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Streamflow Characteristics of the Joplin Area, Missouri

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain metric unit
feet (ft)	0.305	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	28.32	liters per second (L/s)
	0.028	cubic meters per second (m^3/s)

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ABSTRACT

Low-flow and peak-flow frequency data and flow-duration data, based on records from 21 gaging stations in the Joplin area of southwestern Missouri, are presented. Generalized equations and graphs based on gaging-station records are shown so that estimates of frequency data and the effects of urbanization on peak flows can be made at ungaged sites. An analysis of a histogram of annual flood peaks shows that the chances for delay in construction work due to flooding are greatest during April through June and in September.

INTRODUCTION

In 1976 the U.S. Geological Survey, in cooperation with the Ozark Gateway Council of Governments, made a study of streamflow characteristics in the Joplin area of southwestern Missouri. The purpose of this study was to update and revise flow-frequency and flow-duration data from a previous report by Feder and others (1969). These data, in conjunction with streamflow measurements made during water-quality sampling, were to be used for planning and design by federal and state agencies and in a study of the effects of abandoned mines and tailings piles on ground and surface waters in the Joplin area (Barks, 1977).

The gaging-station network that provided information on the streams of the Joplin area is shown in figure 1. This network consisted of continuous-record gaging stations, where a complete record of stream stage and discharge was collected, and partial-record stations, where only low-flow or peak-flow data were collected. In addition to data from this network, low-flow information was obtained at additional stream sites during basin seepage runs and is presented in the report by Barks (1977).

FIG. 1 (near here)

The continuous-record stations provided the most complete basic data for the study. They were also used as index stations in defining low-flow frequency data for the partial-record stations.

Figure 1.--Location of gaging stations, 7-day 10-year low flows, and 100-year flood peaks.

A continuing program of streamflow data collection is being carried out in the Joplin area. Any streamflow information collected in the future can be obtained from the district office of the U.S. Geological Survey in Rolla, Mo.

DEFINITION OF TERMS

Cubic feet per second (ft^3/s) - The unit expressing rate of discharge. One ft^3/s is the rate of discharge of a stream having a cross-sectional area of 1 square foot and an average velocity of 1 foot per second. It is equivalent to 449 U.S. gallons per minute or 0.646 millions of U.S. gallons per day.

Drainage area (A) - All contributing drainage upstream from a point along the river channel, expressed in mi^2 (square miles).

Frequency data - Information that relates the magnitude of a variable to the frequency of its occurrence. For example, a 2-year flood peak is one that will occur on the average of once in 2 years.

Main-channel slope (S) - An average slope that is determined from elevations at points 10 and 85 percent of the distance along the channel from a gaging station to the divide.

Recurrence interval - The average interval of time within which a given event will be exceeded once. Recurrence intervals are averages and do not imply regularity of occurrence; an event with 50-year recurrence interval might be exceeded in consecutive years or it might not be exceeded in a 100-year period. In other words a 50-year flood or drought has a 2-percent chance of occurrence in any year.

Seepage run - A series of discharge measurements made in a short time to identify stream reaches where gains or losses in flow occur.

Standard error of estimate - A measure of the reliability of a regression. It is the standard deviation of the distribution of residuals about the regression line.

X-day Q_n - The average minimum flow for X consecutive days that has a recurrence interval of n years. For example, the 7-day Q_{10} is the 7-day average minimum flow with a recurrence interval of 10 years.

MAGNITUDE AND FREQUENCY OF PEAK FLOWS

Increasing use of the flood plains of streams by industry, municipalities, and individuals poses special problems during periods of flooding. With this increase in use always comes a corresponding increase in the risk for appreciable losses from flooding. Flood-frequency data can be especially ~~helpful~~ useful in ~~insuring~~ the ~~proper~~ planning and design of water facilities on the flood plains and ~~in~~ for locating structures so as to minimize risks.

The peak-flow frequency data shown in table 1 were determined for the most part by ~~computer~~ mathematically fitting a Pearson Type III distribution to the logarithms of the annual peak discharge data, as described by the Water Resources Council (1976). A graphical frequency curve, plotted on extreme value graph paper, was used for those stations for which the Pearson Type III curve was not a reasonable fit to the data or for stations with short periods of record.

Table 1.--Magnitude and frequency of annual low-flows and peak-flows

Station number (fig. 1)	Station name	Record used in analysis	Drainage area (mi²)	Period, days	Low-flow frequency data: Annual low-flow in ft³/s for indicated recurrence interval, in years: 2	5	10	20	50	Peak-flow frequency data: Magnitude of flood in ft³/s for indicated recurrence interval, in years: 2	5	10	25	50	100
1	Spring River at Larussell---	1957-76	306	7	47	28	20	15	10	5,580	10,500	14,400	19,700	23,900	28,300
				14	48	30	22	17	12						
				30	53	32	24	18	13						
				60	55	37	28	22	15						
2	White Oak Creek near Avilla---------------------	1954, 1962-64, 1976	---	7	0	0	0	0	0	-----	------	------	------	------	-----
3	Spring River at Carthage----	1951-54, 1966-76	425	7	50	---	19	13	---	13,000	22,000	28,500	37,000	43,500	50,000
4	Spring River near Neck City---------------------	1954, 1962-64, 1976	---	7	51	---	18	---	---	-----	------	------	------	------	-----
5	O'Possum Creek at Jasper----	1955-75	9.67	7	0	0	0	0	0	1,150	1,750	2,140	2,670	2,980	3,330
6	North Fork Spring River near Galesburg------------	1947, 1954, 1962-64, 1976	---	7	0.8	---	0	0	0	-----	------	------	------	------	-----
7	Spring River near Waco------	1925-76	1,164	7	53	30	18	11	5.8	17,200	31,000	41,600	56,200	67,500	80,100
				14	60	35	22	13	7.0						
				30	68	33	24	15	7.8						
				60	80	47	30	18	9.0						
8	Center Creek near Wentworth-----------------	1968-72	---	7	15	---	6.0	---	---	------	------	------	------	------	-----
9	Center Creek near Sarcoxie--	1954, 1962-65, 1967, 1976	---	7	16	---	6.8	---	---	-----	------	------	------	-------	-----
10	Center Creek near Fidelity--	1962-65, 1967, 1969-70, 1976	---	7	22	---	7.6	---	---	-----	------	------	------	------	-----
11	Grove Creek near Scotland[1]--	1953, 1961-66, 1976	---	---	---	---	---	---	---	-----	------	------	------	------	-----

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Table 1.--Magnitude and frequency of annual low-flows and peak-flows--continued

Station number (fig. 1)	Station name	Record used in analysis	Drainage area (mi²)	Period, days	Low-flow frequency data: Annual low-flow in ft³/s for indicated recurrence interval, in years: 2	5	10	20	50	Peak-flow frequency data: Magnitude of flood in ft³/s for indicated recurrence interval, in years: 2	5	10	25	50	100
12	Center Creek near Carterville[2]	1962-76	232	7	26	---	9.4	---	---	4,380	8,170	11,100	15,100	18,300	21,600
13	Center Creek near Webb City[2]	1962-64, 1966, 1975	---	7	32	---	10	---	---	-----	-----	-----	-----	-----	-----
14	Center Creek near (at) Coal Junction[2]	[illegible] 1952, 1954, 1962-67, 1969-70, 1976	---	7	35	---	11	9.0	---	-----	-----	-----	-----	-----	-----
15	Capps Creek near Berwick	1962-64, 1965-68, 1970	---	7	20	---	11	---	---	-----	-----	-----	-----	-----	-----
16	Clear Creek near Ritchey	1953, 1961-64, 1965-67	---	7	7.0	---	2.2	---	---	-----	-----	-----	-----	-----	-----
17	Shoal Creek at Ritchey	1954, 1962-67, 1969-70	---	7	54	---	20	13	---	-----	-----	-----	-----	-----	-----
18	Shoal Creek at Neosho	1941-43, 1945-46, 1949, 1952, 1954, 1962-65, 1967	---	7	60	---	23	16	---	-----	-----	-----	-----	-----	-----
19	Hickory Creek at Neosho	1961, 1962-65, 1967, 1969-70	---	7	9.8	---	3.9	---	---	-----	-----	-----	-----	-----	-----
20	North Fork Carver Branch at Diamond	1955-75	0.33	7	0	0	0	0	0	77	159	227	325	405	482
21	Shoal Creek above Joplin	1942-76	410	7	92	54	35	22	13	7,880	16,600	24,100	35,300	44,900	55,400
				14	96	56	38	25	15						
				30	102	60	42	28	18						
				60	120	70	50	35	25						

[1]Significant low-flow augmentation from industrial operations.

[2]Low-flow patterns affected by industrial operations in Grove Creek basin. As much as 10 percent of low-flow is a result of pumpage from wells and dewatering of mines.

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Peak-Flow Frequency at Ungaged Sites in Rural Basins

In basins where flood peaks have not been appreciably altered by man's activities, it is recommended that peak-flow frequency equations developed by Hauth (1974) be used to compute estimates of peak discharges for selected recurrence intervals. These equations were developed for statewide use, but an analysis of the equation residuals (observed station values divided by computed values) indicated a random pattern for the Joplin area with ratios ranging from 0.74 to 1.32. Thus it was not considered worthwhile to attempt an improvement in the equations already available.

The peak-flow frequency equations, shown in table 2, can be solved by using two drainage basin characteristics: (1) drainage area (A), which is the contributing drainage in mi^2 upstream from any site along a stream channel, and (2) average main-channel slope (S), which is defined as the average basin slope, in ft/mi (feet per mile), between points 10 and 85 percent of the total mainstem distance upstream from the site. An example of the steps necessary in the solution of the equations is as follows:

Assume that the magnitude of a flood peak with recurrence interval of 100 years is needed for a site on a small rural stream near Joplin. The following steps are necessary in solving the problem:

(a) Determine the drainage area in mi^2 by planimetering along the drainage divide for the basin upstream from the site. Assume that the drainage area is 0.5 mi^2.

(b) Compute the average main-channel slope in ft/mi by determining the difference in elevations and the distance between sites that are 10 and 85 percent of the main-channel distance upstream from the site. Assume that the distance, stepped off by using dividers set at 0.1 mi, is 0.3 mi and that the difference in elevation between the two points is 21 ft. The average main-channel slope is 21 ft/0.3 mi=70 ft/mi.

(c) From table 2, the equation for the 100-year flood peak is $Q_{100}=85.1\ A^{0.934A^{-0.02}}S^{0.576}$. Substituting the values of 0.5 mi^2 and 70 ft/mi in the equation and solving it, a value of 511 ft^3/s is obtained for the 100-year flood. For convenience in solving the equations, graphical presentations of the equations are ~~presented~~ shown in figures 2 to 7. Using figure 7, and entering the appropriate values of drainage area and slope, a value of 500 ft^3/s is obtained.

FIG. 2-7 (near here)

Figure 2.--Graphical solution of the 2-year equation.

Figure 3.--Graphical solution of the 5-year equation.

Figure 4.--Graphical solution of the 10-year equation.

Figure 5.--Graphical solution of the 25-year equation.

Figure 6.--Graphical solution of the 50-year equation.

Figure 7.--Graphical solution of the 100-year equation.

Table 2.--Peak-flow regression equations

Recurrence interval (years)	Magnitude of flood (ft³/s)	Standard error of estimate (percent)
2	$53.5A^{0.851A^{-0.02}}S^{0.356}$	39
5	$64.0A^{0.886A^{-0.02}}S^{0.450}$	35
10	$67.6A^{0.905A^{-0.02}}S^{0.500}$	34
25	$73.7A^{0.924A^{-0.02}}S^{0.542}$	35
50	$79.8A^{0.926A^{-0.02}}S^{0.560}$	33
100	$85.1A^{0.934A^{-0.02}}S^{0.576}$	33

Peak-Stage-Frequency Data

In many instances the stage or elevation of the flood peak above the streambed is more critical than the magnitude of flow involved. For this reason peak-stage-frequency data are very useful in the location of structures on or near the flood plains of streams.

Generalized peak-stage-frequency relationships were developed by Gann (written commun., 1974) from data at continuous-record streamflow stations. The equations and curves, as shown on figure 8, were studied to determine their applicability to streams in southwestern Missouri and were found to be well within the limits of accuracy defined by the standard error for each of the equations. Therefore, these data should be useful in the Joplin area for estimating flood-height frequency.

There are some limitations to the use of stage-frequency data that should be emphasized. Note that these relationships are applicable only to unregulated streams with natural channels and insignificant flow losses. Also, it is not possible to adjust rural stage-frequency relationshps to urban conditions unless precise survey data are available to show the location and size of structures on the urban flood plain.

Because there may be some changes over a period of time in stage-discharge relationships at individual gaging stations, the peak-stage-frequency data for continuous-record stations in the Joplin area are not tabulated in this report. If such information is required near a continuous-record streamflow station in the area, contact the District Chief, U.S. Geological Survey, 1400 Independence Road, Mail Stop 200, Rolla, Mo., 65401.

Figure 8.--Peak-stage frequency relations for streams in the Joplin area, Mo.

The following example will illustrate the use of figure 8. Assume that an estimate of the 100-year flood height is needed for a site near Joplin on a stream draining 50 mi^2.

Step 1: Determine the elevation of zero flow at the upper end of the first riffle downstream from the site. The point of zero flow will be the deepest point along the riffle. Assume that the elevation of this point is about 950 ft above mean sea level.

Step 2: Determine the flood height graphically from figure 8 for a 50 mi^2 drainage area and a 100-year flood to be about 16 ft. The same value may be obtained by using the appropriate equation shown on figure 8 ($H_{100}=7.95A^{0.173}$).

Step 3: Add the elevation of point of zero flow to flood height from figure 8 and obtain an elevation of approximately 966 ft for the 100-year flood.

Effects of Urbanization on Peak-Flow Frequency

The effects of urbanization on the peak-flow frequency equations of table 2 can be estimated by a method proposed by Gann (1971). Although it is a highly generalized method that applies only to small urban basins (≤50 mi^2), it will be useful for planning and design purposes in the Joplin area until more definitive urban runoff data are available.

To utilize this method, four data items are required: (1) the percent of impervious area in the basin, (2) the percent of area served by storm sewers, (3) the area and slope of the basin as defined in the glossary, and (4) an estimate of the magnitude of the 2-year recurrence interval flood-peak (see table 2 and fig. 2). These data are then combined and used in the following equation: $Q_x=R_1R_2P_2$,

where

Q_x is the magnitude of a flood with x-year recurrence interval in ft^3/s,

R_1 is the ratio of discharge after urbanization to discharge before urbanization for the 2-year flood, from figure 9,

FIG. 9 & 10 (enter here)

R_2 is the flood-frequency ratio from figure 10, and

P_2 is the magnitude of the 2-year flood in ft^3/s.

Figure 9.--Effect of urbanization on the 2-year flood. (After Leopold, 1968.)

Figure 10.--Relation of floods in Springfield, Mo., area to the 2-year flood for selected degrees of basin imperviousness.

The following example will illustrate the use of these procedures for urban basins. Assume that the peak discharge for the 100-year flood is needed for a small basin near Joplin where the projected degree of development will be 40-percent imperviousness in the basin and 40 percent of the area served by storm sewers.

Step 1: From a topographic map of the area, compute the drainage area and basin slope. Assume that the drainage area is 10 mi^2 and the slope is 30 ft/mi.

Step 2: From the equation shown in table 2 or the graphical solution of figure 2, compute the 2-year flood to be $53.5(10)^{0.851}(10)^{-0.02}(30)^{0.356}$=1,160 ft^3/s, or graphically, about 1,200 ft^3/s.

Step 3: Using the projected degree of development, enter figure 9 and select the ratio R_1 to be 2.5.

Step 4: Using the recurrence interval of 100 years and projected degree of imperviousness, enter figure 10 and select ratio R_2 to be 3.4.

Step 5: Solution of the equation $Q_x=R_1R_2P_2$ is the final step. $Q_{100}=(2.5)(3.4)(1,200)=10,200$ ft^3/s.

The following limitations should be considered in using these procedures to estimate urban flood peaks. First, these urban flood-frequency relations are highly generalized and only provide a rough approximation of the true frequency relation for urban areas. Second, the sizes of drainage basins to be considered when using these methods are limited to areas of 0.1 to 50 mi^2. Third, the relationships only apply to the condition of areally complete basin development; that is, they should not be used where only a part of the drainage basin, such as the upper half or lower half, is expected to be developed.

DISTRIBUTION OF ANNUAL FLOOD PEAKS BY MONTHS

Flooding from storm runoff can occur during any month of the year in the Joplin area, but it is most frequent during the period April through June. A histogram of annual flood peaks from gaging stations in the area is shown in figure 11. The pattern shown in the histogram is about the same for both large and small drainage areas. It is interesting to note that only a small percentage of flood peaks occur in August, December, or January. Percentagewise, the chances for delay in construction work due to flooding in the area are greatest during April through June and in September.

Figure 11.--Distribution of annual flood peaks by months for gaging stations in the Joplin area, Mo.

FLOW-DURATION DATA

The flow duration data in table 3 show the percent of time that specified discharges were exceeded at a site during a given period of record. These data should not be considered probability data in the strictest sense; theoretically they apply only to the period for which streamflow data were used for computations.

Duration data do provide a convenient means of comparing basins and studying the flow characteristics of streams through a wide range of flows. Note in figure 12 that when duration data are made comparable (by dividing the flow by drainage area size), the slopes of the curves may be compared to determine relative low-flow and floodflow characteristics. The two curves in figure 12 indicate that low flows in the Shoal Creek basin are better sustained but that higher flows (above 10-percent duration) are very similar in the two basins.

Figure 12.--Flow-duration curves for long-time continuous-record stations.

Table 3.—Flow-duration data for continuous-record stations

Station and site no.	Spring River at Larussell (1)	Spring River near Waco (7)	Center Creek near Carter-ville (12)	Shoal Creek above Joplin (21)
Drainage area (mi^2)	306	1,164	232	427
Record used in analysis	1958-73	1924-72	1963-73	1941-72
Percent of time	Flow, in ft^3/s, that was exceeded for indicated percent of time			
99.5	23	13	15	31
99	25	17	17	37
98	29	22	19	44
95	36	34	23	58
90	44	50	28	74
80	60	80	36	100
70	76	115	46	130
60	94	160	58	160
50	120	220	74	195
40	150	310	98	240
30	200	470	130	310
20	270	820	190	410
10	430	1,800	340	640
5	640	3,300	550	1,000
2	1,020	6,500	960	1,800
1	1,500	10,000	1,400	2,700
0.5	2,100	15,000	2,000	4,200
0.1	5,200	26,000	4,500	12,000

MAGNITUDE AND FREQUENCY OF LOW FLOWS

Low-flow frequency data for continuous- and partial-record stations are shown in table 1. These data were computed by using methods described by Skelton (1976).

For the continuous-record stations, the method consisted of fitting (by computer) the Pearson Type III distribution to the logarithms of the lowest mean discharges to provide low-flow frequency estimates for each station. For comparative purposes, the data were also analyzed graphically on log-Gumbel paper, which has a logarithmic ordinate scale and an abscissa scale based on the theory of extreme values.

For the low-flow partial-record stations, low-flow measurements were related graphically to concurrent discharges at nearby continuous-record stations. Then 7-day data for two or three recurrence intervals were tranferred through the relationship to obtain frequency estimates. This procedure provides reliable estimates of median values (the 2-year recurrence interval) and estimates of less reliability for more extreme events. However, there is no way to mathematically evaluate the magnitude of the errors involved in the procedure.

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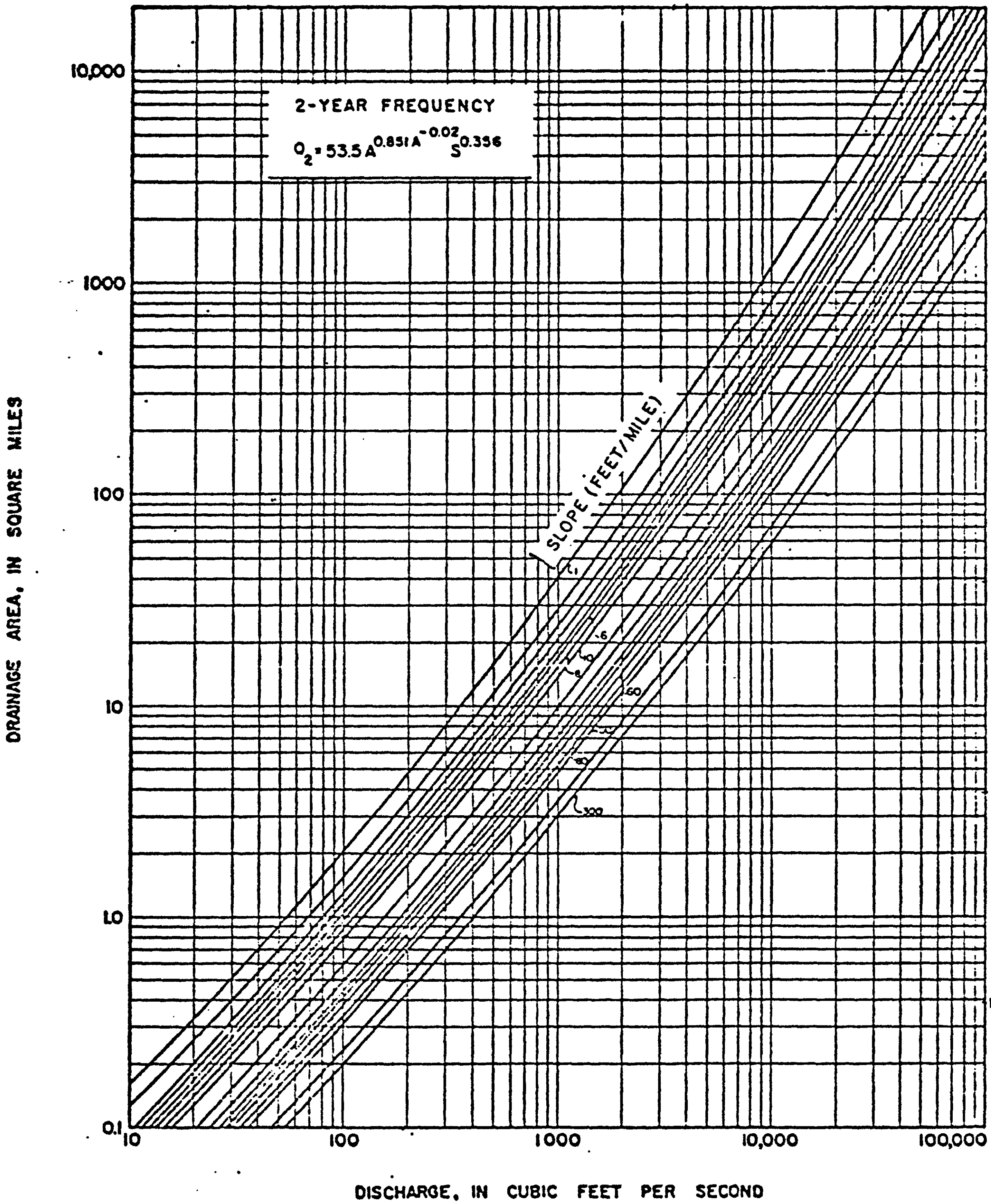


FIGURE 2 Graphical solution of the 2-year equation.

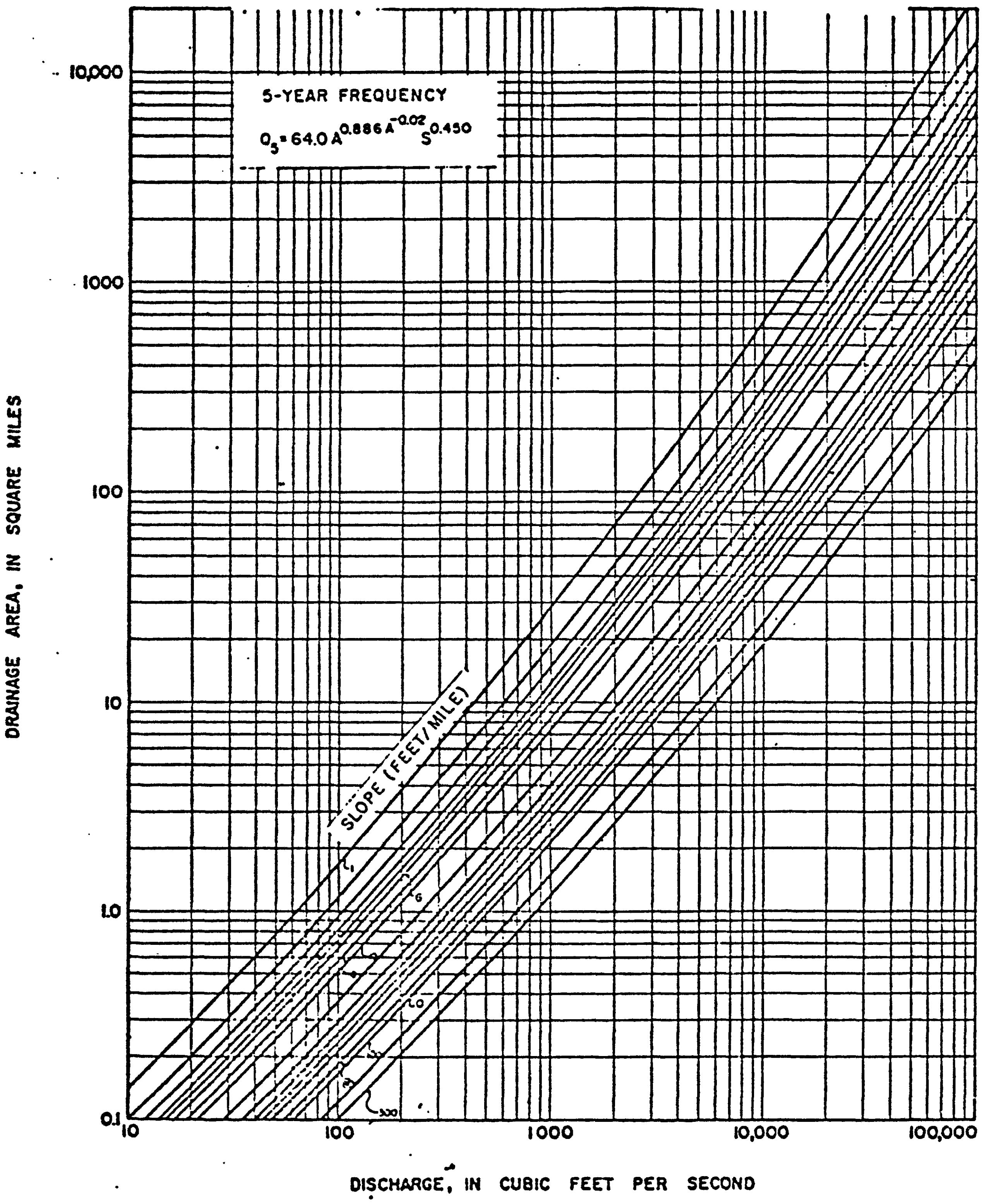


FIGURE 3 Graphical solution of the 5-year equation.

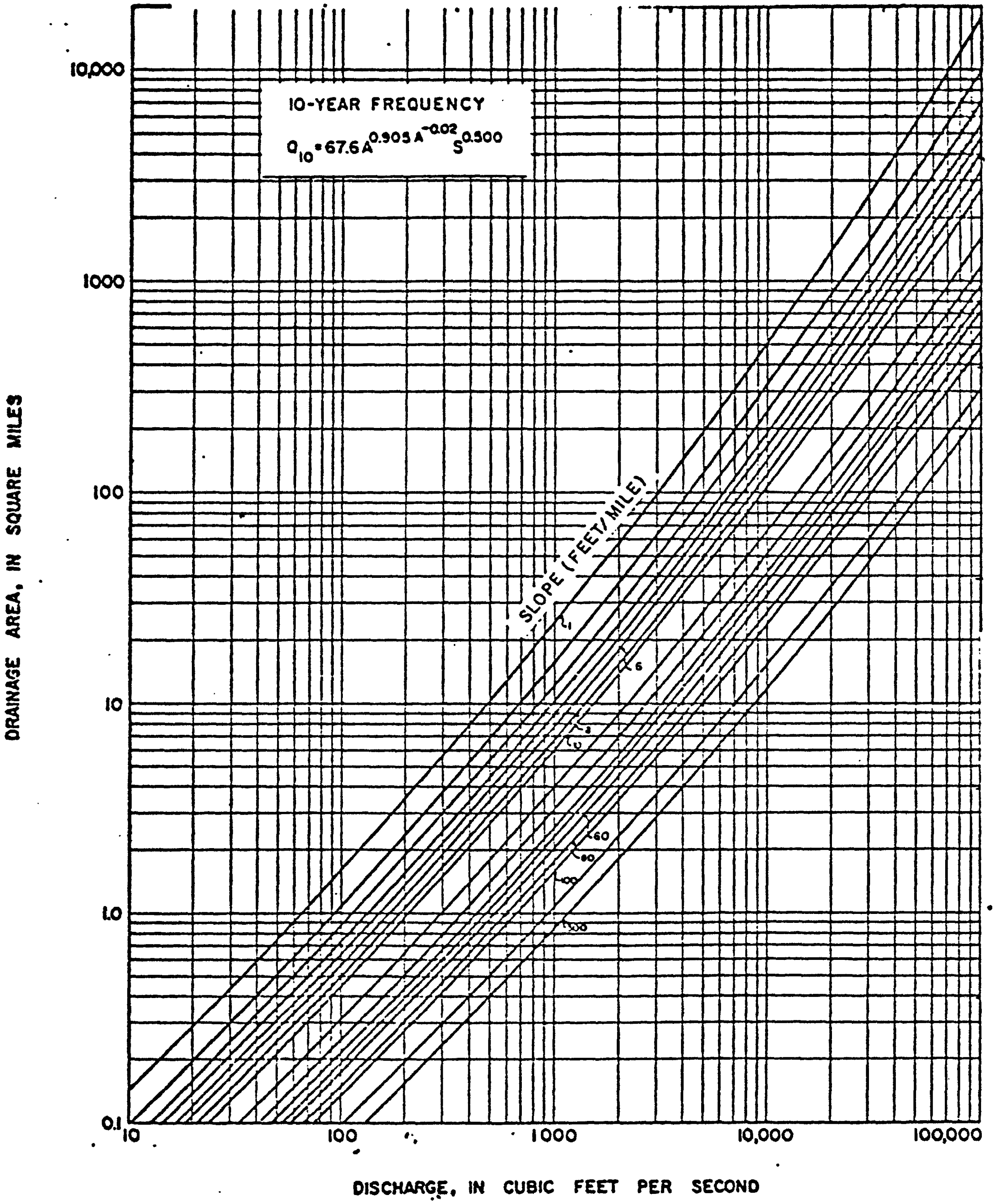


FIGURE 4 Graphical solution of the 10-year equation.

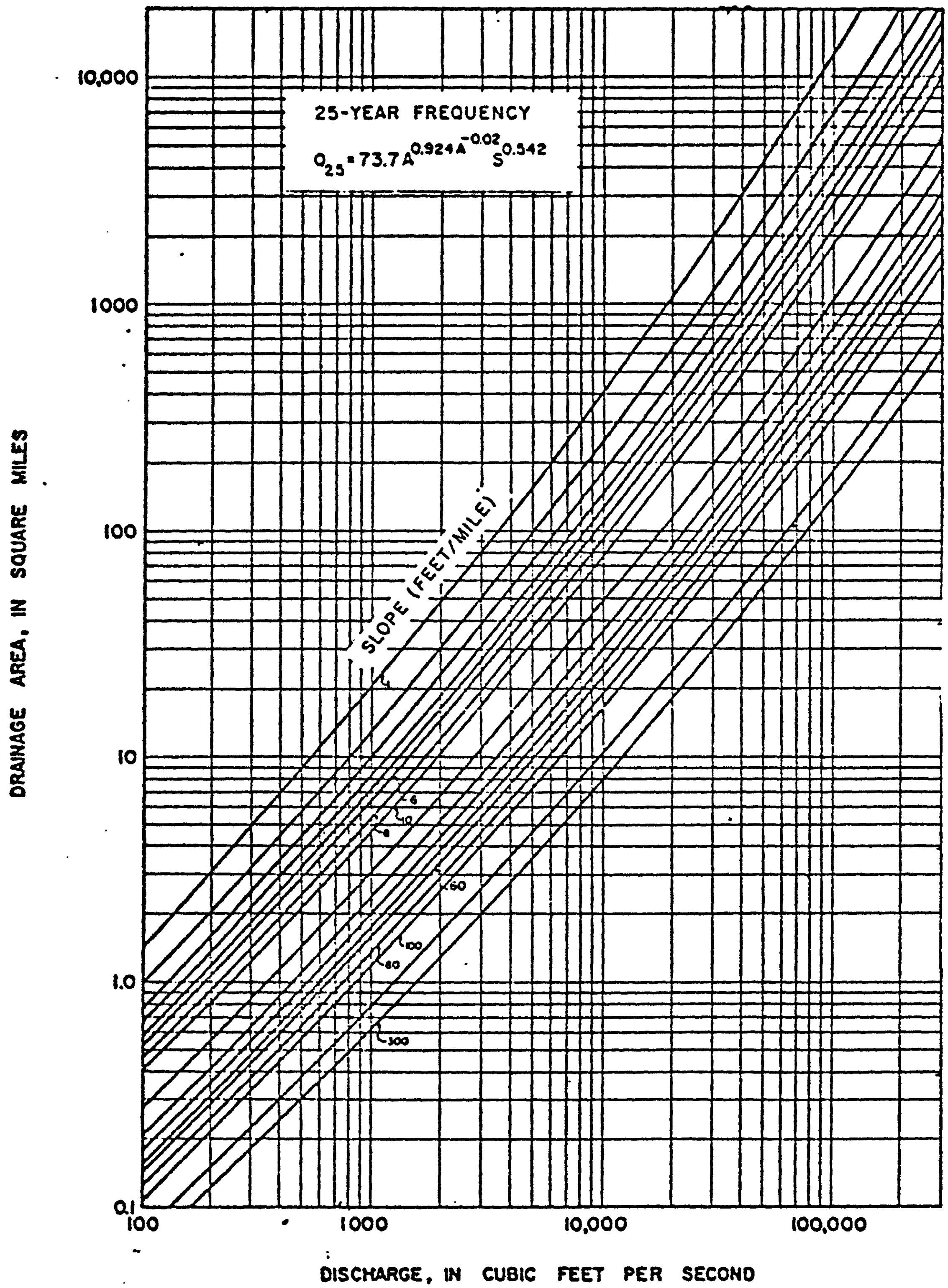


FIGURE 5 Graphical solution of the 25-year equation.

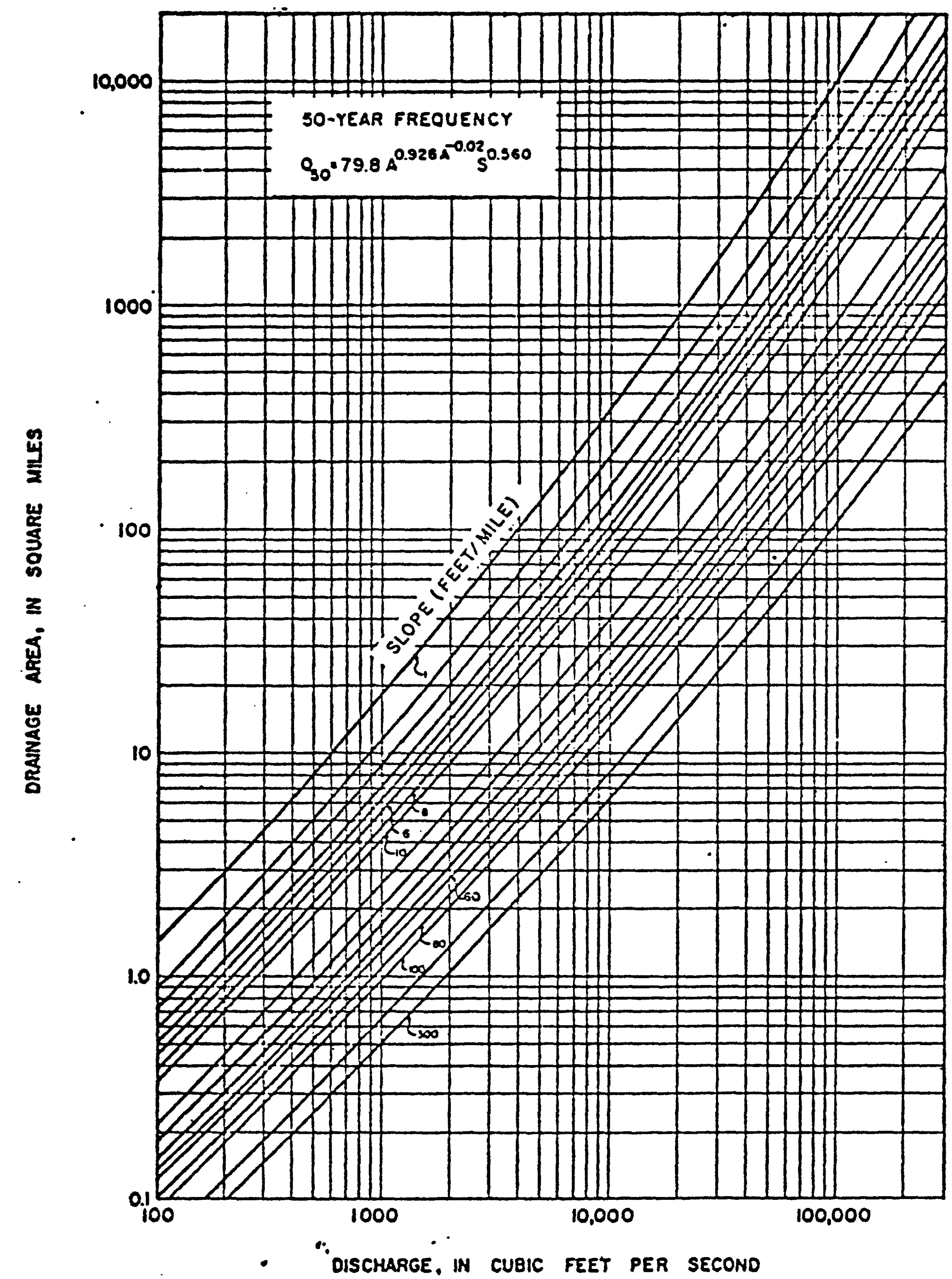


FIGURE 6. Graphical solution of the 50-year equation.

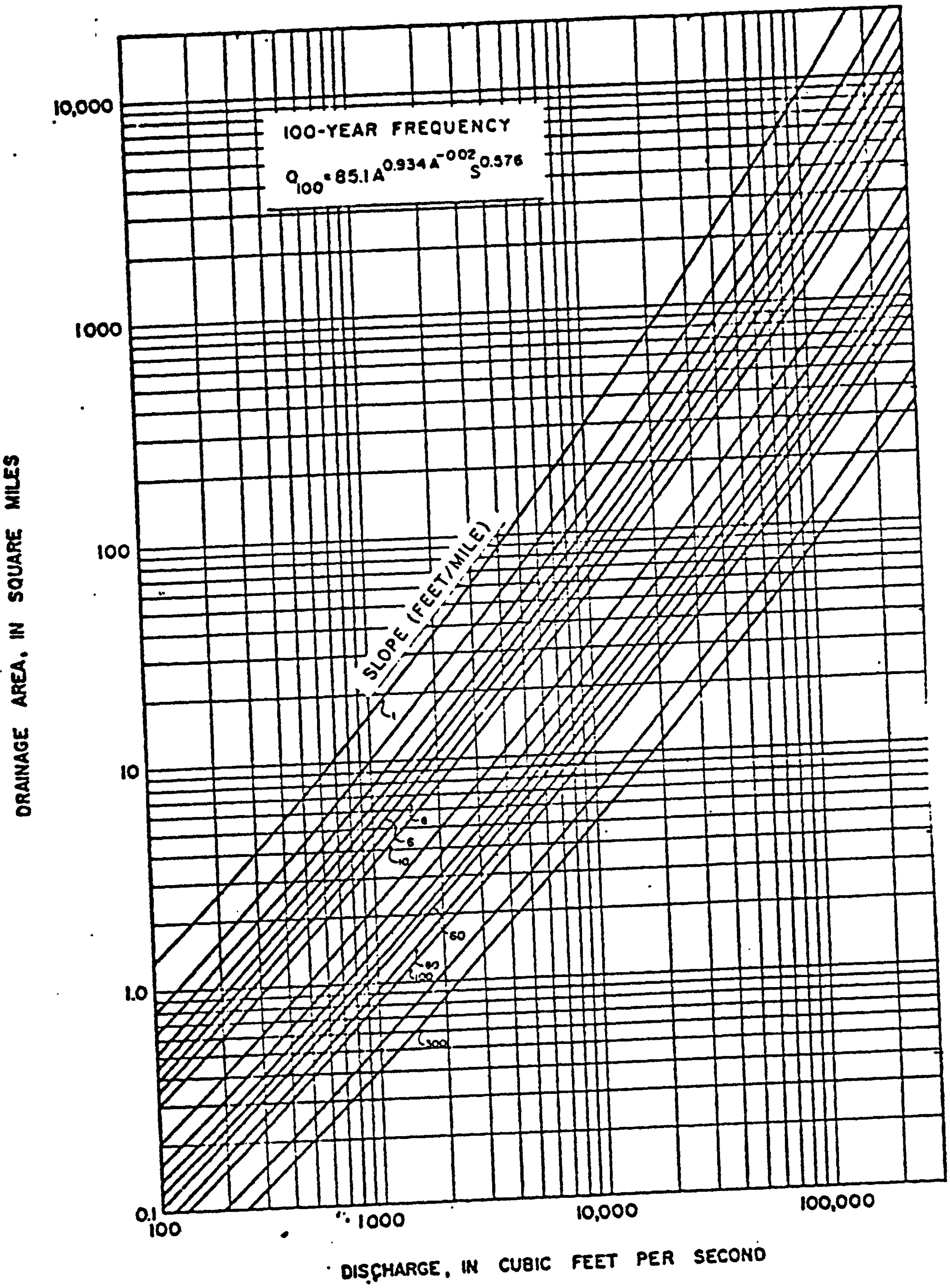


FIGURE 7 Graphical solution of the 100-year equation.

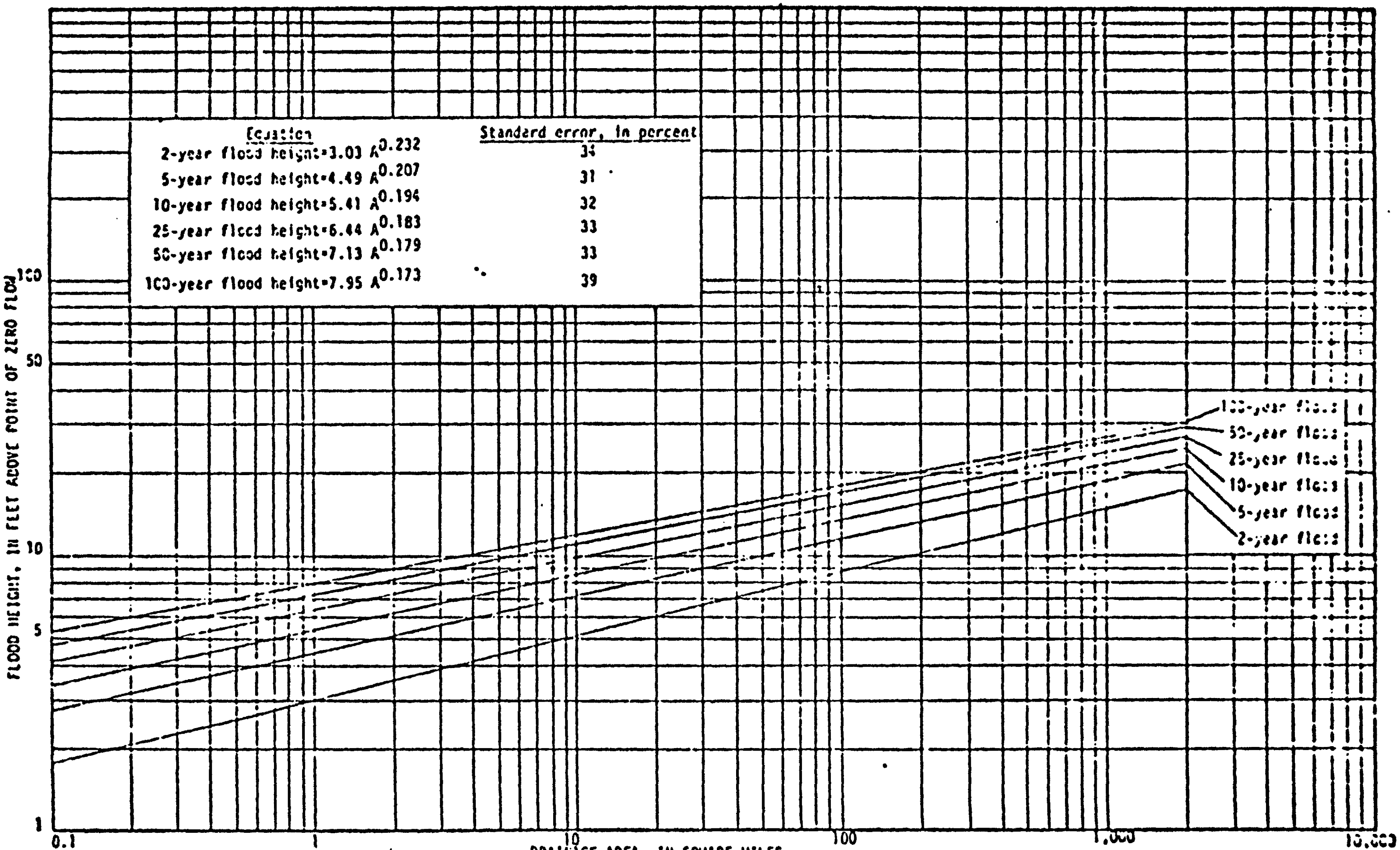
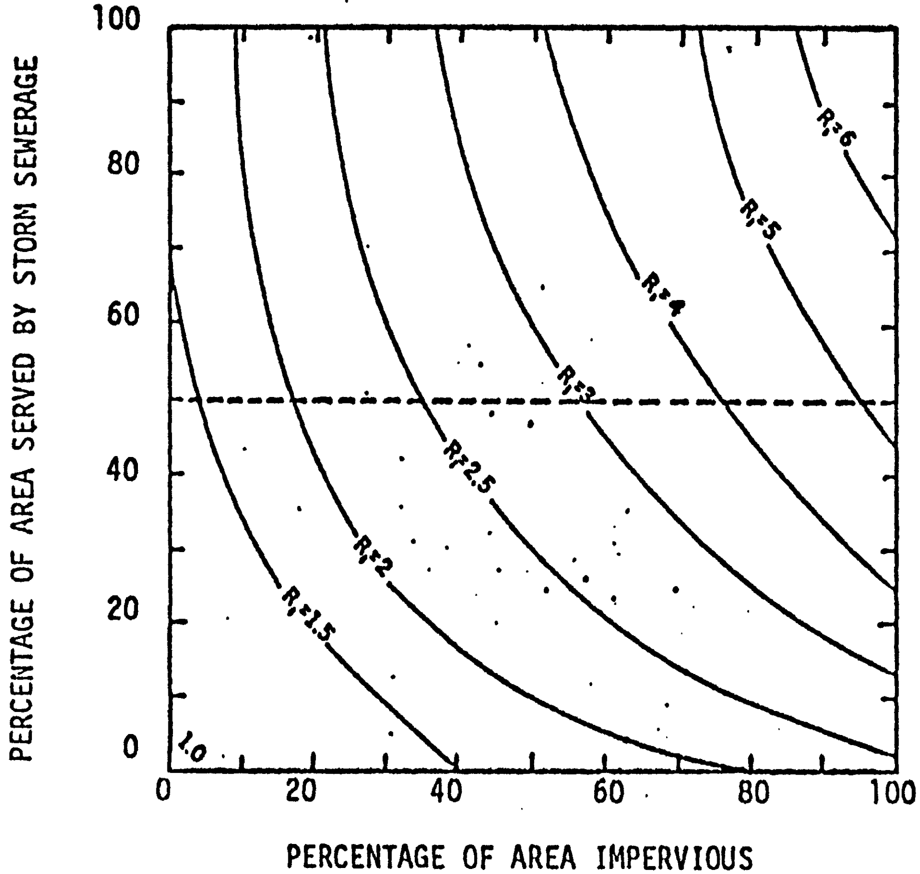


Figure 8.--Peak-stage-frequency relations for streams in the Joplin area, Mo.



Note.--Use dashed line for a 100-percent sewered basin with natural main channel.

Parameter R_1 is ratio of peak discharge after urbanization to discharge before urbanization for the 2-year flood.

Figure 9.--Effect of urbanization on the 2-year flood. (After Leopold, 1968.)

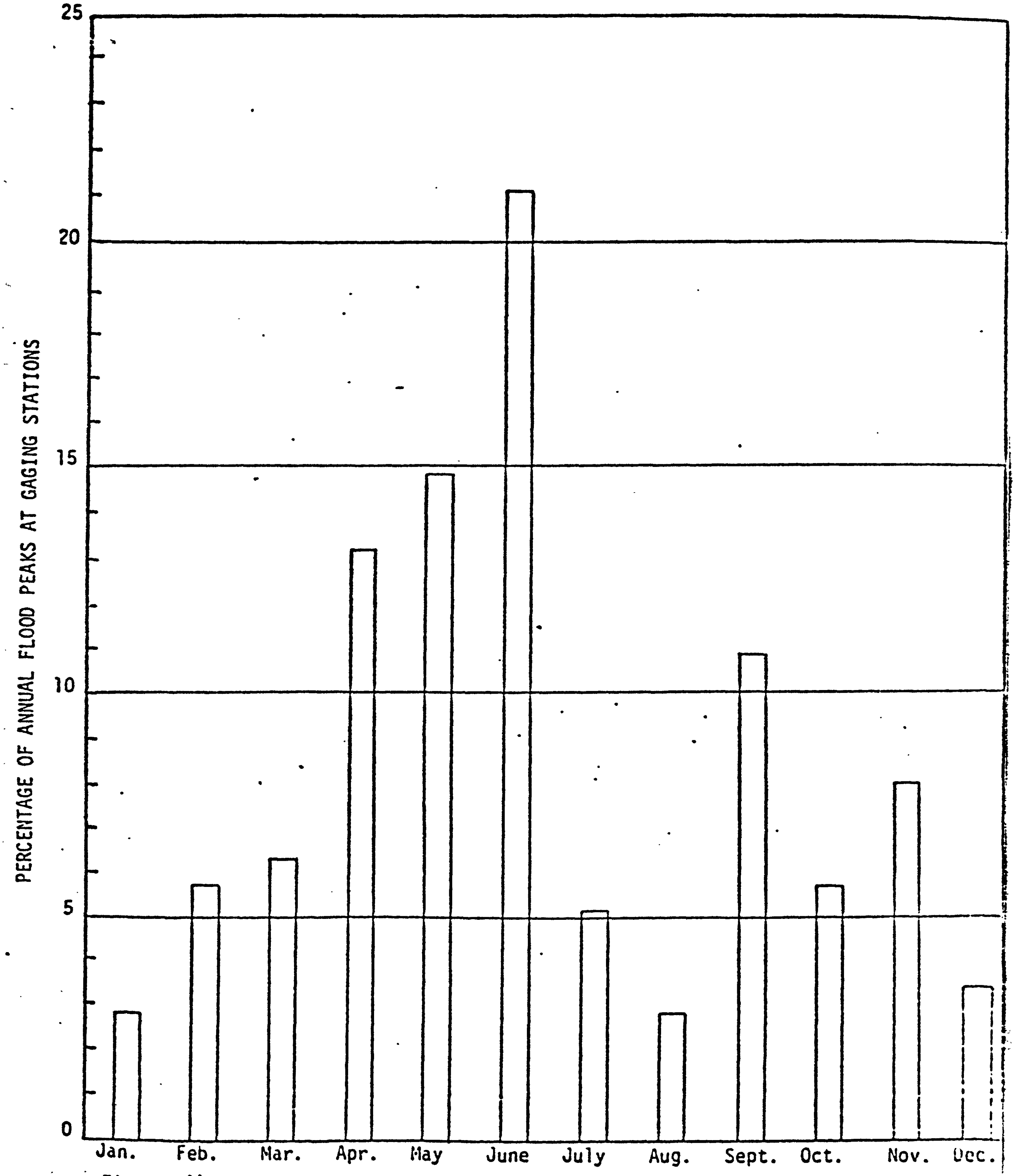


Figure 11.-Distribution of annual flood peaks by months for gaging stations in the Joplin area, Mo.

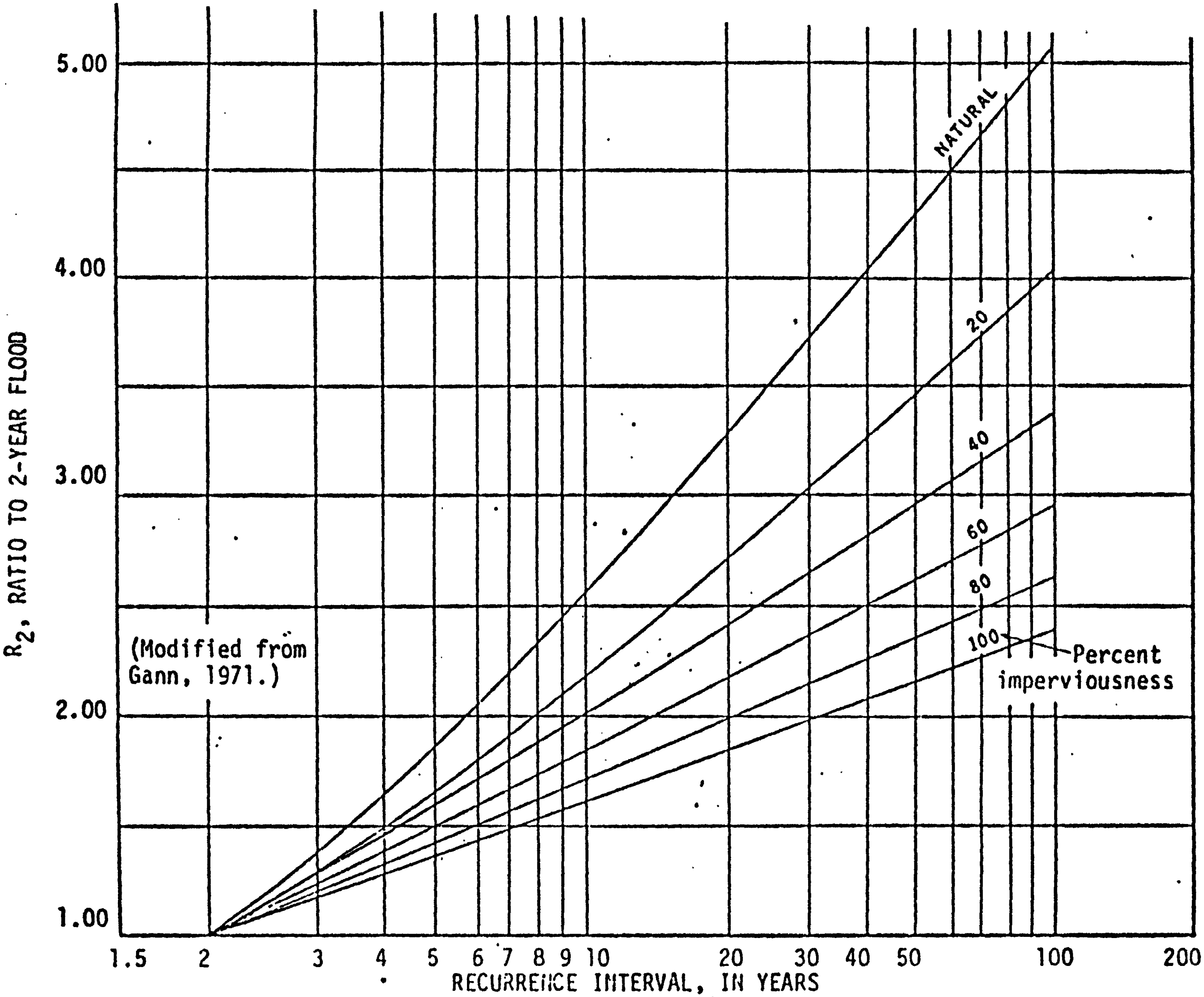


Figure 10.--Relation of floods in Springfield, Mo., area to the 2-year flood for selected degrees of basin imperviousness.

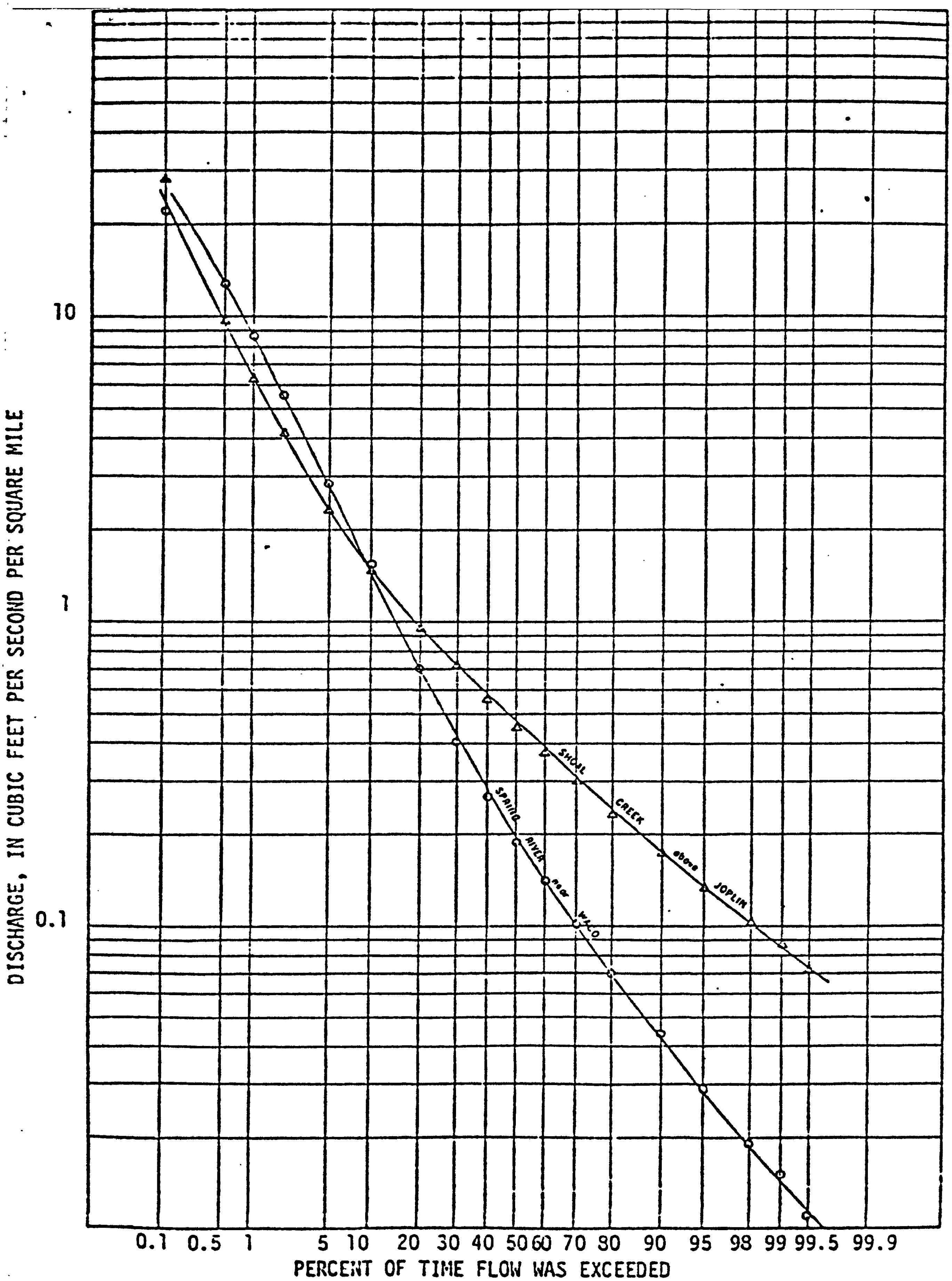


Figure 12.--Flow-duration curves for long-time continuous-record stations.