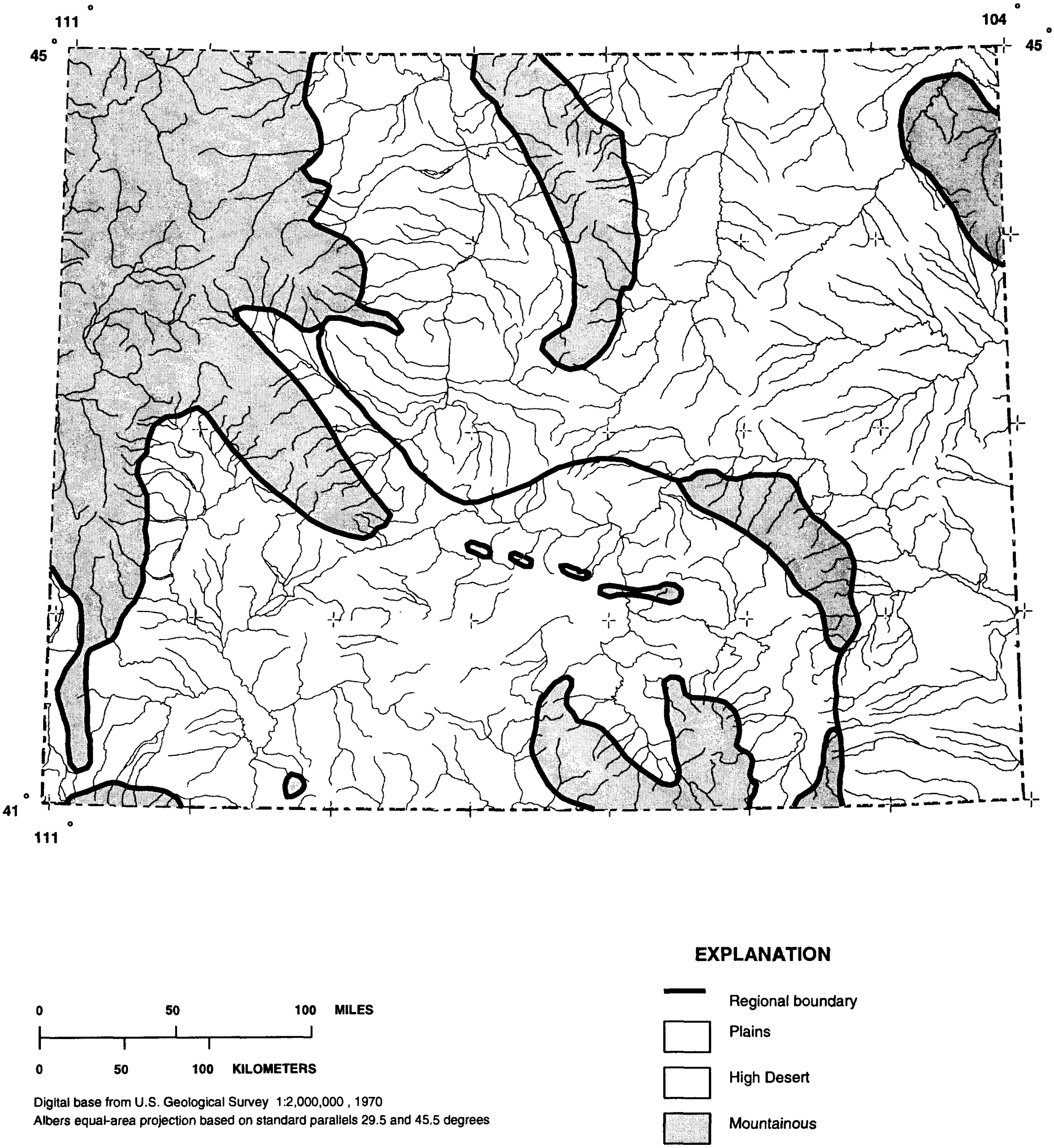
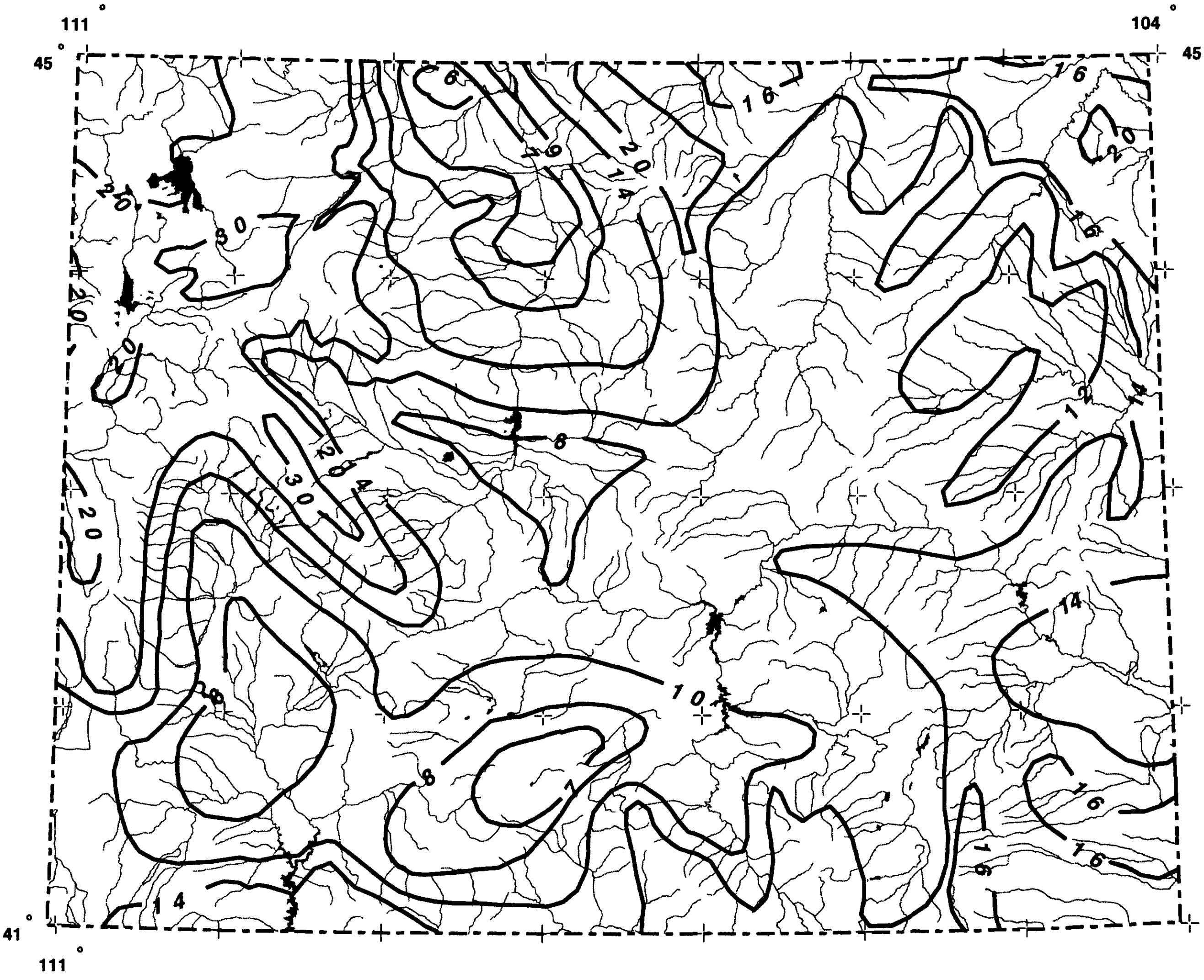


Figure 1. Flood-frequency region map for Wyoming.



0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— 7 — Line of equal average annual precipitation, (interval, in inches, is variable)

Figure 2. Mean annual precipitation for Wyoming.

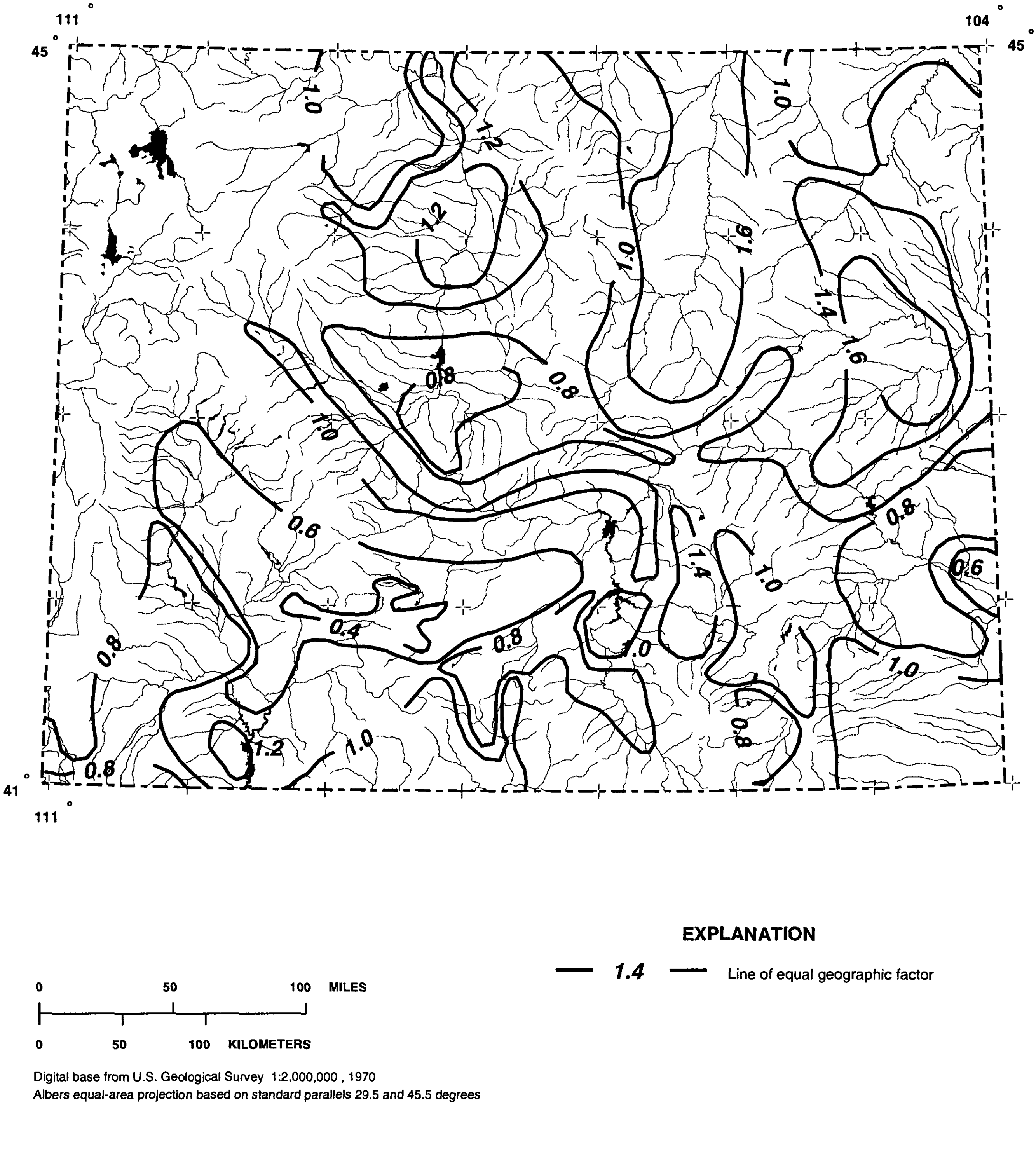


Figure 3. Geographic factors for Wyoming.

SOUTHWESTERN UNITED STATES

Summary

A regional flood-frequency study was completed for an area of the southwestern United States, including all of Arizona, Nevada, and Utah, and parts of California, Colorado, Idaho, New Mexico, Oregon, Texas, and Wyoming (fig. 1). The study area was divided into 16 hydrologic flood regions as shown in Figure 1. Region 1 comprises high-elevation areas throughout the study area. The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (AREA), in square miles; mean basin elevation (ELEV/1000), in feet above sea level divided by 1000; mean annual precipitation (PREC), in inches; mean annual free water surface evaporation (EVAP), in inches; latitude of the gaged site minus 28 divided by 10 ((LAT-28)/10), in decimal degrees; and longitude of the gaged site minus 99 divided by 10 ((LONG-99/10)), in decimal degrees. The variables ELEV, LAT and LONG are modified by the given constants in the computer applications of the equations. The user should enter the actual values of ELEV, LAT and LONG. The variables AREA, ELEV, LAT and LONG can be measured from topographic maps. The variable PREC can be obtained from normal-annual precipitation maps (1:500,000 scale) in U.S. Weather Bureau (1959-61, 1963). The variable EVAP can be obtained from figures 2 and 3. The regression equations were developed from peak-discharge records available as of 1986 at 1,162 stations in the 10-state study area. The equations are most applicable to unregulated streams with drainage areas less than 200 square miles. In all regions some stations with drainage areas between 200 and 2000 square miles were used in developing the regression equations. Judicious use should be made of the equations for basins between 200 square miles and the upper limit of the calibration data (this upper limit is provided in the NFF program). The average standard error of prediction of the regression equations range from 45 to 135 percent.

Procedure

Use topographic maps, mean annual precipitation maps in U.S. Weather Bureau (1959-61, 1963), mean annual free water surface evaporation maps in figures 2 and 3, and the following regression equations to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

High-Elevation Region 1

$$Q2 = 0.124AREA^{0.845}PREC^{1.44}$$
$$Q5 = 0.629AREA^{0.807}PREC^{1.12}$$
$$Q10 = 1.43AREA^{0.786}PREC^{0.958}$$
$$Q25 = 3.08AREA^{0.768}PREC^{0.811}$$
$$Q50 = 4.75AREA^{0.758}PREC^{0.732}$$
$$Q100 = 6.78AREA^{0.750}PREC^{0.668}$$

Northwest Region 2

$$Q2 = 13.1AREA^{0.713}$$
$$Q5 = 22.4AREA^{0.723}$$
$$Q10 = 55.7AREA^{0.727}(ELEV/1,000)^{-0.353}$$
$$Q25 = 84.7AREA^{0.737}(ELEV/1,000)^{-0.438}$$
$$Q50 = 113AREA^{0.746}(ELEV/1,000)^{-0.511}$$
$$Q100 = 148AREA^{0.752}(ELEV/1,000)^{-0.584}$$

South-Central Idaho Region 3

$$Q2 = 0.444AREA^{0.649}PREC^{1.15}$$
$$Q5 = 1.21AREA^{0.639}PREC^{0.995}$$
$$Q10 = 1.99AREA^{0.633}PREC^{0.924}$$
$$Q25 = 3.37AREA^{0.627}PREC^{0.849}$$
$$Q50 = 4.70AREA^{0.625}PREC^{0.802}$$
$$Q100 = 6.42AREA^{0.621}PREC^{0.757}$$

Northeast Region 4

$$Q2 = 0.0405AREA^{0.701}(ELEV/1{,}000)^{2.91}$$
$$Q5 = 0.408AREA^{0.683}(ELEV/1{,}000)^{2.05}$$
$$Q10 = 1.26AREA^{0.674}(ELEV/1{,}000)^{1.64}$$
$$Q25 = 3.74AREA^{0.667}(ELEV/1{,}000)^{1.24}$$
$$Q50 = 7.04AREA^{0.664}(ELEV/1{,}000)^{1.02}$$
$$Q100 = 11.8AREA^{0.662}(ELEV/1{,}000)^{0.835}$$

Eastern Sierras Region 5

$$Q2 = 0.0333AREA^{0.853}(ELEV/1{,}000)^{2.68}[(LAT\text{-}28)/10]^{4.1}$$
$$Q5 = 2.42AREA^{0.823}(ELEV/1{,}000)^{1.01}[(LAT\text{-}28)/10]^{4.1}$$
$$Q10 = 28.0AREA^{0.826}[(LAT\text{-}28)/10]^{4.3}$$
$$Q25 = 426AREA^{0.812}(ELEV/1{,}000)^{-1.10}[(LAT\text{-}28)/10]^{4.3}$$
$$Q50 = 2{,}030AREA^{0.798}(ELEV/1{,}000)^{-1.71}[(LAT\text{-}28)/10]^{4.4}$$
$$Q100 = 7{,}000AREA^{0.782}(ELEV/1{,}000)^{-2.18}[(LAT\text{-}28)/10]^{4.6}$$

Northern Great Basin Region 6

$$Q2 = 0$$
$$Q5 = 32AREA^{0.80}(ELEV/1{,}000)^{-0.66}$$
$$Q10 = 590AREA^{0.62}(ELEV/1{,}000)^{-1.6}$$
$$Q25 = 3{,}200AREA^{0.62}(ELEV/1{,}000)^{-2.1}$$
$$Q50 = 5{,}300AREA^{0.64}(ELEV/1{,}000)^{-2.1}$$
$$Q100 = 20{,}000AREA^{0.51}(ELEV/1{,}000)^{-2.3}$$

South-Central Utah Region 7

$$Q2 = 0.0150AREA^{0.697}(ELEV/1{,}000)^{3.16}$$
$$Q5 = 0.306AREA^{0.590}(ELEV/1{,}000)^{2.22}$$
$$Q10 = 1.25AREA^{0.526}(ELEV/1{,}000)^{1.83}$$
$$Q25 = 122AREA^{0.440}$$
$$Q50 = 183AREA^{0.390}$$
$$Q100 = 264AREA^{0.344}$$

Four Corners Region 8

$$Q2 = 598AREA^{0.501}(ELEV/1{,}000)^{-1.02}$$
$$Q5 = 2{,}620AREA^{0.449}(ELEV/1{,}000)^{-1.28}$$
$$Q10 = 5{,}310AREA^{0.425}(ELEV/1{,}000)^{-1.40}$$
$$Q25 = 10{,}500AREA^{0.403}(ELEV/1{,}000)^{-1.49}$$
$$Q50 = 16{,}000AREA^{0.390}(ELEV/1{,}000)^{-1.54}$$
$$Q100 = 23{,}300AREA^{0.377}(ELEV/1{,}000)^{-1.59}$$

Western Colorado Region 9

$$Q2 = 0.204AREA^{0.606}(ELEV/1{,}000)^{3.5}$$
$$Q5 = 0.181AREA^{0.515}(ELEV/1{,}000)^{2.9}$$
$$Q10 = 1.18AREA^{0.488}(ELEV/1{,}000)^{2.2}$$
$$Q25 = 18.2AREA^{0.465}(ELEV/1{,}000)^{1.1}$$
$$Q50 = 248AREA^{0.449}$$
$$Q100 = 292AREA^{0.444}$$

Southern Great Basin Region 10

$$Q2 = 12AREA^{0.58}$$
$$Q5 = 85AREA^{0.59}$$
$$Q10 = 200AREA^{0.62}$$
$$Q25 = 400AREA^{0.65}$$
$$Q50 = 590AREA^{0.67}$$
$$Q100 = 850AREA^{0.69}$$

Northeast Arizona Region 11

$$Q2 = 26AREA^{0.62}$$
$$Q5 = 130AREA^{0.56}$$
$$Q10 = 0.10AREA^{0.52}EVAP^{2.0}$$
$$Q25 = 0.17AREA^{0.52}EVAP^{2.0}$$
$$Q50 = 0.24AREA^{0.54}EVAP^{2.0}$$
$$Q100 = 0.27AREA^{0.58}EVAP^{2.0}$$

Central Arizona Region 12

$$Q2 = 41.1AREA^{0.629}$$
$$Q5 = 238AREA^{0.687}(ELEV/1{,}000)^{-0.358}$$
$$Q10 = 479AREA^{0.661}(ELEV/1{,}000)^{-0.398}$$
$$Q25 = 942AREA^{0.630}(ELEV/1{,}000)^{-0.383}$$
$$Q50 = 10^{(7.36-4.17AREA^{**}-0.08)}(ELEV/1{,}000)^{-0.440}$$
$$Q100 = 10^{(6.55-3.17AREA^{**}-0.11)}(ELEV/1{,}000)^{-0.454}$$

Southern Arizona Region 13

$$Q2 = 10^{(6.38-4.29AREA^{**}-0.06)}$$
$$Q5 = 10^{(5.78-3.31AREA^{**}-0.08)}$$
$$Q10 = 10^{(5.68-3.02AREA^{**}-0.09)}$$
$$Q25 = 10^{(5.64-2.78AREA^{**}-0.10)}$$
$$Q50 = 10^{(5.57-2.59AREA^{**}-0.11)}$$
$$Q100 = 10^{(5.52-2.42AREA^{**}-0.12)}$$

Upper Gila Basin Region 14

$$Q2 = 583AREA^{0.588}(ELEV/1{,}000)^{-1.3}$$
$$Q5 = 618AREA^{0.524}(ELEV/1{,}000)^{-0.70}$$
$$Q10 = 361AREA^{0.464}$$
$$Q25 = 581AREA^{0.462}$$
$$Q50 = 779AREA^{0.462}$$
$$Q100 = 1{,}010AREA^{0.463}$$

Upper Rio Grande Basin Region 15

$$Q2 = 18{,}700AREA^{0.730}(ELEV/1{,}000)^{-2.86}[(LONG-99)/10)]^{2.8}$$
$$Q5 = 31{,}700AREA^{0.646}(ELEV/1{,}000)^{-2.67}[(LONG-99)/10)]^{2.7}$$
$$Q10 = 26{,}000AREA^{0.582}(ELEV/1{,}000)^{-2.27}[(LONG-99)/10)]^{2.7}$$
$$Q25 = 34{,}800AREA^{0.532}(ELEV/1{,}000)^{-2.15}[(LONG-99)/10)]^{2.6}$$
$$Q50 = 44{,}200AREA^{0.501}(ELEV/1{,}000)^{-2.11}[(LONG-99)/10)]^{2.5}$$
$$Q100 = 91{,}800AREA^{0.439}(ELEV/1{,}000)^{-2.22}[(LONG-99)/10)]^{2.5}$$

Southeast Region 16

$$Q2 = 14AREA^{0.51}(EVAP - 32)^{0.55}$$
$$Q5 = 37AREA^{0.48}(EVAP - 32)^{0.63}$$
$$Q10 = 52AREA^{0.47}(EVAP - 32)^{0.67}$$
$$Q25 = 70AREA^{0.48}(EVAP - 32)^{0.74}$$
$$Q50 = 110AREA^{0.47}(EVAP - 34)^{0.74}$$
$$Q100 = 400AREA^{0.50}(EVAP - 37)^{0.45}$$

Reference

Thomas, B.E., Hjalmarson, H.W., and Waltemeyer, S.D., 1993, Methods for estimating magnitude and frequency of floods in the southwestern United States: U.S. Geological Survey Open-File Report 93-419, 193 pages.

Additional References

U.S. Weather Bureau, 1959-61, Climates of the States: U.S. Department of Commerce, Weather Bureau, Climatography of the United States, no. 60 [section for each State].

U.S. Weather Bureau, 1963, Normal annual precipitation (1931-60) for the States of Arizona, Colorado, New Mexico, Utah: U.S. Department of Commerce, Weather Bureau maps, scale 1:500,000.

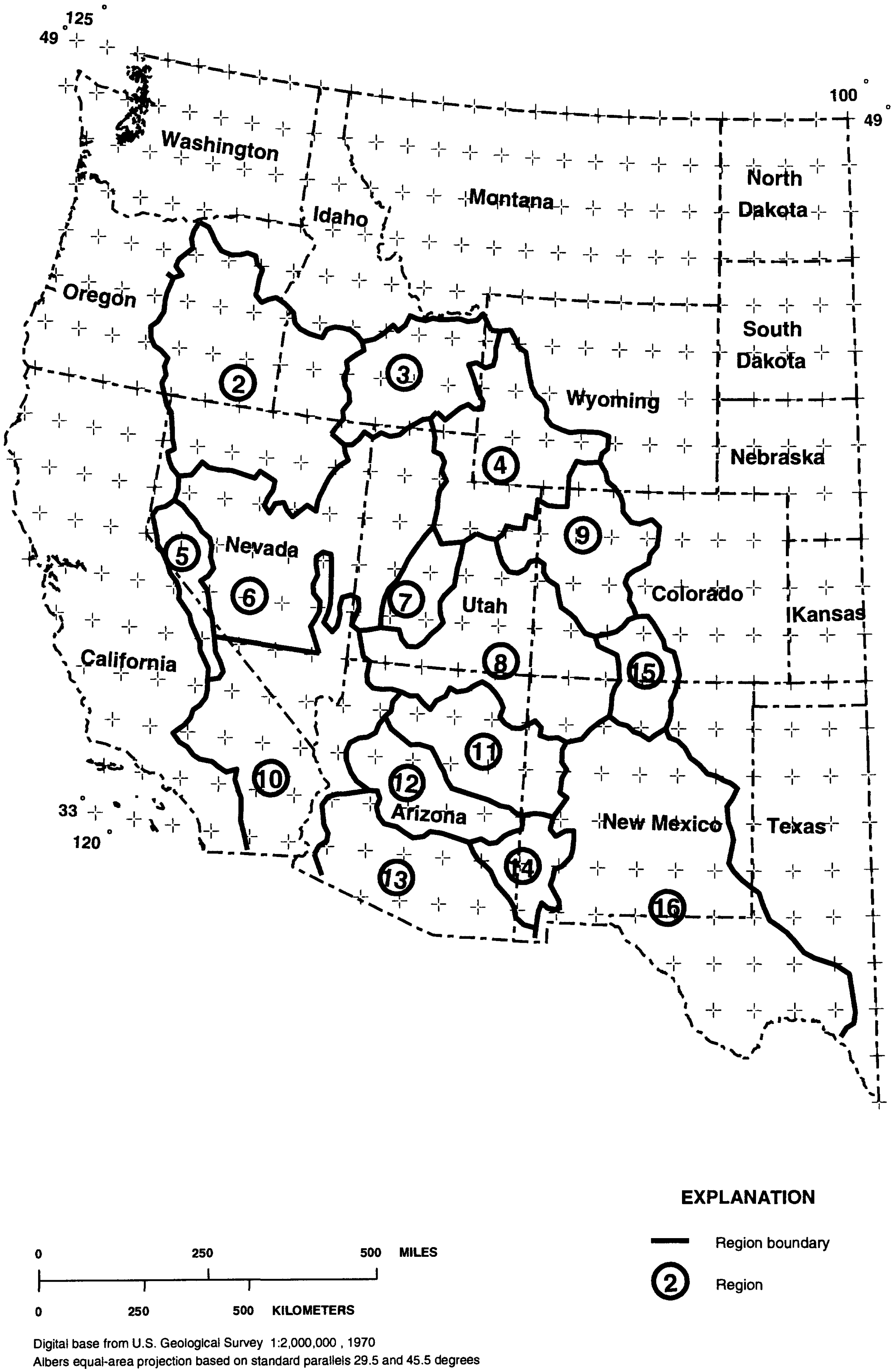


Figure 1. Flood regions in study area.

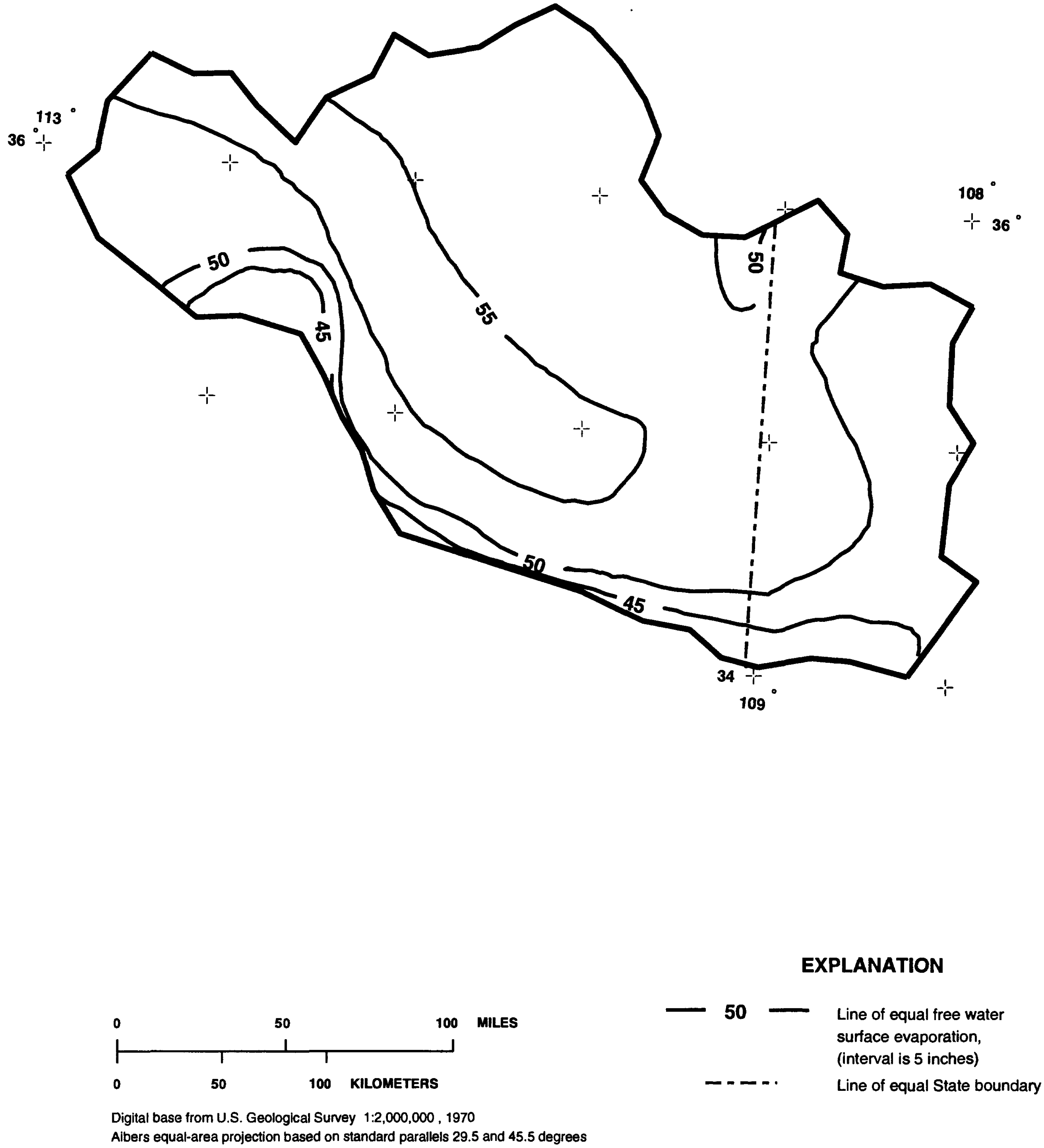


Figure 2. Mean annual free water surface evaporation in region 11.

0 50 100 MILES

0 50 100 KILOMETERS

Digital base from U.S. Geological Survey 1:2,000,000 , 1970
Albers equal-area projection based on standard parallels 29.5 and 45.5 degrees

EXPLANATION

— 50 — Line of equal free water surface evaporation, (interval, in inches, is variable)

-·-—-·· Line of equal State boundary

Figure 3. Mean annual free water surface evaporation in region 16.

APPENDIXES

APPENDIX A -- INSTALLATION OF THE COMPUTER PROGRAM

The National Flood Frequency (NFF) computer program, contained on the diskette included with this report, can be run on a variety of personal computers (PC). It is desirable to have a VGA color monitor, DOS 4.0 or later, and at least 640K bytes of memory. NFF can be run under Microsoft Windows 3.X, but it is not a Windows application. NFF can be used on a PC with a monochrome or text only monitor but it may not be possible to display all the graphics. Some difficulty displaying graphics has been experienced using PC's with LCD displays, such as laptops. Since NFF presents its results in tabular form and optionally as graphics, the lack of ability to produce graphics does not severely limit effective use of the program.

The following files are on the diskette:

nff.exe	executable nff program
nff.ico	raging flood icon for nff (use icon with pif file)
nff.pif	Windows 3.X pif file for nff
open.bmp	opening screen bitmap
state.bin	packed state data file
state.ndx	index into the state data file
readme.text	introductory information about nff

NFF can be run directly from the provided diskette, however, it will run significantly faster if it is installed on your hard disk (if available) and run from there. Perform the following steps to install and run NFF on your hard disk:

1. Make sure the distribution diskette is write protected,
2. Create a directory to contain the NFF files, for example,
   mkdir c:\nff
3. Copy the NFF files from the distribution diskette to your hard disk, for example,
   copy a:*.* c:\nff
4. Change your working directory to the NFF installation directory, for example,
   cd c:\nff
5. Execute the NFF program by typing the command "nff."

The following options may be chosen when running NFF:

-h display a short help message

-t skip display of the initial NFF screen

-s avoid the typing of unnecessary <return> keys

logfile a valid DOS filename to which NFF non-graphical output can be saved (as well as displayed on the screen). Saving this information to the *logfile* is a convenient way to docment the input data used to compute a given flood-frequency curve or flood hydrograph. An example of a NFF *logfile* is given in Appendix B.

Options may be used in combination as long as *logfile* is specified last, for example, "nff -st *logfile*".

There are a few special key strokes that simplify use of NFF. The following is a brief description of these key strokes.

^A abort and restart the current major activity.

^B abort the current major activity and restart the previous major activity.

^C exit NFF completely.

(Note: "^A" means hold down the Control (Ctrl on many keyboards) key and press the letter A key.)

Use of ^A and ^B allows the user to go backwards in NFF to correct a mistake without having to restart the program. Use of ^C allows the user to exit NFF at anytime.

The definition of a "major activity" is somewhat arbitrary, but roughly corresponds to each of these tasks: (a) selecting a state for analysis; (b) entering input data for a flood-frequency computation; (c) making plots; and (d) computing flood hydrographs.

NFF tries to use the highest display resolution that your video driver supports. Display problems may be experienced in the initial screen if the graphics of your monitor does not support the higher resolution modes of your video card. If this is a problem, a specific video mode can be specified for NFF graphics by setting the DOS environment variable named FG_DISPLAY to one of the following values:

CGAHIRES	IBM CGA in 640 X 200 X 2 colors
CGAMEDRES	IBM CGA in 320 X 200 X 4 colors
EGAMONO	IBM EGA in 640 X 350 X 4 colors, but monochrome monitor
EGACOLOR	IBM EGA in 640 X 200 X 16 colors
EGAECD	IBM EGA (enhanced) in 640 X 350 X 16 colors
EGALOWRES	IBM EGA in 320 X 200 X 16 colors
EBGAHIRES	Everex EVGA in 800 X 600 X 16 colors
ORCHIDPROHIRES	Orchid ProDesigner VGA in 800 X 600 X 16 colors
PARADISEHIRES	Paradise VGA in 800 X 600 X 16 colors
TOSHIBA	Toshiba 3100 in 640 X 400 X 2 colors (monochrome)
TRIDENTHIRES	Trident VGA in 800 X 600 X 16 colors
VEGAVGAHIRES	Video 7 Vega VGA in 800 X 600 X 16 colors
VESA6A	Vesa (mode 0x6A) 800 X 600 X 16 colors
VESA2	Vesa (mode 0x102) 800 X 600 X 16 colors

VGA11	IBM VGA in 640 X 480 X 2 colors
VGA12	IBM VGA in 640 X 480 X 16 colors
VGA13	IBM VGA in 320 X 200 X 265 colors
8514A	IBM 8514 display adaptor

It is recommended that you allow NFF to automatically determine and set the display mode (when FG_DISPLAY is NOT set). If the automatic display mode causes problems, and you are unsure which mode to select, try VGA12 as this will work with a large number of video board/monitor combinations. If you have a LCD display, you might first try setting FG_DISPLAY equal to EGAMONO or TOSHIBA.

For example, to set the NFF display mode for use with an IBM VGA monitor with 640 x 480 screen resolution using 16 colors, enter the following DOS command:

SET FG_DISPLAY=VGA12

This must be done at the DOS level and prior to execution of NFF. If your computer hardware configuration requires that you set a specific display mode in order to use NFF, the above command should be placed in your autoexec.bat file so that you will not need to type it everytime you run NFF.

To install NFF as an icon in a MS Windows program group, do the following:

1. Select "new" from the windows "file" menu,
2. The "program to run" is specified as nff.pif from the NFF installation directory, for example,

   c:\nff\nff.pif
3. Select "change icon" from the "new" window and specify the file nff.ico from the NFF installation directory, for example,

   c:\nff\nff.ico

APPENDIX B -- DESCRIPTION OF THE NATIONAL FLOOD FREQUENCY PROGRAM

The National Flood Frequency (NFF) computer program evaluates regression equations for estimating T-year flood-peak discharges for rural and urban watersheds. As many as 7 multiple regression equations (2-, 5-, 10-, 25-, 50-, 100-, and 500-year) are defined for each of 200 or more flood regions. Methods are also available for estimating a typical flood hydrograph corresponding to a given T-year peak discharge.

The NFF computer program is composed of two components -- a state-by-state data base of regression coefficients, standard errors, etc. for about 1,500 multiple regression equations and a calculation routine for rural and urban flood characteristics including tabling and graphing capabilities. The format of the state-by-state data base is described below. As noted earlier, the NFF program is written in the "C" programming language and is designed to run on a microcomputer with at least 640K bytes of user memory.

Figure B1 is a flow chart of the NFF computation options. A State may be selected by a two-character code. Each State will have from 1 to 12 flood regions. When a flood region is selected, the program will prompt the user for the required watershed and climatic characteristics and other information to make the flood computations. Options include the computation of regional regression estimates of the rural flood-peak discharge for a given station, computation of a weighted estimate of the station and regional estimates (if equivalent years of record are provided for the regional equations), computation of urban flood-peak discharges for a given station, the ability to plot and save any computed frequency curve, computation of a flood hydrograph corresponding to a given T-year peak discharge, and the ability to plot and save the computed flood hydrograph. The normal sequence of these computations and plots is shown in figure B1.

An example of a logfile showing the sequence of questions and input data needed for computing a flood-frequency curve for the Fenholloway River near Foley, Florida is illustrated in figure B2. As can be determined by inspection of figure B2, the Fenholloway River near Foley watershed is contained in one hydrologic region - Region B. The NFF program numbers the regions numerically so Region B is identified in NFF as hydrologic region 2. The watershed characteristics input by the user are Drainage Area = 120 square miles and Lake Area = 0.37% of the drainage area. The watershed of interest is contained in maximum flood region 3 as defined by Crippen and Bue (1977) and shown earlier (fig. 3). The Maximum Flood Envelope value of 101,000 cubic feet per second is an estimate of the maximum flow ever experienced for a 120-square-mile watershed in Crippen and Bue's flood region 3.

Given the above input values, a rural flood-frequency curve is then computed and a table of flood-frequency values, standard errors of estimate and equivalent years of record are displayed in figure B2. The flood-frequency curve was computed without using the 500-year equation, therefore the 500-year value shown in figure B2 was determined by extrapolation as defined in the section entitled Estimation of Extreme Floods. The regional flood-frequency curve is shown earlier (fig. 2). In reality, 500-year equations do exist for Florida (Bridges, 1982) and the extrapolated 500-year flood was compared to the value computed from the published 500-year equation. This example was provided to illustrate the applicability of the 500-year extrapolation procedure.

Finally, NFF allows weighting of observed and regional/regression flood estimates (if equivalent years of record available), computation of a urban flood-frequency curve, plotting a flood-frequency curve, and computation of a flood hydrograph. In figure B2, the response N (no) was provided for all these questions.

The flood-frequency curve ordinates and the flood-hydrograph ordinates can be output to a flat file for further analysis with another program.

The flood-frequency curve ordinates are output in the following format:

National Flood Frequency Program

Flood Frequency Data
Date: 09/21/1994 10:30
Basin: Hypothetical River near Example
Consult the log file for the input data

Recurrence Interval, years	Rural Discharge
2	8120
5	13200
10	17400
25	22100
50	26700
100	29800
500	39900

The flood-hydrograph ordinates can be output in two formats -- generic and HYDRAIN. The generic format is simply a listing of the time, in hours, since runoff began and the corresponding discharge for selected points on the hydrograph. The points are listed from 0.25 LT (lagtime) to 2.40 LT in increments of 0.05 LT. An example of the file follows:

Hypothetical River near Example

Time, hours	Discharge
18.75	3574.
22.50	4765.
26.25	6254.
30.00	7743.
33.75	9827.
37.50	11912.
41.25	14592.
45.00	17272.
48.75	19952.
52.50	22633.
56.25	25015.
60.00	26802.
63.75	28291.
67.50	29184.
71.25	29780.
75.00	29482.
.	.
.	.
.	.
180.00	3276.
183.75	2978.

A lagtime (LT) of 75 hours was used in the above example.

The flood-hydrograph ordinates can also be output in a format that is used in the Federal Highway Administration HYDRAIN series of programs (HYDRAIN Version 5.0: Integrated Drainage Design Computer System, Publication No. FHWA-RD-92-061, July 1994). The format of the HYDRAIN output file is as follows:

Flood-hydrograph ordinates:

Description		Format
Line 1:	Comment line	A73
Line 2:	Number of points	I10
Line 3+(N-1):	N, T(N), Q(N)	F10.0, F10.1, F10.3

where N = point number

T(N) = time, in minutes for point N

Q(N) = flow value, in cubic feet per second, for point N

An example of the HYDRAIN format follows:

09/21/1994 10:33 Hypothetical River near Example (HYDRAIN Format)

45

0	1125.	3574.
1	1350.	4765.
2	1575.	6254.
3	1800.	7743.
4	2025.	9827.
5	2250.	11912.
6	2475.	14592.
7	2700.	17272.
8	2925.	19952.
9	3150.	22633.
10	3375.	25015.
11	3600.	26802.
12	3825.	28291.
13	4050.	29184.
14	4275.	29780.
15	4500.	29482.
.	.	.
.	.	.
.	.	.
43	10799.	3276.
44	11024.	2978.

The constants and coefficients for the regression equations are stored in the state-by-state data base in NFF. The general form of the equations used to calculate the flood-peak discharges for each recurrence interval is as follows: (For a few States, a different form of equation was used and these are documented in the individual State sections.)

$$RQx = C \bullet F_1^{e1} \bullet F_2^{e2} \bullet \ldots$$

where RQx = rural flood-peak discharge for recurrence interval x

C = regression constant,

F_i = watershed and climatic characteristic i (Note - The F_i values may be transformed by a modifier by the addition, subtraction, or division of a constant),

ei = regression coefficients or exponents for watershed or climatic characteristic i.

The following information is stored in the state-by-state data files. However, to insure the integrity of the computer program, the following information is stored in a binary compressed file in the program and cannot be changed or viewed by the user. The purpose of providing the following information is to illustrate the information used in the computer program and to document the format of this information.

The following information is stored for each State:

Title	Comment	
State Abbreviation	Abbreviation of state.	
	Examples:	AL
		SC
State Name	Name of state.	
	Examples:	Alabama
		South_Carolina
# of hydrologic regions	Integer number of hydrologic regions within state.	

The following information is stored for each hydrologic region:

Title	Comment
Name of hydrologic region	The name of hydrologic region i; Examples: Area_1 Region_A Southern Region The name of the hydrologic region specified is preceded by a $. Examples: $Atlanta_citywide_urban $Georgia_statewide_urban
# of variables in equations	The number of variables within the region's equations.

The following information is stored for each variable in a region:

Title	Comment
Variable name	Name of variable as it might appear in an equation. Examples: A ST
Variable descriptor	Description of the variable. Examples: Drainage_Area_(sq_mi) Basin_storage_(%)
Variable minimum	Minimum value of variable. A floating point.
Variable maximum	Maximum value of variable. A floating point.

FOR EACH OF THE RECURRENCE INTERVALS IN ORDER (2, 5, 10, 25, 50, 100, 500):

Title	Comment
Standard error for equation	The calculated standard error for the equation. A floating point number. A 0.0 is entered if no standard error data exists.
Equivalent years record	The number of equivalent years record for the equation. A floating point number. A 0.0 is entered if no equivalent years record data exists.
Regression Constant, C	The constant term of the regression. A floating point number. A 0.0 is entered if no data for current recurrence interval exists.
# of components in equation	The number of components (excluding constant) in the regression equation. ALWAYS >= 1. An integer. A 0.0 is entered if no data for current recurrence interval exists.

FOR EACH COMPONENT IN EQUATION:

Title	Comment
Base Variable Index	Index of base variables within the list of name and descriptors entered above. An integer. Examples: 1 (for A) 2 (for ST) A 0.0 is entered if no variable exists for component.
Base Variable Modifier	Modifier added to base variable before the multiplier is applied. A floating point number.
Base Variable Multiplier	Value by which base variable is multiplied. A floating point number.
Exponent Constant	The exponent constant for the base variable. A floating point number.
Exponent Variable Index	The index (in the list of names and descriptors entered above) of the variable which appears in the base variable's exponent. An integer. A 0.0 is entered if no exponent variable exists.
Exponent Variable Modifier	Modifier added to exponent variable
Exponent Variable Exponent	The power to which the exponent variable is to be raised. A floating point number.

EXAMPLE

ID Code: NS

State: North Somewhere

# of regions: 2

(Note - A variety of equations is used to illustrate the various formats that can be used. These equations are merely examples.)

Region 1's Equations:

$RQ2 = 56.7A^{0.335}\,SL^{0.235}$, standard error 46%, 7 equivalent years record

$RQ5 = 64.1A^{0.224}\,(SL - 1.0)^{0.345}\,(ST + 2.0)^{-0.234}$, standard error 38%

$RQ10 = 72.4\,A^{0.345\,A^{-0.02}}\,(SL/1000)^{0.234}$, 10 equivalent years record

RQ25 = NO EQUATION AVAILABLE

$RQ50 = 1.02 \times 10^2 A^{0.657} (10 - F)^{0.235} Gf$, standard error 40%

$\text{Log } RQ100 = 4.37 - 1.78 A^{-0.25} + 0.23 (\text{Log } (R - 18.0)) (\text{Log } I24,100)$, standard error 39%

$\text{Log } RQ500 = 3.044 + 0.646 \text{ Log } A - 0.049 (\text{Log } A)^2 + 0.614 (\text{Log } SL) (\text{Log } (ST+c))$, standard error 42%

Minimum and maximum allowed values for variables:

Variable	Minimum	Maximum
A	0.05	2000.00
SL	0.70	20.00
ST	0.99	50.00
F	5.30	23.00
Gf	10.00	19.00
R	11.29	16.53
I24,100	0.82	5.32

Notes: The total number of variables in ALL equations of this region is 7. The last two equations have to be converted into non-logarithmic form (like RQ2 - RQ50). See below for conversion example.

The citywide urban equations for city "Capitol City":

$UQ2 = 2.028A^{0.383} [K (1.0 + 0.01 AD)]^{0.447}$, standard error 25.1%

$UQ5 = 6.68A^{0.87} (SL - 12)^{0.43} IA^{0.70}$, standard error 30.0%

$UQ10 = 2.27A^{0.53} SL^{0.45} RQ10^{0.23}$, standard error 43.0%

Minimum and maximum allowed values for variables:

Variable	Minimum	Maximum
A	1.33	1.82
SL	0.70	20.00
AD	0.99	50.00
K	5.30	23.00
IA	10.00	19.00

Notes: UQ25-UQ500 are omitted as this is an example.
The total number of variables in ALL equations of this 'region' is 5.
(Note this total does not include RQ10.)
Note that the first equation is converted into this equivalent form in order to be represented for use by NFF:

$$Q2 = 2.028 A^{0.383} K^{0.447} [(100 + AD)\bullet 0.01]^{0.447}$$

Following is an example of the data base containing the regression equations shown above.

```
NS  North_Somewhere
2   Region_1
    7
    A Drainage_Area_(sq_mi) 0.05 2000.0
    SL Slope_(ft/mi) 0.70 20.0
ST Basin_Storage_(%) 0.99 50.0
F Forest_cover_(%) 5.30 23.0
Gf Geographic_factor 10.0 19.0
R Relief 11.29 16.53
I24,100 24_hour_rainfall_intensity_(in) 0.82 5.32
46.0 7.0 56.7 2
            1 0.0 1.0 0.335 0 0.0 0.0
            2 0.0 1.0 0.235 0 0.0 0.0
38.0 0.0 64.1 3
            1  0.0 1.0 0.224 0 0.0 0.0
            2 -1.0 1.0 0.345 0 0.0 0.0
            3  2.0 1.0 -.234 0 0.0 0.0
0.0 10.0 72.4 2
            1 0.0 1.0  0.345 1 0.0 -.02
            2 0.0 0.001 0.234 0 0.0 0.0
0.0 0.0 0.0 0
40.0 0.0 102.0 3
            1   0.0 1.0 0.657 0 0.0 0.0
            4 -10.0 1.0 0.235 0 0.0 0.0
            5   0.0 1.0 1.0  0 0.0 0.0
39.0 0.0 23442.3 2
            6 -18.0 1.0  0.23 -7 0.0 1.0
            0  10.0 1.0 -1.78  1 0.0 -.25
42.0 0.0 1106.62 3
            1 0.0 1.0 0.646  0 0.0 0.0
            1 0.0 1.0 -.049 -1 0.0 1.0
            2 0.0 1.0 0.614 -3 0.0 1.0
$Capitol_City
3
A Contributing_Drainage_Area_(sq_mi) 1.33 1.82
SL Slope_(ft/mi) 0.70 20.0
AD Percentage_of_Urban_Development_(%) 0.99 50.0
K Bank-full_Channel_Conveyance 5.3 23.0
 IA Impervious_Surfaces_(%) 10.0 19.0
25.1 0.0 2.028 3
            -1 0.0 1.0 0.383 0 0.0 0.0
            4 0.0 1.0 0.447 0 0.0 0.0
            3 100.0 0.01 0.447 0 0.0 0.0
30.0 0.0 6.68 3
            -1 0.0 1.0 0.87 0 0.0 0.0
            2 -12.0 1.0 0.43 0 0.0 0.0
            5 0.0 1.0 0.70 0 0.0 0.0
43.0 0.0 2.27 3
            -1 0.0 1.0 0.53 0 0.0 0.0
            2 0.0 1.0 0.45 0 0.0 0.0
            -2 0.0 1.0 0.23 0 0.0 0.0
```

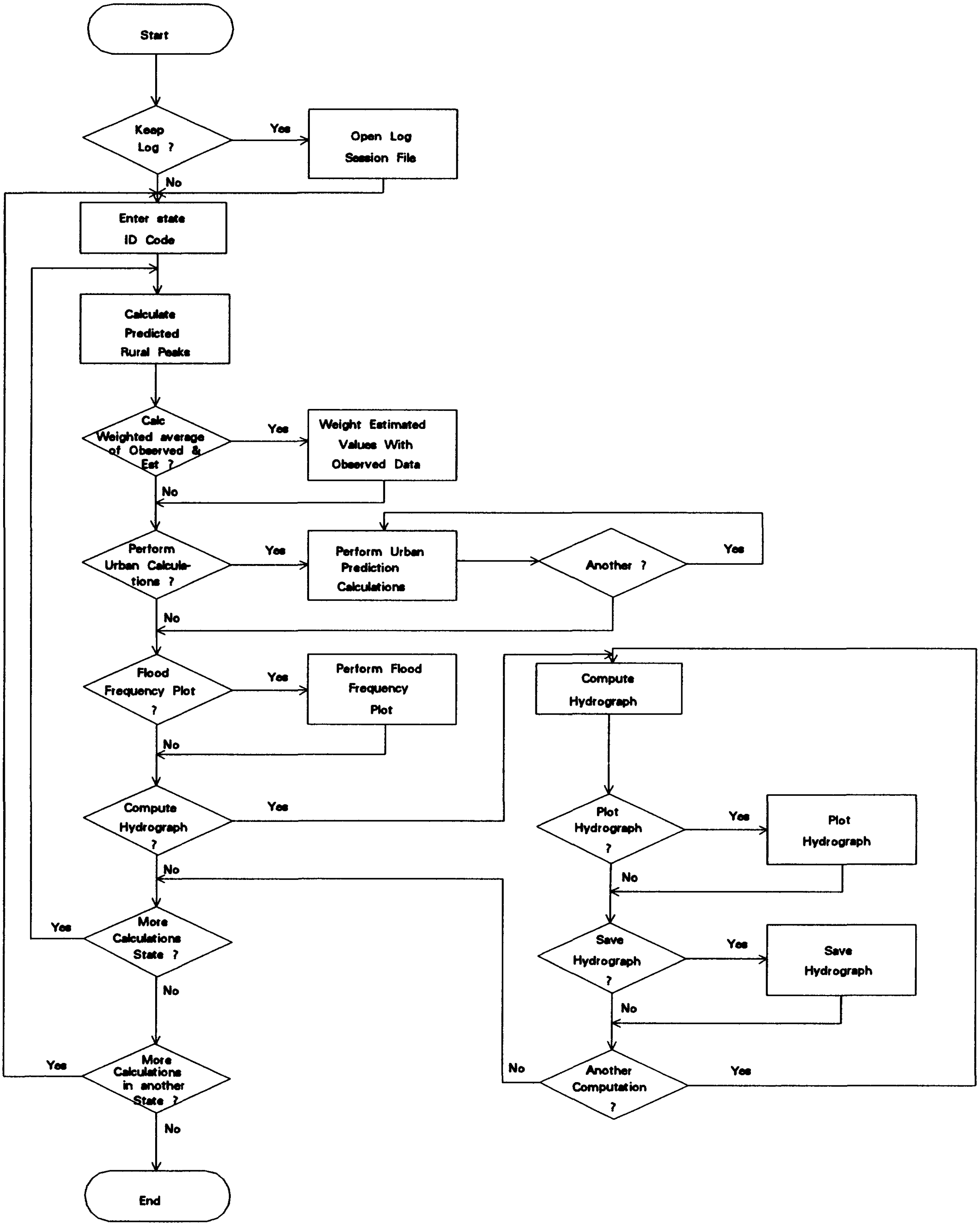


Figure B1. Flow chart for the National Flood Frequency Program. (From Jennings and Cookmeyer, 1989.)

```
-----------------------------------------National Flood Frequency Log Session-----------------------------------------
NFF Log session start 07/03/1990 09:04
Enter state id code: FL
Enter name of basin under study : FENHOLLOWAY RIVER NEAR FOLEY, FL.
List of Hydrologic Regions
in Florida
Region
Number Region Name
=================
    1 Region   A
    2 Region   B
    3 Region   C
Is basin contained in more than one
hydrologic region (Y/N)N
hydrologic region (1-3) : 2
Region B parameters:
Drainage Area (sq mi), DA (13.90-9640.0) : 120.0
Lake Area (%), LK (0.00-13.1) : 0.37
Enter maximum flood region within which the basin is contained (See Report).
Enter 0 if not applicable (e.g. outside of conterminous United States) : 3
Table of rural flood event values
FENHOLLOWAY RIVER NEAR FOLEY, FL.
```

Recurrence Interval,yrs	Peaks cfs	% Std. Err.	Eq.Yrs. Record
2	1050	60.9	2
5	2170	59.7	3
10	3150	59.9	3
25	4650	60.9	5
50	5980	61.9	5
100	8000	63.1	6
500	12800		

```
=====================================
     MAXIMUM FLOOD ENVELOPE = 101000 cfs
   List of Entered Parameters
     Name      Value
==========================
          DA : 120.000
          LK : 0.370
Do you want to calculate a weighted average of observed and regression
estimates? (Y/N)N
Do you want to perform urban calculations? (Y/N)N
Do you want to write a flood frequency plot input file for TELAGRAF? (Y/N)N
Do you want to compute a hydrograph for the rural peak calculated? (Y/N)N
Do you want to do more flood frequency  calculations in Florida? (Y/N)N
Do you want to do flood frequency calculations in another state? (Y/N)N
Program terminated.
NFF Log session ended 07/03/1990 09:05
```

Figure B2. Summary of input data, questions and responses during an interactive session with the National Flood Frequency Program.

APPENDIX C -- SUMMARY OF EQUATIONS FOR ESTIMATING BASIN LAGTIME

[LT, basin lagtime, in hours]

State/Area/Region	Equation	Standard Error in percent
ALABAMA		
North of fall line	$LT=2.66A^{.46} S^{-.08}$	32
South of fall line	$LT=5.06A^{.50} S^{-.20}$	31
Statewide, urban	$LT=2.85A^{.295} S^{-.183} IA^{-.122}$	21
TENNESSEE		
East	$LT=1.26L^{.825}$	47
Central	$LT=0.94L^{.86}$	39
Central, urban	$LT=1.64L^{.49} IA^{-.16}$	16
West	$LT=0.707A^{.73}$	43
West, urban	$LT=2.65A^{.348} IA^{-.357}$	39
GEORGIA		
North of fall line	$LT=4.64A^{.49} S^{-.21}$	31
South of fall line	$LT=13.6A^{.43} S^{-.31}$	25
Atlanta urban	$LT=161A^{.22} S^{-.66} IA^{-.67}$	19
SOUTH CAROLINA (average basin LT)		
Blue Ridge	$LT=3.71A^{.265}$	7
Piedmont	$LT=2.66A^{.460}$	26
Inner Coastal Pl.	$LT=6.10A^{.417}$	34
Lower Coastal Pl.		
Region 1	$LT=6.62A^{.341}$	26
Region 2	$LT=10.88A^{.341}$	26
SOUTH CAROLINA (Qp adj. LT)		
Blue Ridge	$LT=7.21A^{.322} Qp^{-.112}$	--
Piedmont	$LT=3.30A^{.614} Qp^{-.120}$	--
Inner Coastal Pl.	$LT=7.03A^{.375} Qp^{-.010}$	--
Lower Coastal Pl.		
Region 1	$LT=6.95A^{.348} Qp^{-.022}$	--
Region 2	$LT=11.7 A^{.348} Qp^{-.022}$	--
OHIO		
Small rural	$LT=16.4S^{-.78} (F+10)^{.38} (ST+1)^{.31}$	35
Small urban	$LT=1.07L^{.54} S^{-.27} (13-BDF)^{.42}$	48
ARKANSAS		
Rural	$LT=256A^{.90}(P-30)^{.61} Q100^{-.65}Qp^{-.16} S^{-.25}$	33
Memphis urban	$LT=2.05A^{.35} C^{-.87} IA^{-.22}$	24
MISSOURI RURAL		
Equation 1	$LT=2.79L^{.39} S^{-.195}$	26
Equation 2	$LT=1.46A^{.27}$	26
MISSOURI URBAN		
Equation 1	$LT=0.87L^{.60} S^{-.30} (13-BDF)^{0.45}$	23
Equation 2	$LT=0.32A^{.50} (13-BDF)^{.37}$	22
OKLAHOMA	$LT=0.206A^{.239} S^{-.280} RI24^{2.54}$	40
NATIONWIDE URBAN		
Equation 1	$LT=0.85L^{.62} S^{-.31} (13-BDF)^{0.47}$	76
Equation 2	$LT=.0030L^{.71}(13-BDF)^{.34}(ST+10)^{2.53} RI2^{-.44}IA^{-.20}S^{-.14}$	61

A = drainage area, in square miles
S = main channel slope, in fpm
L = main channel length, in miles
Qp = peak discharge, in cfs
F = percent forest area
ST = percent of surface storage in basin
P = mean annual precipitation, in inches
Q100 = 100-year recurrence interval peak discharge, in cfs
IA = percent of basin covered by impervious surfaces
BDF = basin development factor
RI2 = 2-year 2-hour rainfall intensity
RI24 = 2-year 24-hour rainfall
C = channel condition (unpaved 1, full paved 2)