[redacted]
c.1

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

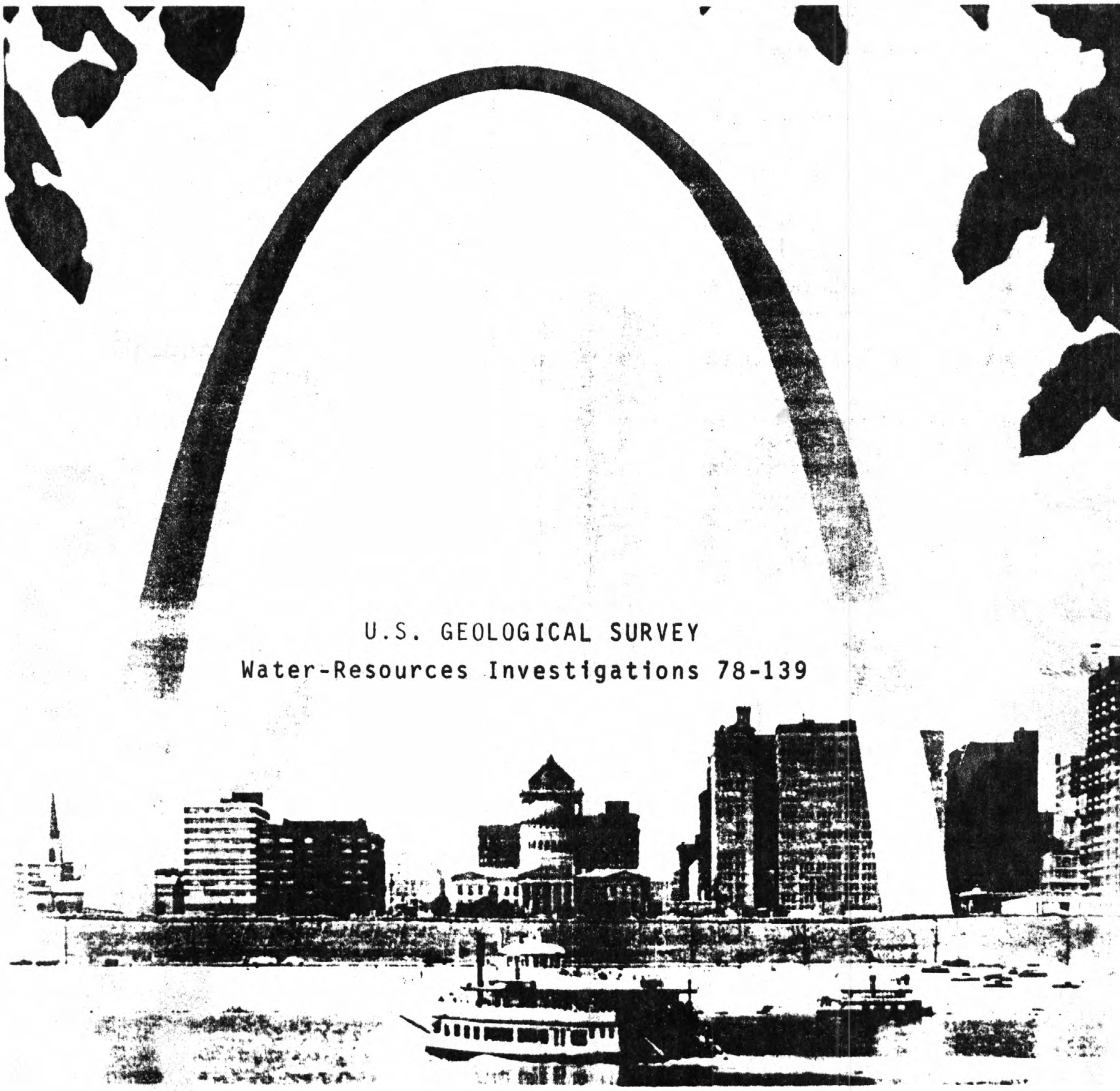
PB-298 245

Technique for Estimating the Magnitude and Frequency of Floods in St. Louis County, Missouri

(U.S.) Geological Survey, Rolla, MO Water Resources Div

Nov 78

TECHNIQUE FOR ESTIMATING THE MAGNITUDE AND FREQUENCY OF FLOODS IN ST. LOUIS COUNTY, MISSOURI



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 78-139

Prepared in cooperation with
County of St. Louis, Missouri

U. S. DEPARTMENT OF THE INTERIOR
March 3, 1849

PB298245

BIBLIOGRAPHIC DATA SHEET	1. Report No. USGS/WRD/WRI-79/019	2.	3. Recipient's Accession No.

4. Title and Subtitle

TECHNIQUE FOR ESTIMATING THE MAGNITUDE AND FREQUENCY OF FLOODS IN ST. LOUIS COUNTY, MISSOURI

5. Report Date

November 1978

6.

7. Author(s)

D. W. Spencer and T. W. Alexander

8. Performing Organization Rept. No. USGS/WRI-78-139

9. Performing Organization Name and Address

U.S. Geological Survey, Water Resources Division
1400 Independence Road Mail Stop 200
Rolla, Missouri 65401

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

U.S. Geological Survey, Water Resources Division
1400 Independence Road Mail Stop 200
Rolla, Missouri 65401

13. Type of Report & Period Covered

Final

14.

15. Supplementary Notes

Prepared in cooperation with County of St. Louis, Missouri.

16. Abstracts

Equations and nomographs in this report can be used to estimate peak flood-discharges having recurrence intervals up to 100 years in rural and urban areas of St. Louis County, Mo. The basin characteristics significant at the 5-percent probability level were drainage area and percentage imperviousness. Drainage area can be measured from maps, while percentage of imperviousness can either be measured from aerial photographs or estimated from land-use projections. These equations are based upon the analysis of hydrologic data collected at 30 continuous-recording gaging stations with drainage areas ranging from 0.8 to 39.0 square miles, and with impervious areas ranging from 1 to 32 percent.

17. Key Words and Document Analysis. 17a. Descriptors

*Urban hydrology, *Design flow, *Peak flow, *Surface runoff, *Small watersheds, *Urbanization, *Regression analysis, Frequency analysis, Floods.

17b. Identifiers/Open-Ended Terms

*Rainfall-runoff model.

17c. COSATI Field/Group

18. Availability Statement

No restriction on distribution
Prepared for NTIS by U.S. Geological Survey, WRD

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

22. Price PC A03 MF A01

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 82

TECHNIQUE FOR ESTIMATING THE MAGNITUDE AND FREQUENCY OF FLOODS IN ST. LOUIS COUNTY, MISSOURI

By Donald W. Spencer and Terry W. Alexander

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 78-139

Prepared in cooperation with
County of St. Louis, Missouri

Cover photograph courtesy of
Department of the Interior,
National Park Service

November 1978

I -(a)

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey, WRD
1400 Independence Road Mail Stop 200
Rolla, MO 65401

U.S. Geological Survey, WRD
2222 Schuetz Road, Suite 205
Creve Coeur, MO 63141

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

The following factors may be used to convert the inch-pound units published herein to the International System of Units (SI).

Multiply inch-pound units	By	To obtain SI units
	Linear measures	
inches (in.)	2.540	centimeters (cm)
feet (ft)	0.3048	meters (m)
square miles (mi^2)	2.590	square kilometers (km^2)
miles (mi)	1.609	kilometers (km)
feet per mile (ft/mi)	0.1893	meters per kilometer (m/k)
	Volume measure	
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)

GLOSSARY

Flood frequency. The relation between return period or recurrence interval, in years, and flood-magnitude, in cubic feet per second.

Model error. An expression in percentage of the root-mean square error of the model computed values versus the observed values.

Multiple regression. A statistical technique for defining the relationship between a dependent variable and two or more independent variables.

Objective function. A calculated value based upon the sum of squared logarithm deviations between observed and simulated values.

Recurrence interval. An average interval of time, in years, within which a given discharge is expected to be exceeded once. The reciprocal of the recurrence interval is the probability of occurrence during any one year. (A 50-year flood, Q_{50}, has a 2-percent chance of being exceeded in any given year.) Recurrence intervals do not imply regularity of occurrence; a 50-year flood event might be exceeded in consecutive years, or it might not be exceeded in a period many times 50 years in length.

Standard error of estimate. A measure of the scatter of the dependent variable for a given independent variable about the regression line.

Skew. One measure of the departure of the data from a normal distribution about the mean.

Synthesized skew. The skew coefficient determined from the synthesized station data.

Technique for Estimating the
Magnitude and Frequency of Floods
in St. Louis County, Missouri

By Donald W. Spencer and Terry W. Alexander

ABSTRACT

Equations and nomographs in this report can be used to estimate peak flood-discharges having recurrence intervals up to 100 years in rural and urban areas of St. Louis County, Mo. The basin characteristics significant at the 5-percent probability level and used as independent variables in the equations are drainage area and percentage imperviousness. Drainage area can be measured from maps, while percentage of imperviousness can either be measured from aerial photographs or estimated from land-use projections. These equations are based upon the analysis of hydrologic data collected at 30 continuous-recording gaging stations with drainage areas ranging from 0.8 to 39.0 square miles, and with impervious areas ranging from 1 to 32 percent.

ACKNOWLEDGMENTS

Special acknowledgment is made to the officials of St. Louis County for their cooperation in furnishing both general information and specific data valuable to this report. Also, the use of streamflow and rainfall data collected in cooperation with Metropolitan St. Louis Sewer District is gratefully acknowledged.

INTRODUCTION

St. Louis County is considered the "Gateway to the West" mainly because it is a major transportation center at the confluence of the two most heavily traveled inland navigable rivers, the Mississippi and Missouri. Its location has permitted and encouraged industrial and urban development.

The population growth of the county, according to the U.S. Census figures furnished by the East-West Gateway Coordinating Council, has gone from 274,230 in 1940; to 406,349 in 1950; to 703,532 in 1960; to 951,671 in 1970; to an estimated 1,060,000 by 1980; and to an estimated 1,160,000 by 1990. By the year 2000, population in St. Louis County is expected to reach approximately 1,216,000. This represents census growth rates of:

1940-50	48 percent
1950-60	73 percent
1960-70	35 percent
1970-80	11 percent*
1980-90	9 percent*
1990-2000	5 percent*

*Estimated

Recent development includes large shopping centers that place hundreds of acres under paved parking lots. These centers are usually surrounded by high-density office or dwelling structures that in turn are surrounded by high-density residential subdivisions. Such changes may produce problems not readily apparent to the local residents.

As a rural area is developed, the most notable results are that the depth of flooding tends to increase and the lag time is reduced (Carter, 1961; Anderson, 1968; Harris and Rantz, 1964; Martens, 1968). This is graphically illustrated in figure 1 (Leopold, 1972). These effects can increase property damage and reduce flood-warning time.

Meteorologically, urbanization has a tendency to reinforce frontal systems by strengthening convective currents as the storm system passes over the area. As a result, storms of higher intensity and shorter duration rainfall are produced (Huff, 1977). Therefore, it follows that changing patterns of storm runoff and infiltration cause changes in the flooding patterns of small drainage areas.

Purpose and Scope

In 1970 the U.S. Geological Survey in cooperation with St. Louis County began to collect and analyze the data necessary to define the effects of urban development on surface runoff. The project provided for collection of hydrologic data, analytical investigation, bridge-site hydraulic studies, and for the delineation of areas that would be inundated by a flood having a recurrence interval of 100 years.

The purpose of the project was to furnish planners and designers with information on flood-frequency and magnitude, areal extent of inundation, and estimated depth of flooding. This report presents a technique for estimating the magnitude of peak floodflows with recurrence intervals up to 100 years. The delineation of the 100-year flood in areas generally north, west, and south of Lindbergh Boulevard (fig. 2) will be shown on maps that are to be published by St. Louis County.

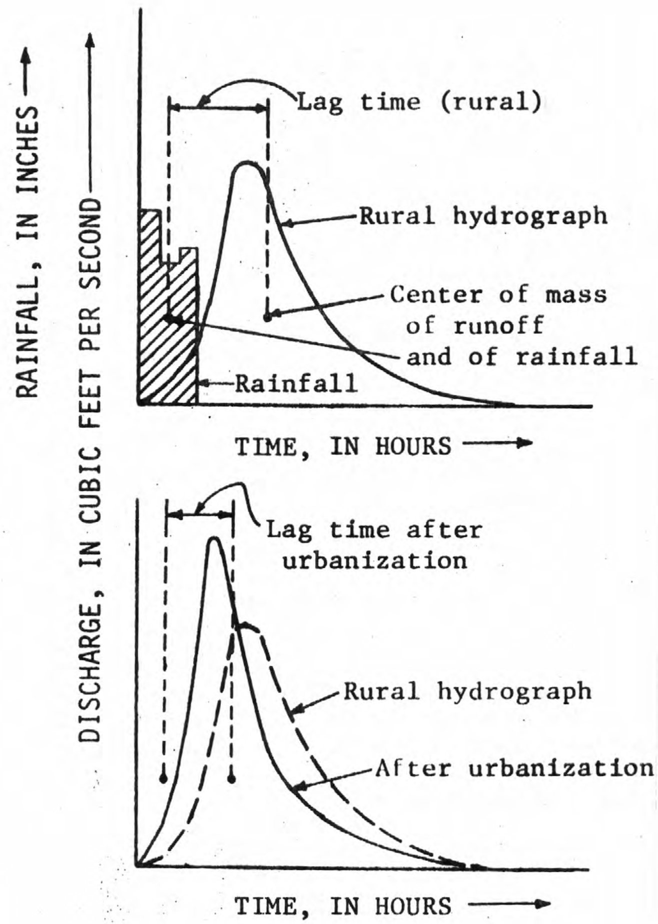


Figure 1.--Hydrographs depicting hypothetical relation of runoff to rainfall, with definitions of significant terms (modified from Leopold, 1972).

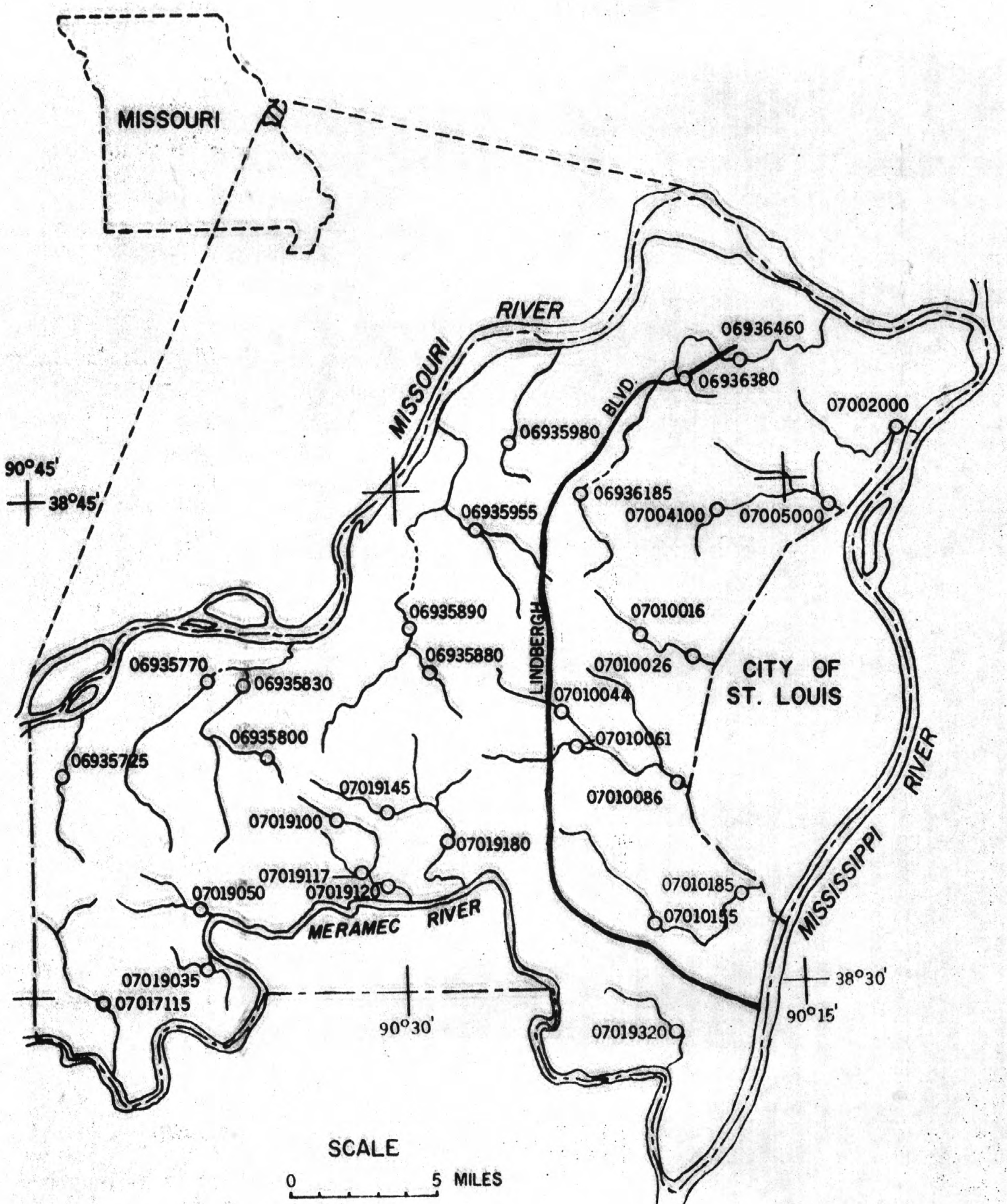


Figure 2.--Location of St. Louis County and U.S. Geological Survey gaging stations used in the study.

Equations derived by a multiple-regression technique are presented in graphical and mathematical form. These equations can be used to estimate peak-flood discharges for recurrence intervals up to 100-years in areas having varying degrees of development.

DATA ACQUISITION

A data-collection network was established using 30 stations instrumented with continuous-recording (5-minute interval) streamflow and rainfall gages (fig. 2). A station's location within a basin was determined after considering several factors: geographic distribution, overhead clearance for rainfall collection, variation in distribution of drainage area sizes, and the hydraulic flow condition at the site itself. Where streamflow and rainfall data were collected at the same station, synchronous data were obtained by electrically connecting all recording gages. Major tributaries were selected and instrumented in a similar manner.

Station characteristics to be used in the regression analysis that are described in a subsequent section of the report were determined by measurement from maps and are given in table 1. The distribution of station characteristics that were used in the study (drainage areas, degrees of imperviousness, and channel slopes) are shown in figure 3.

Drainage area was obtained by mechanical planimeter. Stream length was scaled from a standard USGS 7½-minute quadrangle topographic maps. Channel slope was computed from the difference in elevation between two points, 10 and 85 percent of the total length of main channel as measured from the desired location in the basin to the drainage divide; this elevation difference is then divided by the length of main channel between the two points (Benson, 1959). Imperviousness was computed as percentage of the total drainage area composed of streets,sidewalks, driveways, roofs, and parking lots. The amount of bare rock surface was negligible.

A procedure to determine percentage of imperviousness was developed for this project. Aerial photomaps made in 1970 at a scale of 1:8,400 were obtained from the Wastewater Division of St. Louis County. Overlays of the drainage areas delineated on 7½-minute quadrangle topographic maps were enlarged to 1:8,400, then placed over the photomaps, and areas of similar imperviousness were outlined in color. Macroscopes equipped with scalar reticules were used to measure the roof, drive, street, and sidewalk areas on several randomly selected lots in residential areas or developments having consistent patterns. The average percentage of imperviousness was computed and assigned to the area outlined in a given color. The color outlines were planimetered and summed for the entire basin. Total imperviousness was determined from the relation of these subareas to the total.

These computations of imperviousness, however, are only indices of the amount of reduction in area available for infiltration because parts of some subdivisions have roof gutters piped directly into storm-sewer laterals, which prevent rainfall from infiltrating. In other areas the guttering dumps onto the lawn and is concentrated at three or four points around the house. It is not possible to differentiate between the two types of systems on aerial photographs.

Table 1.--Station characteristics used to calibrate the U.S. Geological Survey rainfall-runoff model

Station No.	Stream and location	Length of record (years)	Drainage area (A) (mi^2)	Channel slope (S) (ft/mi)	Impervious area (I) (percent)
06935725	Wildhorse Creek at Wildhorse Creek Rd.	5	9.80	38.1	2
06935770	Bonhomme Creek at Highway CC	5	11.6	32.3	3
06935800	Shotwell Creek at Highway 340	5	0.81	84.8	22
06935830	Caulks Creek at Highway 340	5	17.1	33.6	5
06935880	Smith Creek at Mason Road	5	4.44	53.5	18
06935890	Creve Coeur Creek at Highway 340	5	22.0	16.4	15
06935955	Fee Fee Creek at McKelvey Rd.	5	11.7	29.4	25
06935980	Cowmire Creek at Kirchner Inc. (private road)	5	3.70	32.1	20
06936185	Coldwater Creek at St. Louis Internat. Airport	7	7.47	30.1	32
06936380	Paddock Creek at Lindbergh Blvd.	4	2.64	29.3	32
06936460	Coldwater Creek at Old Halls Ferry Road	7	38.9	8.67	25
07002000	Watkins Creek at Coal Bank Rd.	6	6.17	24.7	10
07004100	Maline Creek at Bermuda Ave.	7	9.16	29.4	20
07005000	Maline Creek at Bellefontaine Rd.	7	24.1	16.4	25
07010016	River Des Peres at Hafner Pl.	7	5.64	34.4	25
07010026	River Des Peres at Pennsylvania Ave.	7	9.65	25.3	30
07010044	Deer Creek at Warson Rd.	7	8.59	29.7	25
07010061	Two Mile Creek at Trent Drive	7	6.42	32.1	25
07010086	Deer Creek at Big Bend Blvd.	7	36.5	15.9	25
07010155	Gravois Creek at Tesson Ferry Rd.	7	12.1	31.1	32
07010185	Gravois Creek at Bayless Rd.	7	22.3	20.0	32
07017115	Fox Creek at Old Highway 66	5	15.6	41.0	2
07019035	Forby Creek at Highway 109	5	3.14	72.5	2
07019050	Hamilton Creek at Highway 109	5	9.85	68.8	1
07019100	Fishpot Creek at Old Ballwin Rd.	5	2.40	57.7	27
07019117	Fishpot Creek trib. at Sulphur Springs Rd.	5	2.40	69.8	17
07019120	Fishpot Creek at Hanna Rd.	5	9.60	37.0	25
07019145	Grand Glaize Creek at Highway 141	5	3.89	43.2	20
07019180	Grand Glaize Creek at Dougherty Ferry Rd.	5	19.8	27.2	22
07019320	Mattese Creek at Yaeger Rd.	5	9.01	38.8	25

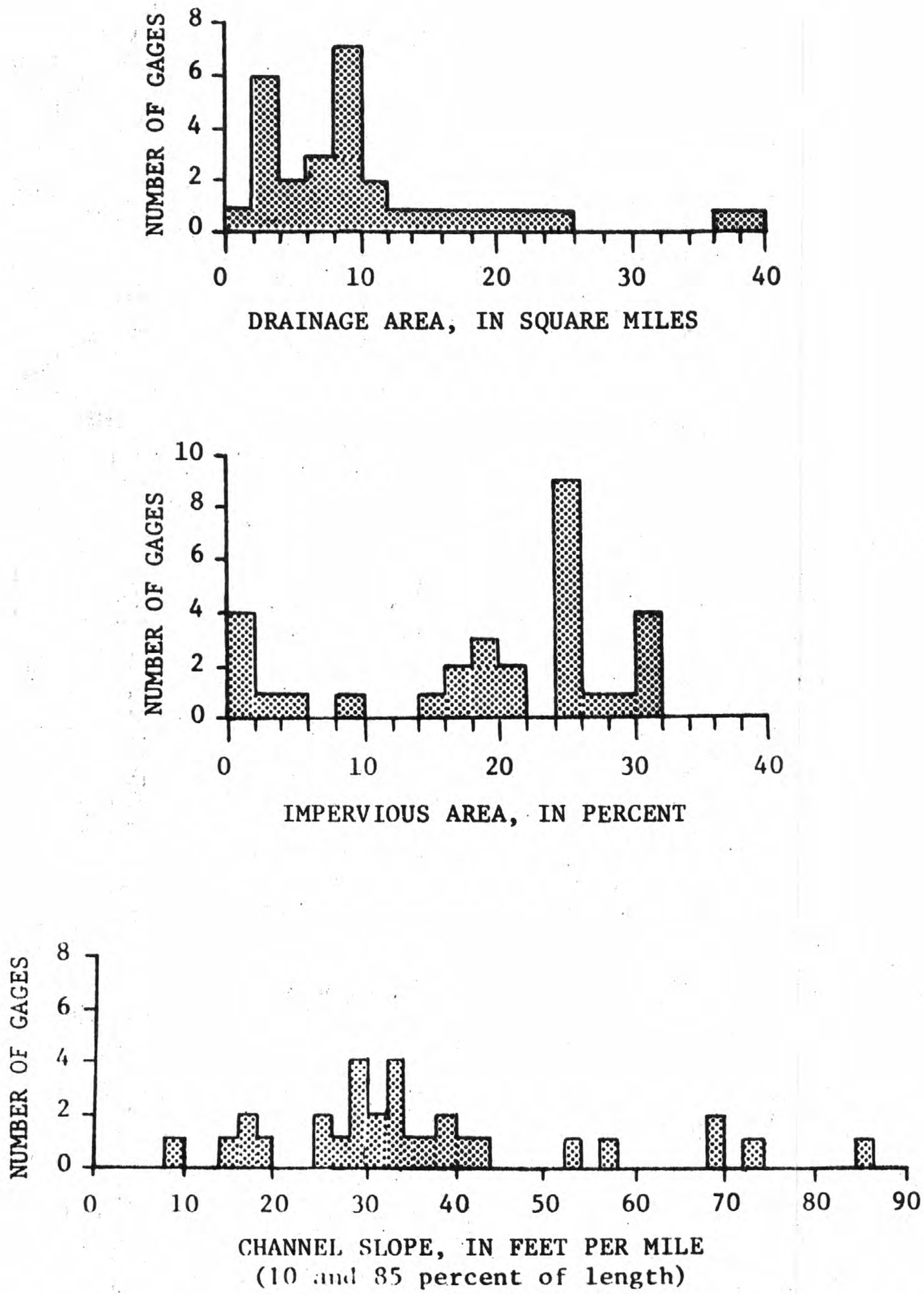


Figure 3.--Histogram showing the distribution of station characteristics used in this study.

DESCRIPTION OF RAINFALL-RUNOFF MODEL

The present (1978) shortage of data collected in urban environments has led to the development and use of many different mathematical models capable of extending short periods of rainfall-runoff data to provide a more reliable frequency analysis.

The U.S. Geological Survey rainfall-runoff model developed by Dawdy, Lichty, and Bergmann (1972), was selected for this study. This parametric simulation model is based on 10 bulk-parameters (table 2) that approximate the physical laws governing antecedent soil moisutre, infiltration, and routing of surface runoff. A schematic outline of the model is given in figure 4. Daily rainfall, daily pan evaporation, and the station unit-time (5-, 10-, 15-, 30-, or 60-minute) rainfall-runoff data are required input to the model.

The overall functions of the three components shown in table 2 are as follows:

1. The antecedent-moisture accounting component establishes the initial infiltration rate of the soil, distribution of soil moisture, and simulates evapotranspiration.
2. The infiltration component uses the modified Philip equation (1954) to compute that portion of rainfall that infiltrates the soil.
3. The routing component uses the modified Clark unit hydrograph to translate the rainfall excess into a flood-discharge hydrograph at the station location.

The rural version of the model can be adapted to urban watersheds. The percentage of impervious area is subtracted directly form the total drainage area.

METHOD OF ANALYSIS

The analysis phase of this project included three separate and distinct processes:

1. Determine optimum parameter values for each station.
2. Synthesize annual flood peaks from long-term rainfall data and then define each station's flood-frequency curve.
3. Define by linear multiple-regression method the 2-, 5-, 10-, 25-, 50-, and 100-year flood-frequency equations.

Calibration of Model Parameters

Initial station parameter values were estimated from the geology, soil cover, and actual observed runoff hydrographs. Parameter constraints (upper and lower limits) were in most part suggested by Lichty and Dempster (oral commun., 1976).

Table 2.--The 10 U.S. Geological Survey rainfall-runoff model parameters and their application in the modeling process (from Curtis, 1977)

Parameter	Units	Definition and application
		Antecedent-moisture accounting component
EVC	------------	Coefficient to convert pan evaporation to potential evapotranspiration values.
RR	------------	Proportion of daily rainfall that infiltrates the soil.
BMSM	Inches	Soil moisture storage volume at field capacity.
DRN	Inches per hour	A constant drainage rate for redistribution of soil moisture.
		Infiltration component
PSP	Inches	Product of moisture deficit and suction at the wetted front for soil moisture at field capacity.
KSAT	Inches per hour	The minimum (saturated) hydraulic conductivity used to determine infiltration rates.
RGF	-----------	Ratio of the product of moisture deficit and suction at the wetted front for soil moisture at wilting point to that at field capacity.
		Routing component (surface runoff)
KSW	Hours	Time characteristic for linear reservoir routing.
TC	Minutes	Length of the base of the triangular translation hydrograph.
TP/TC	------------	Ratio of time to peak to base length of the triangular translation hydrograph.

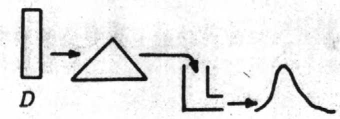
ANTECEDENT-MOISTURE ACCOUNTING COMPONENT	INFILTRATION COMPONENT	ROUTING COMPONENT
Saturated-unsaturated soil moisture regimes	Philip infiltration equation	Modified Clark instantaneous unit hydrograph
	$\frac{di}{dt} = K[1 + \frac{P(\bar{m} - m_o)}{i}]$	
Parameter: *EVC*, *RR*, *BMSM*, *DRN* **Variable**: *BMS*, *SMS*	**Parameter**: *PSP*, *KSAT*, *RGF* **Variable**: *BMS*, *SMS*	**Parameter**: *KSW*, *TC*, *TP*
INPUT DATA		
Daily rainfall Daily pan evaporation Initial condition	Unit rainfall *BMS* *SMS*	Rainfall excess
OUTPUT DATA		
BMS *SMS*	Rainfall excess	Discharge

Figure 4.--Schematic outline of U.S. Geological Survey rainfall-runoff model, showing components, parameters, and variables (from Wibben, 1976).

Optimization of the parameters is accomplished by a mathematical trial-and-error procedure that compares the observed input with the simulated output. The comparison is made by testing for a minimum value of objective function.

The calibration of each station model requires three separate phases which optimizes three objective functions. Phase one optimizes the seven parameters affecting runoff volumes (rainfall excess - first two components of model). The second phase holds the runoff volume parameters constant and optimizes on the three routing parameters (hydrograph shape) until the objective function of synthesized peak discharges versus the observed peak discharges has been minimized. The third phase is a combination of phase one and two. The routing parameters are held constant from phase two, while the runoff volume parameters are readjusted to produce the best fit between simulated and observed peaks. A list of the 10 model parameters for each station from the calibration method are given in table 3.

The average calibrated model error for the 30 basins in the study area was 32.7 percent, the range in errors was from 18.9 to 63.1 percent. The average calibrated model error for basins with impervious areas of 10 percent or less was 48.9 percent, while basins with impervious areas greater than 10 percent had a 28.8 percent average model error. This could indicate that urbanization has the effect of smoothing out some of the variability in nature, at least in the calibration of the model parameters.

Flood-Frequency Analysis

In order to relate flood-peak magnitude to recurrence interval at each gaging station, it was necessary to first use each set of calibrated station parameters along with 69 continuous years of long-term rainfall and pan evaporation data as input to the model. This resulted in 69 continuous years of synthesized peak discharges for each gaging station. Then using the synthesized peak discharges a flood-frequency relationship for each station was computed (table 4) using the log-Pearson Type III distribution as recommended by the U.S. Water Resources Council, Bulletin 17A (1977).

The long-term rainfall and pan evaporation data used in the study were from National Weather Service first-order stations at St. Louis International Airport and Urbana, Ill.

Regression Analysis

Station flood-frequency information generally is available at only a few locations where flood data are needed. Thus, there is a need for a method to estimate flood-frequency data at ungaged sites, and the step-forward multiple-regression was chosen as the method for doing this.

TABLE 3.—SUMMARY OF CALIBRATED U.S. GEOLOGICAL SURVEY RAINFALL-RUNOFF MODEL PARAMETERS

[PSP AND BMSM, INCHES; KSAT AND DRN, INCHES PER HOUR; KSW, HOURS; TC, MINUTES; REMAINING PARAMETERS, UNITLESS]

Station No.	PARAMETERS									
	PSP	KSAT	DRN	RGF	BMSM	EVC	RR	KSW	TC	TP/TC
06935725	2.11	0.070	1.00	15.2	5.22	0.65	0.95	1.12	161	0.50
06935770	2.00	.050	1.00	18.0	4.10	.65	.95	1.45	195	.50
06935800	2.05	.045	1.00	15.3	4.41	.65	.90	0.18	42	.50
06935830	2.62	.065	1.00	13.2	4.07	.65	.95	1.30	160	.50
06935880	2.62	.047	1.00	15.2	4.62	.65	.92	1.06	99	.50
06935890	3.41	.064	1.00	15.0	5.30	.65	.92	2.60	270	.50
06935955	2.92	.089	1.00	23.9	4.61	.65	.90	1.13	135	.50
06935980	2.20	.048	1.00	22.2	3.70	.65	.90	0.80	73	.50
06936185	5.83	.089	1.00	25.0	1.23	.65	.90	0.93	63	.50
06936380	1.56	.036	1.00	24.5	5.60	.65	.90	0.50	48	.50
06936460	3.07	.055	1.00	20.2	4.83	.65	.90	2.10	185	.50
07002000	5.53	.094	1.00	15.1	5.78	.65	.90	0.50	108	.50
07004100	5.87	.069	1.00	26.0	4.67	.65	.90	0.65	90	.50
07005000	3.07	.052	1.00	20.5	2.89	.65	.90	1.52	108	.50
07010016	3.66	.052	1.00	24.0	2.80	.65	.90	0.58	46	.50
07010026	4.69	.083	1.00	21.8	3.49	.65	.90	0.70	70	.50
07010044	2.00	.083	1.00	23.9	3.54	.65	.90	0.76	70	.50
07010061	2.83	.068	1.00	19.7	4.02	.65	.90	0.51	83	.50
07010086	5.99	.146	1.00	25.4	4.91	.65	.90	1.58	161	.50
07010155	4.75	.083	1.00	24.2	3.09	.65	.90	0.94	61	.50
07010185	2.75	.086	1.00	24.8	2.37	.65	.90	1.67	259	.50
07017115	2.00	.070	1.00	14.3	4.10	.65	.95	2.00	180	.50
07019035	2.52	.053	1.00	16.2	3.22	.65	.95	0.75	110	.50
07019050	2.18	.054	1.00	12.2	4.20	.65	.95	2.43	101	.50
07019100	2.10	.040	1.00	19.8	4.55	.65	.90	0.83	50	.50
07019117	2.15	.037	1.00	9.5	3.00	.65	.92	0.75	50	.50
07019120	3.00	.068	1.00	19.5	6.25	.65	.90	0.97	100	.50
07019145	2.35	.058	1.00	11.4	5.30	.65	.90	0.64	55	.50
07019180	3.85	.058	1.00	17.8	4.00	.65	.90	1.90	160	.50
07019320	2.70	.063	1.00	18.8	5.67	.65	.90	1.20	80	.50

Table 4.--Summary of T-year discharges from synthesized record for the modeled stations

Station No.	Values of discharge in cubic feet per second (ft^3/s)					
	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
06935725	1,850	3,160	4,190	5,650	6,860	8,160
06935770	2,010	3,320	4,380	5,960	7,310	8,820
06935800	560	830	1,100	1,460	1,670	1,870
06935830	3,060	5,170	6,910	9,510	11,800	14,300
06935880	1,240	1,950	2,510	3,310	3,980	4,720
06935890	2,340	3,900	5,200	7,170	8,900	10,900
06935955	2,280	3,680	4,840	6,590	8,120	9,870
06935980	1,240	1,950	2,520	3,370	4,110	4,930
06936185	1,900	2,940	3,790	5,040	6,130	7,360
06936380	1,560	2,290	2,790	3,430	3,920	4,410
06936460	5,950	9,460	12,300	16,600	20,400	24,600
07002000	1,210	2,170	2,980	4,180	5,230	6,390
07004100	2,040	3,410	4,560	6,320	7,880	9,670
07005000	4,780	7,720	10,200	14,000	17,400	21,300
07010016	2,170	3,480	4,570	6,210	7,660	9,310
07010026	2,780	4,460	5,890	8,140	10,200	12,600
07010044	2,690	4,310	5,670	7,730	9,570	11,700
07010061	2,280	3,650	4,760	6,420	7,860	9,480
07010086	5,010	7,690	9,910	13,300	16,300	19,800
07010155	3,160	5,020	6,600	9,100	11,400	14,000
07010185	3,230	5,070	6,640	9,120	11,400	14,000
07017115	2,230	3,760	5,020	6,890	8,490	10,300
07019035	820	1,390	1,850	2,530	3,110	3,760
07019050	1,600	2,590	3,380	4,500	5,540	6,650
07019100	1,000	1,510	1,880	2,400	2,810	3,250
07019117	1,160	1,700	2,080	2,640	3,070	3,520
07019120	2,480	3,950	5,090	6,720	8,060	9,530
07019145	1,750	2,670	3,300	4,180	4,850	5,520
07019180	3,030	4,900	6,480	8,910	11,100	13,600
07019320	2,340	3,680	4,720	6,180	7,400	8,720

In using this method, the 2-, 5-, 10-, 25-, 50-, and 100-year flood discharges for each gaging station were used as the dependent variable. Drainage area (A), in square miles; impervious area (I), in percentage; and channel slope (S), in feet per mile were used as independent variables. The model defines the dependent variable as a function, or functions, of the independent variables.

The model used in the regression analysis is of the form,

$$Q_T = K\ A^{a} S^{b} I^{c} ***,$$

where Q_T is a discharge at a given T-year recurrence interval,

K is a regression constant,

A, S, and I are basin characteristics, and

a, b, and *c* are exponents (constants).

This equation form assumes a linear relation between the logarithms of the variables. In this study, linearity was confirmed by graphical methods.

The regression model examines each of the independent variables and tests each for its significance in relation to the dependent variable. The least significant variable at a stated probability level is then eliminated from the equation. When two independent variables are highly correlated the significance of one may be lost during regression. High correlation logically exists between the channel slope and drainage area because of the geometric interrelation between the two. This may explain why the channel slope (S) variable was found to be insignificant at the 5-percent probability level. However, values computed at the 5- and 1-percent probability levels gave the same results within ±2.5 percent on the average. Thus, the simplest equation form,

$$Q_T = K\ A^{a} I^{c},$$

was chosen.

From this method, the recommended final countywide flood-frequency estimating equations are:

Frequency of flood (years)	Equation for estimating flood-peak discharge (5-percent probability level)	Standard error of estimate (percent)
100	$1640\ A^{0.642} I^{0.101}$	17.8
50	$1430\ A^{0.620} I^{0.103}$	16.1
25	$1220\ A^{0.598} I^{0.106}$	15.7
10	$928\ A^{0.579} I^{0.112}$	15.8
5	$714\ A^{0.567} I^{0.121}$	16.2
2	$436\ A^{0.546} I^{0.145}$	17.1

Upon selection of the desired recurrence interval, once the drainage area and percentage of impervious area have been determined, peak-flow discharges can either be calculated from the equations or read from the nomographs (figs. 5-10).

LIMITS OF USE

Results from this study are applicable only to streams in St. Louis County with drainage areas of 0.8 to 39 mi^2, and impervious areas between 1 and 32 percent. Any basin characteristic beyond these limits should be used with caution and with the knowledge that the results could, at best, be only rough estimates. The use of the regression equations for urban areas outside of St. Louis County is not recommended because there is insufficient data from other urbanized areas in the State to verify the equations' applicability.

SUMMARY AND CONCLUSIONS

Equations in this report can be used to estimate the magnitude and frequency of floods at ungaged sites in St. Louis County, Mo. The equations represent the statistical best fit to a linear multiple-regression model. The most significant independent variables (basin characteristics) were drainage area (A), and impervious area (I). Addition of a third independent variable, channel slope (S), did not significantly affect or improve the results of the equations.

The St. Louis County flood-frequency equations were compared with the results obtained by Hauth (1974) in his study of rural basins in Missouri. The comparison indicates that the St. Louis County equations provide estimates that are 75 to 100 percent higher than estimates obtained from the equations given by Hauth. There may be several reasons (besides urbanization) for the higher discharges from the St. Louis County equations. First, Hauth's study was based on rainfall data with 10- to 15-minute unit-time intervals rather than 5-minute data used in this study. According to Dawdy and others (1972), rainfall errors have a magnified effect on the calibration of the model. Thus, there would be a direct effect on the accuracy of regression equations. Secondly, skew coefficients used by Hauth were taken from a regional skew map in Water Resources Council Bulletin 15 (1967) for rural basins. However, in the St. Louis County study the gaging-station synthesized skew was used because of the urban setting, and this did account for a large part of the difference in results obtained from the two sets of regression equations.

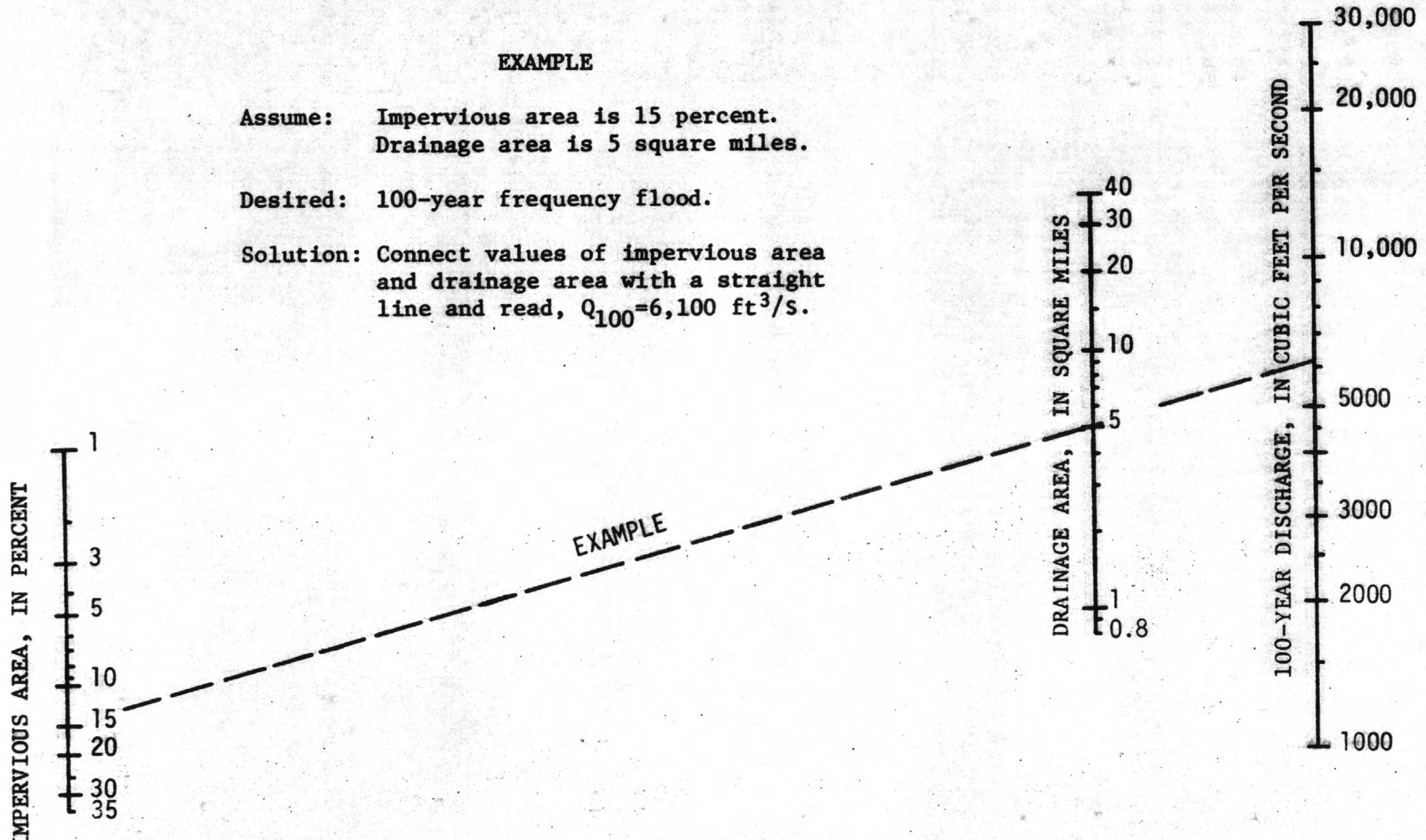


Figure 5.--Nomograph for solution of the equation,

$$Q_{100}=1640\ A^{0.642}I^{0.101}$$

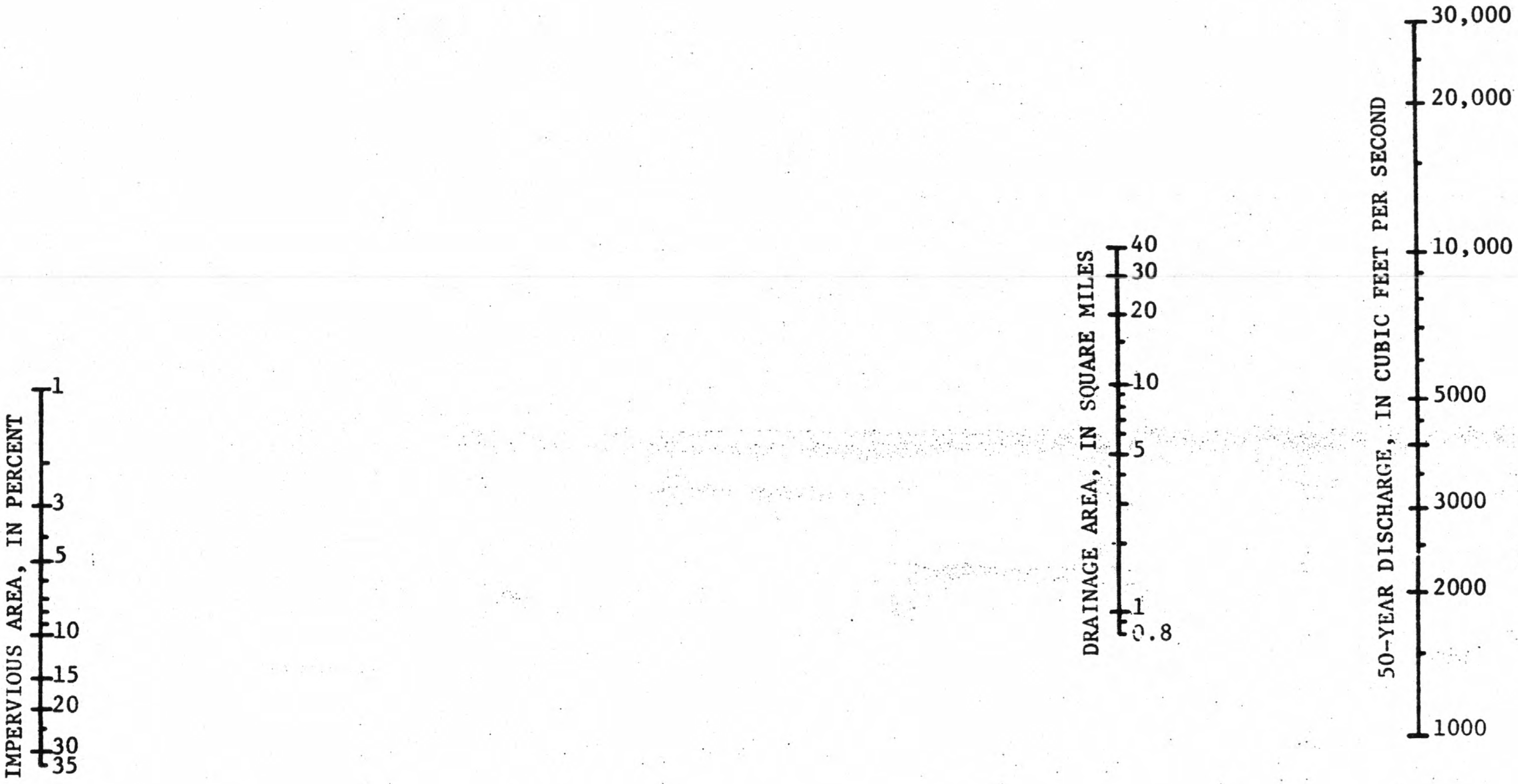


Figure 6.--Nomograph for solution of the equation,

$$Q_{50}=1430\ A^{0.620}I^{0.103}$$

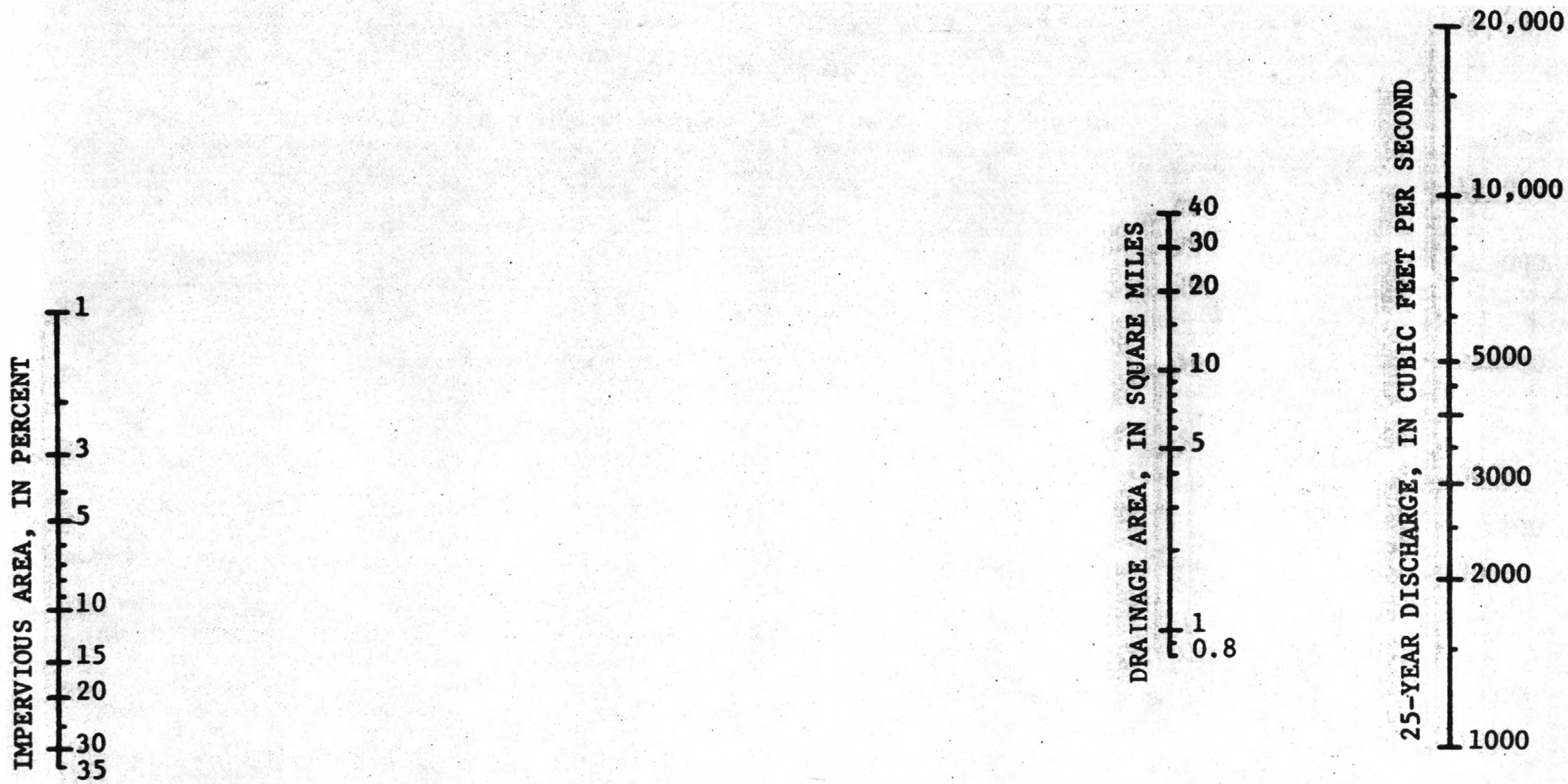


Figure 7.--Nomograph for the solution of the equation,

$$Q_{25}=1220\ A^{0.598}I^{0.106}$$

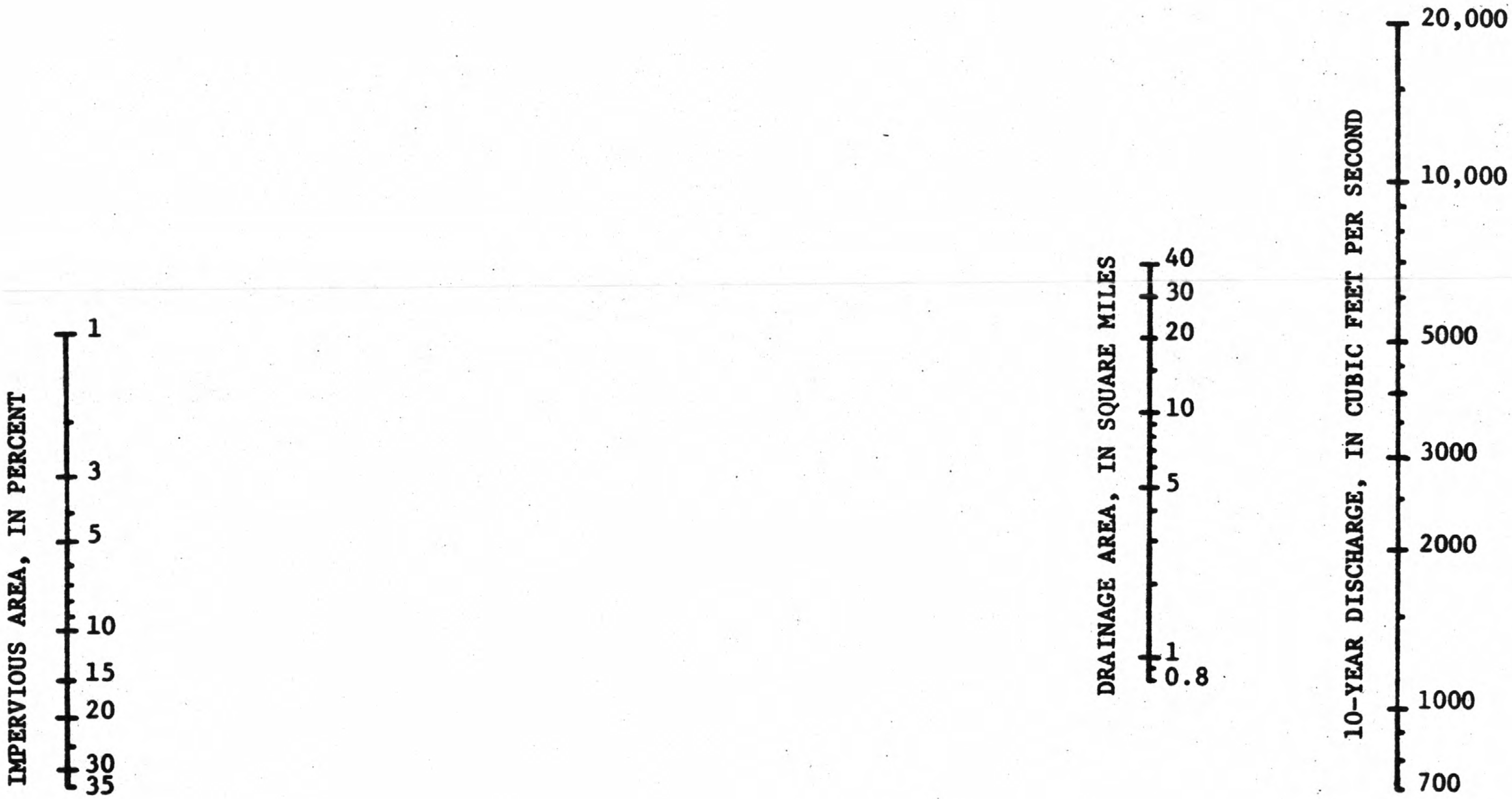


Figure 8.--Nomograph for solution of the equation,

$$Q_{10}=928\ A^{0.579}I^{0.112}$$

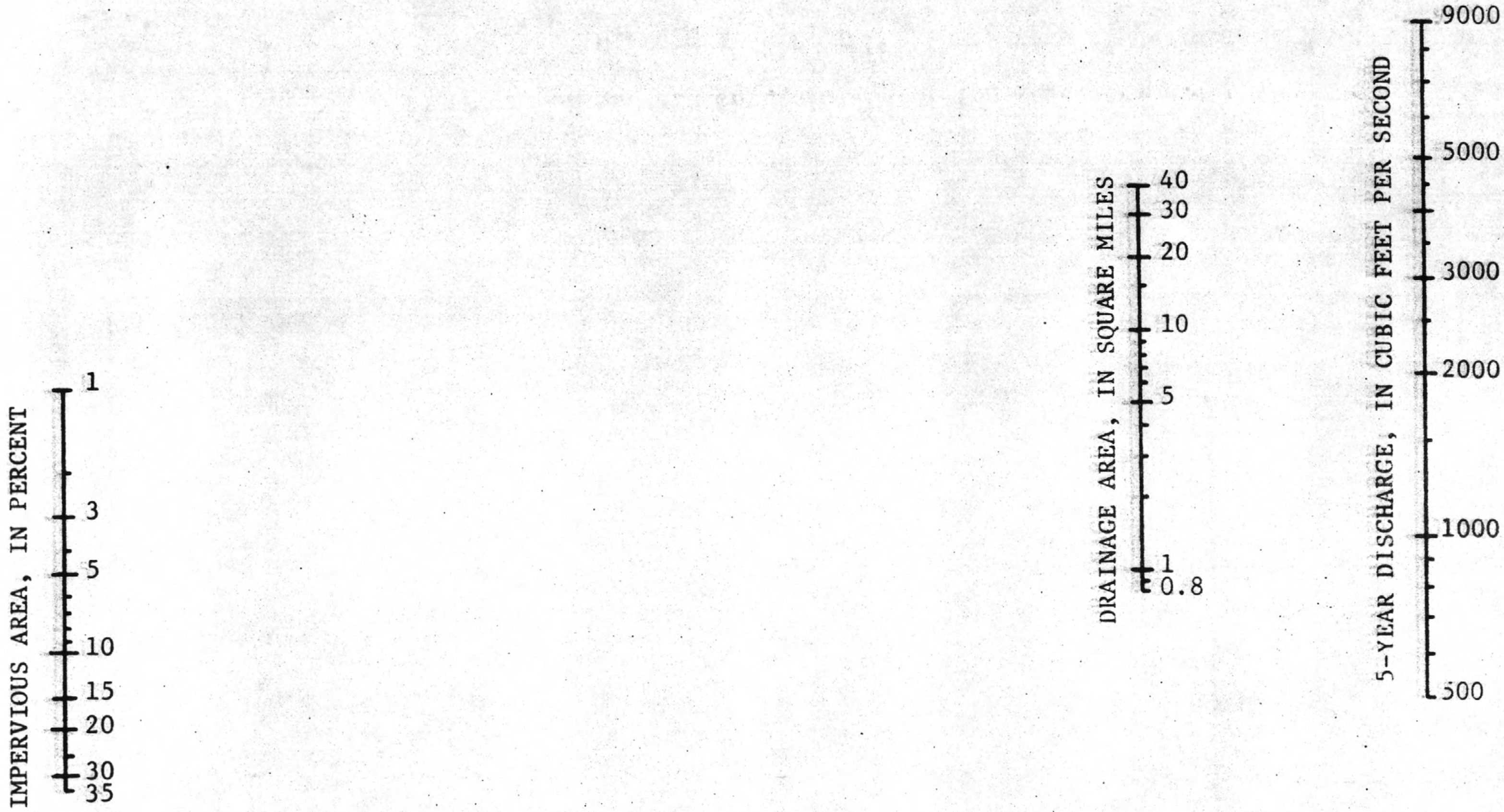


Figure 9.--Nomograph for solution of the equation,

$$Q_5=714\ A^{0.567} I^{0.121}$$

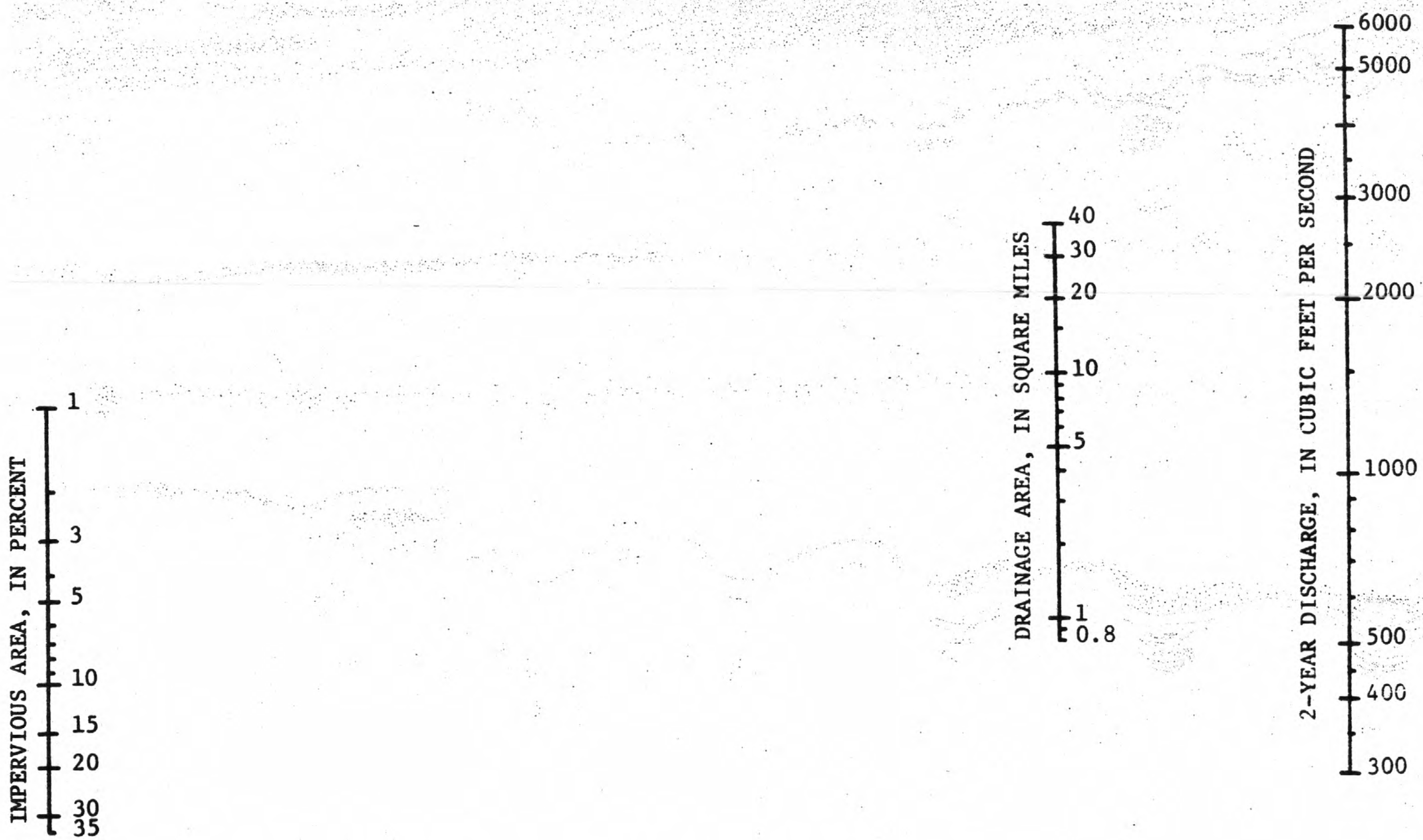


Figure 10.--Nomograph for solution of the equation,

$$Q_2=436\ A^{0.546}I^{0.145}$$

SELECTED REFERENCES

Anderson, D. G., 1968, Effects of urban development on floods in northern Virginia: U.S. Geological Survey Water-Supply Paper 2001-C, 22 p.

Benson, M. A., 1959, Channel-slope factor in flood-frequency analysis: American Society of Civil Engineers, separate no. 1994, 9 p.

Carrigan, P. H., Jr., 1973, Calibration of U.S. Geological Survey rainfall-runoff model for peak flow synthesis --- natural basins: U.S. Department of Commerce, National Technical Information Service, PB-226, 217/AS, 115 p.

Carter, R. W., 1961, Magnitude and frequency of floods in suburban areas *in* Geological Survey Research 1961: U.S. Geological Survey Professional Paper 424-B, p. B9-B11.

Curtis, G. W., 1977, Frequency analysis of Illinois floods using observed and synthetic streamflow records: U.S. Geological Survey Water-Resources Investigations 77-104, 32 p.

Dawdy, D. R., Lichty, R. W., and Bergmann, J. M., 1972, A rainfall-runoff simulation model for estimation of flood peaks for small drainage basins: U.S. Geological Survey Professional Paper 506-B, 28 p.

Golden, H. G., and Price, McGlone, 1976, Flood-frequency analysis for small natural streams in Georgia: U.S. Geological Survey Open-File Report 76-511, 75 p.

Harris, E. E., and Rantz, S. E., 1964, Effect of urban growth on streamflow regimen of Permanente Creek, Santa Clara County, California: U.S. Geological Survey Water-Supply Paper 1591-B, p. B1-B18.

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

_____ 1974b, Model synthesis in frequency analysis of Missouri floods: U.S. Geological Survey Circular 708, 16 p.

Huff, F. A., 1977, Effects of the urban environment on heavy rainfall distribution: American Water Resources Association, Water Resources Bulletin, v. 13, no. 4, August 1977, p. 807-816.

Leopold, L. B., 1972, Hydrology for urban land planning - A guidebook on the hydrologic effects of urban land use: U.S. Geological Survey Circular 554, 18 p.

Lutzen, E. E., and Rockaway, J. D., Jr., 1971, Engineering geology of St. Louis County, Missouri: Missouri Geological Survey and Water Resources, Engineering Geology Series no. 4, 23 p., 1 pl., 3 tables.

Martens, L. A., 1968, Flood inundation and effects of urbanization in metropolitan Charlotte, North Carolina: U.S. Geological Survey Water-Supply Paper 1591-C, p. C1-C60.

Randolph, R. J., and Gamble, C. R., 1976, Technique for estimating magnitude and frequency of floods in Tennessee: Tennessee Department of Transportation, 52 p.

U.S. Geological Survey and Missouri Geological Survey and Water Resources, 1967, Mineral and water resources of Missouri: U.S. 90th Congress, 1st session, Senate Document 19, 399 p. (Also available from Missouri State Geologist.)

U.S. Water Resources Council, 1967, A uniform technique for determining flood flow frequencies: U.S. Water Resources Council Bulletin 15, 15 p.

_____1977, Guidelines for determining flood flow frequencies: U.S. Water Resources Council Bulletin 17A, 26 p.

Wibben, H. C., 1976, Application of the U.S. Geological Survey rainfall-runoff simulation model to improve flood-frequency estimates on small Tennessee streams: U.S. Geological Survey Water-Resources Investigations 76-120, 51 p.

_____1976, Effects of urbanization on flood characteristics in Nashville-Davidson County, Tennessee: U.S. Geological Survey Water-Resources Investigations 76-121, 33 p.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978--666408/226