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GEOLOGICAL SURVEY

WEST VIRGINIA DEPARTMENT OF HIGHWAYS

RESEARCH PROJECT 16

"Runoff Studies on Small Drainage Areas"

(Technique for Estimating Magnitude and Frequency of Floods in West Virginia)

By G. S. RUNNER

Open-File Report 80-1218

Prepared in cooperation with the

West Virginia Department of Highways

and the

Federal Highway Administration

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October 1980

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16. Abstract

A technique is presented for estimating the magnitude and frequency of floods on unregulated, virtually natural streams in West Virginia. Multiple-regression techniques were used to develop relations between dependent variables, flood peaks, and independent variable, drainage areas. Data collected at 170 stream-gaging sites were used in the analyses.

Analyses of all residuals errors indicated that the best estimate of flood peaks could be made by dividing the state into three regions.

Peak discharges can be estimated for drainage areas from about 0.3 square mile up to 2000 square miles. Graphs are provided to estimate the flood peak having recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years and drainage areas between 1 and 1000 square miles. For drainage areas less than 1 and greater than 1,000 square miles peak flows can be estimated using equations listed on each graph.

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FINAL REPORT

WEST VIRGINIA DEPARTMENT OF HIGHWAYS
RESEARCH PROJECT 16
"Runoff Studies on Small Drainage Areas"
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Frequency of Floods in West Virginia)

BY

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Geological Survey

A research project conducted in cooperation
with the West Virginia Department of Highways
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CONTENTS

ILLUSTRATIONS

CONTENTS (Cont.)

Illustrations

ABSTRACT

A technique is presented to provide a method of estimating the magnitude of peak discharges of T-year frequencies for unregulated, virtually natural streams in West Virginia. Multiple regression techniques were used to develop the relation between peak discharges and drainage area. Data collected at 170 stream gaging sites were used in the analyses.

Analyses indicated that the best estimating equations could be derived by dividing the state into three regions, Regions 1 and 2 covering the Ohio River basin in West Virginia and Region 3 covering the Potomac River basin in West Virginia.

The method is applicable for drainage areas between 0.3 and 2,000 square miles. Graphs are provided to estimate the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood peaks for drainage areas between 1 and 1,000 square miles. Peak discharges for drainage areas less than 1 or greater than 1,000 square miles can be estimated using the appropriate equations provided on each graph.

RESEARCH IMPLEMENTATION

Application: Prior to the study, flood frequency estimates were made using techniques that were, in many instances, based on data from areas not necessarily similar to those found in West Virginia. Hydrologic information was lacking, especially for streams whose drainage area was less than 50 square miles. The data collection phase of this research study was designed to provide information on streams having small drainage areas. The technique discussed in this report was developed using data obtained from these small drainage area streams, combined with hydrologic data available from U.S. Geological Survey long-term sites having drainage areas between 50 and 2,000 square miles. The technique should therefore be especially applicable to West Virginia using the data collected over a wide range of hydrologic conditions.

Implementation: The technique provided in this report could be implemented through a West Virginia Department of Highways Roadway Design Division Directive or as an update to the Drainage Manual.

Expected Benefits: The technique should provide an easier, more reliable, method for estimating peak discharges for drainage areas in West Virginia. The method was developed from data collected in the State, therefore, greater confidence could be placed in the flood-frequency estimates which are necessary for the safe, economical, design of drainage structures.

WEST VIRGINIA DEPARTMENT OF HIGHWAYS

RESEARCH PROJECT 16

"Runoff Studies on Small Drainage Areas"

(Technique for Estimating Magnitude and Frequency of Floods in West Virginia)

INTRODUCTION

This is the final report in the cooperative project between the West Virginia Department of Highways, Federal Highway Administration and the U.S. Geological Survey. This project was designed to provide a technique for estimating the magnitude of peak discharges of T-year frequencies on unregulated streams in West Virginia. The project began in 1963 and continued through 1978. The first phase of the project required an extensive search for suitable stream-gaging sites. Therefore, the first three years of the study were used for site reconnaissance and installation of approximately 60 crest-stage gages. Later in the project, 20 additional sites were selected as dual digital sites where both continuous stage and rainfall were collected. Fifteen of these latter stations were finally selected to use with the U. S. Geological Survey rainfall-runoff model. The records were extended to about 70 years by using long-term rainfall records and then appropriate frequency curves were drawn.

The basic small-streams flood data collected during the project were supplemented by the regular U.S. Geological Survey stream-gaging network. This network consists mainly of large drainage-area stations (greater than 50 square miles) with length of records greater than forty years. The lack of small-stream stations in the regular network was one of the main reasons for this flood-frequency study. Prior to this project flood frequency estimates for small drainage areas in West Virginia were based on empirical relations or data collected in other parts of the country.

Frye and Runner (1969) presented relations for estimating flood magnitude and frequency within the State of West Virginia that were taken from U.S. Geological Survey Water Supply Papers 1672 and 1675. This flood-frequency study was country-wide and combined available records from all states to develop regional or major river basin frequency curves. These relations were only recommended for use on drainage areas greater than 50 square miles in the Ohio River basin and 30 square miles in the Potomac River basin.

Another technique for estimating magnitude and frequency on West Virginia streams is presented in the report "A Proposed Streamflow Data Program for West Virginia" (Frye and Runner 1970). This method used an analytical technique similar to one proposed by Benson (1962). Data for all natural flow streams in West Virginia with discharge records of 10 years or longer were used in the analysis. Because of the absence of stations on small streams with the required length of record, this estimating method was recommended for streams having drainage areas greater than 50 square miles.

In 1971, "A Preliminary Report on Small Streams Flood Frequency in West Virginia", provided a method for estimating the 2-, 5-, and 10-year peak discharges for streams in the Ohio River basin of West Virginia, having drainage areas between 1 and 50 square miles. This study used all the peak discharge data made available by the small-streams program to that date. At that time the length of record for the small-streams stations averaged about 6 years. These records were correlated with long-term regular station records to determine time bias and appropriate corrections made.

Estimates of the magnitude and frequency of floods are needed for all size drainage areas for safe and economical design of hydraulic structures and flood-plain management. Peak flow records collected to define small-streams flood frequency were combined with available long-term U.S. Geological Survey streamflow records to define a complete range of flood frequency for West Virginia. Multiple-regression techniques were used to correlate flood magnitudes with basin characteristics to develop regional flood-frequency relations. This report provides a method for estimating peak discharges for recurrence intervals ranging between 2 and 500 years for ungaged sites on streams in West Virginia that have drainage areas between 0.3 and 2,000 square miles. Graphs are provided to estimate peak discharges for drainage areas between 1 and 1,000 square miles. Peak discharges for other size drainage areas can be estimated by solving the appropriate equation provided on each curve.

When developing frequency curves for the larger drainage area ungaged sites (>100 square miles) the user is instructed to check for nearby station frequency curves. Within reason, gaged site data may be transferred to the ungaged site using procedures outlined in U.S. Water Resources Council, Bulletin 17, 1976. The user is also reminded that frequency curves may be developed using Soil Conservation Service or U.S. Army Corps of Engineers routing techniques.

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

Multiply Inch-Pound Unit	By	To obtain SI units
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)

This study was conducted during the period 1963-77 by the U.S. Geological Survey in cooperation with the West Virginia Department of Highways and the Federal Highway Administration. The basic small-stream data collected for the study are supplemented by flood data from the regular stream-gaging network, other cooperative hydrologic studies, and flood data from studies in Maryland and Virginia. The opinions, findings, and conclusions in this report reflect the views of the author who is responsible for the data presented herein. The contents do not necessarily reflect the policies of the West Virginia Department of Highways or the Federal Highway Administration.

ANALYTICAL TECHNIQUES

Flood frequency curves were computed for 170 stream gaging sites, using the procedures recommended by the U.S. Water Resources Council (1976), Bulletin 17. The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year peak discharges were determined for each station and used as dependent variables in the regression analysis. Regional skew values were weighted with station skew values and used to adjust each station record. The regional skew values were taken from the generalized skew map in WRC Bulletin 17.

Hydrologic data used in the regression analysis, and a listing of station locations are available in Open-File Report 80-560, "Hydrologic Data for Runoff Studies on Small Drainage Areas" West Virginia Department of Highways Research Project 16, 169 p. Other data used in the study but not contained in the report are available from U.S. Geological Survey computer files using Watstore programs. These files contain unit-rainfall and unit-discharge data for 15 smallstream stations, unit and daily values of rainfall for the long-term rainfall stations, and pan-evaporation data for two stations. These data were too voluminous to be included in the hydrologic data report. Also contained in the data report are maps showing the locations for all stations used in the regression analyses.

Fifteen small-stream station frequency curves were adjusted using the U.S. Geological Survey rainfall-runoff model. These were the only stations in the small-stream network with enough reliable unit data to justify using the model technique. The model was used to simulate flood-volume and flood-peak data at stations where concurrent discharge and rainfall data were collected. The model was developed to generate flood hydrographs for small-drainage basins using daily evaporation, unit and daily rainfall, and unit and daily discharges.

The two phases involved in using the model are calibration and optimization. To calibrate each basin, concurrent runoff and rainfall data for the site, plus general evaporation data are used to fit the model to the conditions that exist on the gaged basin. The final values for basin parameters are determined by an optimization process. These parameters are then used along with long-term rainfall data as input to the model to generate a series of flood peaks equivalent to the length of record at the long-term rainfall station. Evaporation data from the National Weather Service stations at Sutton Lake, Bluestone Lake, and Kearneysville, West Virginia, were used for small stream sites. Long-term rainfall data from Elkins, and Parkersburg, West Virginia, and Wytheville, Virginia, were used to synthesize peak discharges for the fifteen stations. All short-term and long-term data used to calibrate the model and synthesize the peak discharges are on U.S. Geological Survey unit value and daily value computer files. A detailed discussion of the rainfall-runoff model is given in U.S. Geological Survey Professional Paper 506-B by Dawdy, Lichty, and Bergmann (1972).

Frequency curves developed using station data and frequency curves developed using the synthesized flood peaks were combined to give a composite curve for each of the fifteen stations. These data along with frequency data for 155 regular and project streamflow stations were used as input to the regression analysis. The estimating equations developed by this study are listed on page 16. As an example of the equations, figure 1 shows station's frequency data for Q_{50} compared to the 50-year frequency curve for Region 1. The final curve is a composite of the long-term station frequency curve and the curve developed by combining the long-term stations with the project stations. The lack of stations in the range of 10 to 50 square miles in drainage area, or even 10 to 100 square miles should be noted. The author felt the long-term stations' frequency could stand alone in a frequency report but all parties would be better served if all stations were combined in a single report. This would eliminate the possibility of having different discharge values for the same frequency or discontinuous frequency curves. Shown on figure 2 are maximum station discharges in Region 1 for the long-term stations, project stations, and indirect measurement sites. These values are compared with the Q_{100} frequency curves for Region 1.

Twelve basin and climatic characteristics were determined for each station and used as independent variables in the regression analysis. Those characteristics determined were:

A......drainage area, in square miles
S......stream slope, in feet per mile measured between 0.1 and 0.85 length
L......length of stream, in miles from gaging point to divide
St.....storage area of lakes and ponds, in percent of basin area plus 1.0 percent.
E......mean basin elevation, in thousands of feet above sea level
F......forest cover, in percent of drainage area.
P......mean annual precipitation, in inches.
$I_{24,2}$..24 hour rainfall intensity at 2-year recurrence interval in inches.
T......mean minimum January temperature, in °F.
Sn.....mean annual snowfall, in inches.
Si.....soil index, in inches.
R......ratio of basin length to width.

Multiple regression techniques were used to relate each of the specified peak discharges to the basin and climatic characteristics. This method was described by Benson (1962).

Initially all variables and all stations were used in the regression analysis. Later analyses separated the stations into groups having drainage areas less than 50 square miles and those greater than 50 square miles. Analyses were also conducted using a breakdown of long-term records versus short-term records, and with and without regional skew values.

Analysis of the resultant residual errors for each flow characteristic led to the division of the state into three geographic regions. When using the three regions approach, there was an improvement in the standard error of estimate throughout the state.

The analysis for each region required regression analysis:

1) Using all available stations,
2) using stations having less than 50 square miles in drainage area, and
3) using station with more than 50 square miles of drainage area.

A study of each regression equation was made by dropping one significant variable (at 95 percent confidence level) from the equation at a time and noting the change in standard error. The final analysis indicates that the most useful estimating equations for each flow characteristic (Q_2, Q_5, etc.) would contain only drainage area as a variable. The results of the final analyses for the three regions and the final estimating equations are shown on the graphs in figures 4 through 24 and listed on page 16.

Also present on each figure are the flow characteristic plus one standard error of estimate and the flow characteristic plus two standard errors of estimate. These values above the mean curve show graphically the approximate upper limit of data used in this flood study. The user of this report should note that at the drainage area breakpoint there are two standard errors (SE). One SE for the equation using only long-term stations, and one SE for equation that used all available stations. Rather than have a discontinuous Q + 1 SE and Q + 2 SE on each graph (figures 4 to 24) an average value was used and the appropriate curve drawn. This should not introduce any appreciable error into calculations for frequency plus standard error.

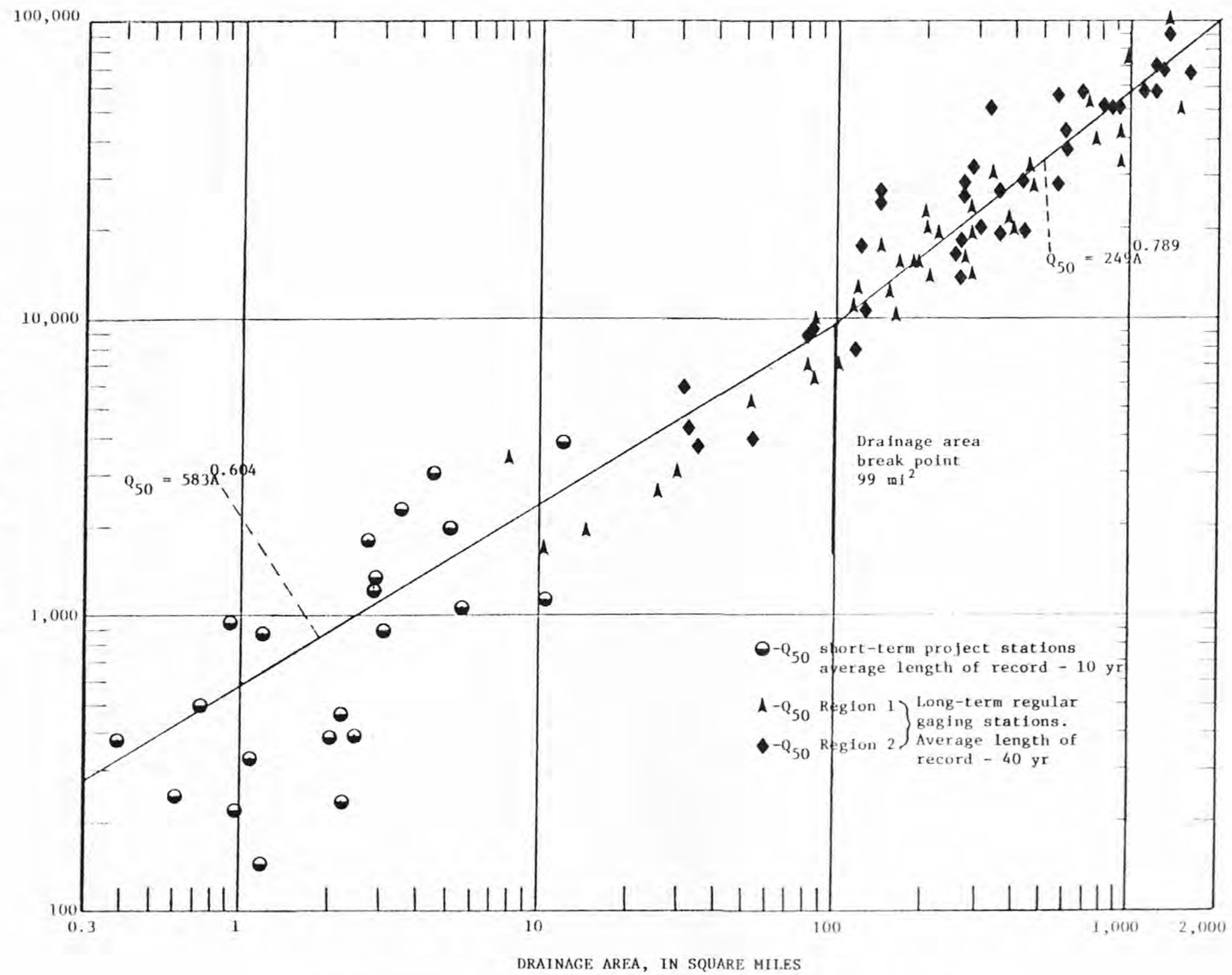

Figure 1.--Comparison of station Q_{50} to 50-year flood-frequency curve for Region 1

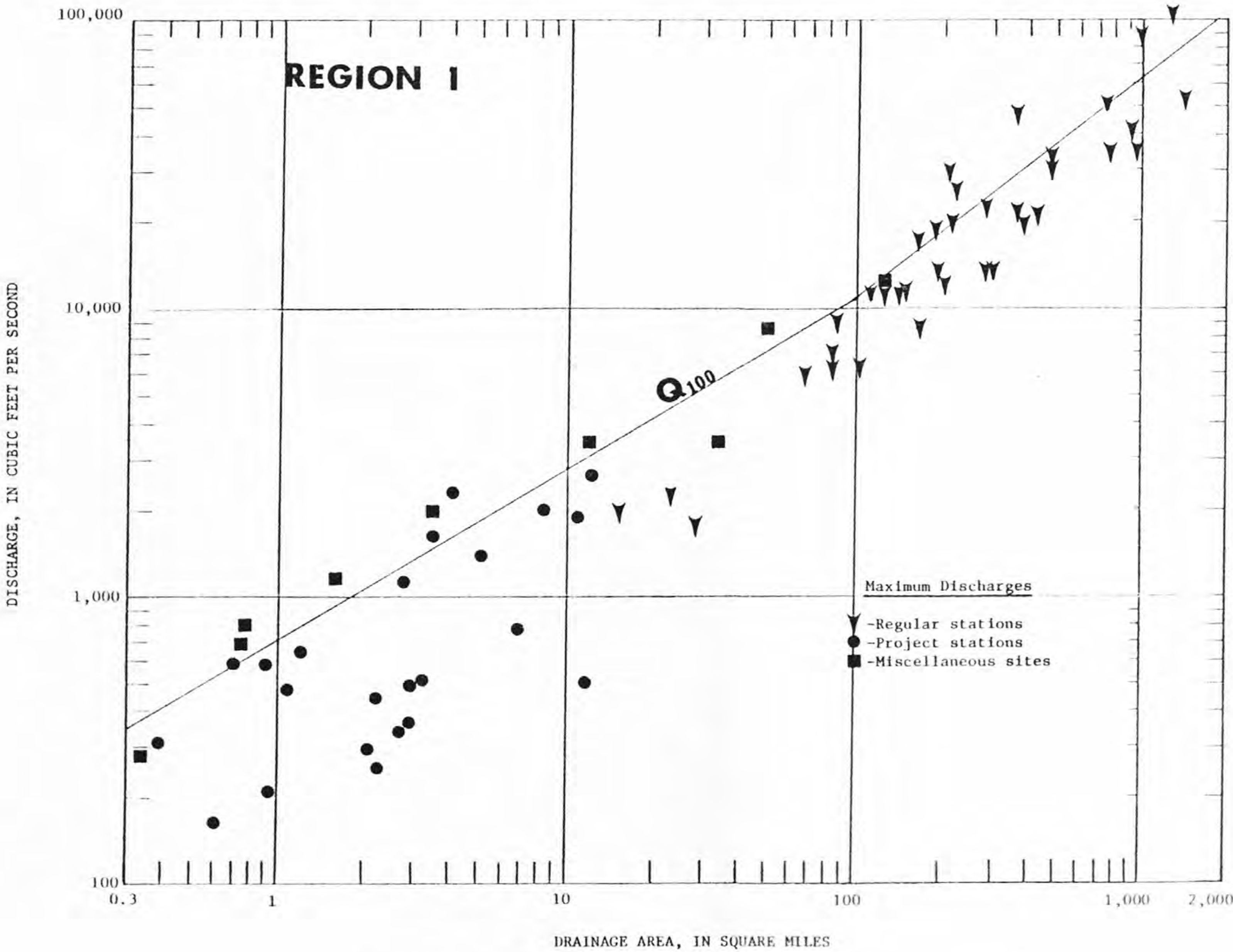

Figure 2.--Comparison of maximum station discharge to Q_{100} for Region 1

ACCURACY AND LIMITATIONS

Flood frequency estimates used in this study are based on peak discharge data through September 1977. These flood frequency values are probably the most reliable estimates of future peak discharges at these gaged sites, if basin characteristics remain fairly constant. All small stream stations installed for this research project were discontinued at the end of the study.

The standard error of estimate is a measure of how well the flood peaks, as determined by station frequency analysis of the observed and simulated annual peak discharge, compared with those computed using the estimating equations. About two-thirds of the station flood-frequency values should fall within one standard error of estimate and 19 out of 20 values should be within two standard errors of estimate. In this study it was noted that peak-discharge estimates could be made more reliably for the larger size drainage areas. When stations having less than 50 square miles of drainage area were added to the data set, the standard error of estimate increased.

Separate analyses were made for a range of drainage area sizes. In general, the division in drainage areas was above and below approximately 50 square miles in the Ohio River basin and above and below approximately 40 square miles in the Potomac River basin. To develop the lower section of the frequency curve, a comparison was made, of the estimating equations and standard errors, when all stations were used in the analysis against the results of using only stations having less than 50 square miles. The final results indicated that no loss of accuracy would occur by combining stations with large and small drainage areas in each region and using these equations to develop the lower section of the discharge versus drainage area curves for each frequency (figures 4-24). By combining stations it also assured that there would not be any discontinuous frequency curves. In all cases the combined station analysis gave a larger discharge value for a given frequency up to the drainage area where the curves are equal. The regression equations, average standard errors, and drainage area breakpoints for each region (see figure 3) for recurrence intervals 2 to 500 years are listed on following page.

The user of these data should note that there is no relation between the curves (figures 4-24) and the division of the stations into those with less than 50 square miles and those greater than 50 square miles in drainage area. The intersections for the curves were determined mathematically; therefore, each graph has a different drainage area break point and will not necessarily fall at 50 square miles.

List of Estimating Equations, Standard Errors, and Drainage Area Break Points

Recurrence Interval yrs.	Estimating Equation (All stations)	Standard Error	Drainage Area Break Point	Estimating Equation (long-term stations)	Standard Error
		Region 1			
2	$131 A^{0.734}$	37	160	$74 A^{0.847}$	25
5	$235 A^{0.683}$	37	125	$115 A^{0.831}$	25
10	$324 A^{0.655}$	37	116	$149 A^{0.818}$	27
25	$461 A^{0.625}$	39	106	$203 A^{0.801}$	29
50	$583 A^{0.604}$	40	99	$249 A^{0.789}$	32
100	$724 A^{0.586}$	42	95	$303 A^{0.777}$	35
500	$1137 A^{0.547}$	46	84	$462 A^{0.750}$	41
		Region 2			
2	$85 A^{0.830}$	43	--	--	
5	$148 A^{0.792}$	39	586	$115 A^{0.831}$	25
10	$201 A^{0.771}$	38	549	$149 A^{0.818}$	27
25	$282 A^{0.748}$	40	485	$203 A^{0.801}$	29
50	$354 A^{0.733}$	41	529	$249 A^{0.789}$	32
100	$437 A^{0.719}$	44	530	$303 A^{0.777}$	35
500	$679 A^{0.689}$	50	552	$462 A^{0.750}$	41
		Region 3			
2	$74 A^{0.774}$	39	18.4	$68 A^{0.803}$	29
5	$141 A^{0.762}$	32	77.8	$98 A^{0.845}$	27
10	$203 A^{0.754}$	33	93.2	$122 A^{0.866}$	29
25	$303 A^{0.747}$	38	100	$159 A^{0.887}$	34
50	$397 A^{0.743}$	43	106	$191 A^{0.899}$	38
100	$511 A^{0.740}$	50	116	$228 A^{0.910}$	42
500	$556 A^{0.831}$	54	162	$335 A^{0.930}$	53

EXAMPLE

Region 1 - Q_{50}

The regression equation for Q_{50} using only the larger drainage area stations (>50 square miles):

$$Q_{50} = 249\ A^{0.789} \quad \text{(figure 8)}$$

The regression equation for Q_{50} when all stations for the region are included in the analysis is:

$$Q_{50} = 583\ A^{0.604}$$

At what point (drainage area) are these equations equal?

$$249\ A^{0.789} = 583\ A^{0.604}$$

$$\log 249 + .789 \log A = \log 583 + .604 \log A$$

$$0.185 \log A = .3694$$

$$\log A = 1.99675$$

$$A = 99.3 \text{ square miles}$$

In this example the equations will give the same Q_{50} for a drainage area of 99.3 square miles (9,371 ft^3/s). Note that there is one case where the "break point" did not occur within our range of drainage areas of 0.3 to 2,000 square miles (Q_2 - Region 2). In this case, we show the equation that produces the larger discharge.

The graphs and equations presented in this report should not be used to estimate peak flows for sites draining urban basins, areas with significant regulation, karst terrain areas, or where drainage areas are less than 0.3 square mile or greater than 2,000 square miles.

ESTIMATING TECHNIQUE

The magnitude of floods of T-year frequency on unregulated streams in West Virginia may be estimated using the graphs provided or the equations on each graph of the form:

$$\text{(1) Average } Q_{T_{(i)}} = aA^{b}$$

where:

$Q_{(T)}$ = the T-year annual peak discharge, in cubic feet per second

T = recurrence interval of 2, 5, 10, 25, 50, 100, or 500 years.

i = appropriate state region (see figure 3)

A = drainage area in square miles

a = regression constant

b = regression coefficient

Drainage area should be determined from the best available maps. These are usually either the 7½-minute or 15-minute series of the U.S. Geological Survey topographic quadrangle maps.

In addition, discharge values for:

$$\text{(2) } Q_{T_{(i)}} + 1 \text{ SE (standard error of estimate)}$$

and

$$\text{(3) } Q_{T_{(i)}} + 2 \text{ SE}$$

are shown on each graph (figures 4-24). The user of these curves and equations should realize that there is also a negative standard error associated with the mean curves. In this study only positive values are shown.

SAMPLE COMPUTATION

Assume it is desired to compute the 50-year discharge for Tug Fork at Welch, W. Va. The site is located in Region 2 (see figure 3, page 23).

The drainage area as determined from topographic maps is 87.8 square miles.

Using the equation on figure 15, page 35, or the equation and standard error on page 16, for Q_{50} to be used up to a drainage area size of 529 square miles.

(1) $Q_{50} = 354\ A^{0.733}$

$Q_{50} = 354 \times 87.8^{0.733}$

$Q_{50} = 9410\ ft^3/s\ (266\ m^3/s)$

(2) $Q_{50} + 1\ SE = 9410\ (1.41) = 13300\ ft^3/s\ (377\ m^3/s)$

(3) $Q_{50} + 2\ SE = 9410\ (1.82 = 17100\ ft^3/s)\ (484\ m^3/s)$

or reading directly from graph

(1) $Q_{50} = 9400\ ft^3/s\ (269\ m^3/s)$

(2) $Q_{50} + 1\ SE = 13100\ ft^3/s\ (371\ m^3/s)$

(3) $Q_{50} + 2\ SE = 16700\ ft^3/s\ (473\ m^3/s)$

If the site in question was on the divide between Regions 1 and 2 and had a drainage area less than 50 square miles, it is suggested an averaging method be used to estimate peak discharge. The reasons for averaging at the divide between Regions 1 and 2 are; they are in the same major river drainage (Ohio River basin) and have similar hydrologic characteristics along the boundary. As an example, if the site was on the divide and had a drainage area of one square mile:

To estimate Q_{50} for 1 square mile:

Region 1 $Q_{50} = 583\ A^{0.604} = 583\ ft^3/s$

Region 2 $Q_{50} = 354\ A^{0.733} = 354\ ft^3/s$

The average estimated Q_{50} for Regions 1 and 2 would be about 470 ft^3/s. Unless the user had specific information about the site in question, the estimated Q_{50} should be used. This averaging method should not be used between Regions 1 and 3 because of the different hydrologic characteristics.

Note: If the drainage area in the example had been greater than 529 square miles, we would have used the equation for that section of the Q_{50} curve ($Q_{50} = 249\ A^{0.789}$) as shown on figure 15 and listed on page 16.

On this graph, at 529 square miles either equation could be used to compute peak discharge. The user is reminded that each graph presented in this report has a definite flex point where the equations will provide equal discharge.

SUMMARY

Prior to 1963 small-stream flood data was nonexistent in West Virginia. The U.S. Geological Survey in cooperation with the West Virginia Department of Highways and the Federal Highway Administration began a small-streams research project to develop a method to estimate flood magnitudes and frequencies. The equations and curves in this report are the result of that research project.

The State has been divided into three regions, each with a set of estimating equations. The equations were developed to estimate flood magnitudes at ungaged sites in West Virginia for recurrence intervals of 2 to 500 years. The equations relate flood magnitudes to size of drainage area and apply to streams that are not affected significantly by urbanization, regulation, or diversion.

In general the report combines two frequency studies. One study on the regular stream-gaging network with generally long records and a second analysis on a combination of the small drainage area, short record project stations and the regular stations.

Standard errors range from 25 to 54 percent for the long-term stations and 37 to 54 percent for the combination of stations.

The user of the equations in this report should realize that long-term records close to an ungaged site could provide a more reliable estimate than the regression equation.

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Figure 3.--Geographic Regions 1 and 2, Ohio River basin
Region 3, Potomac River basin

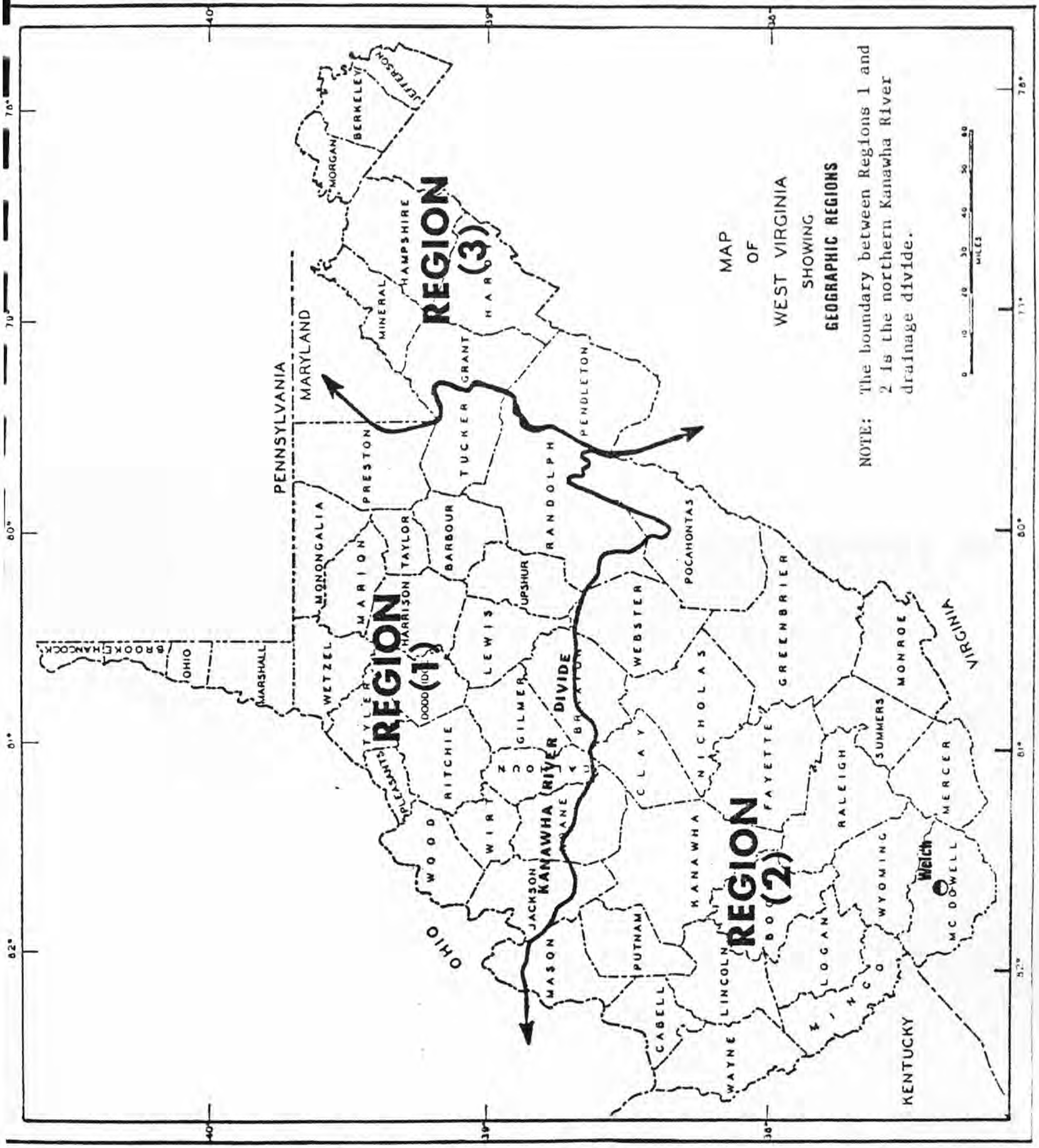

Figure 4.--Relation of 2-year peak discharge to drainage area, Region 1.

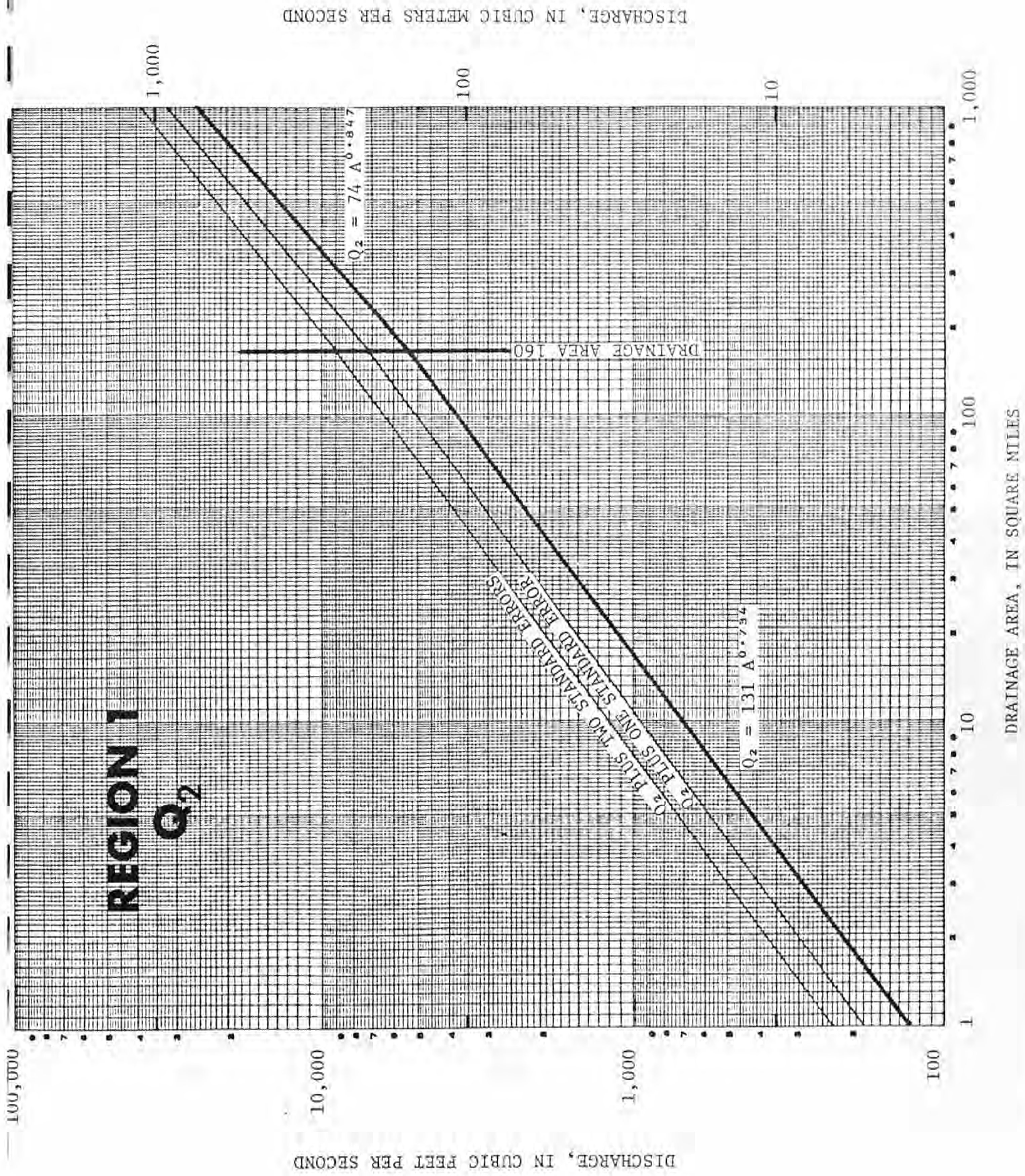

Figure 5.--Relation of 5-year peak discharge to drainage area, Region 1.

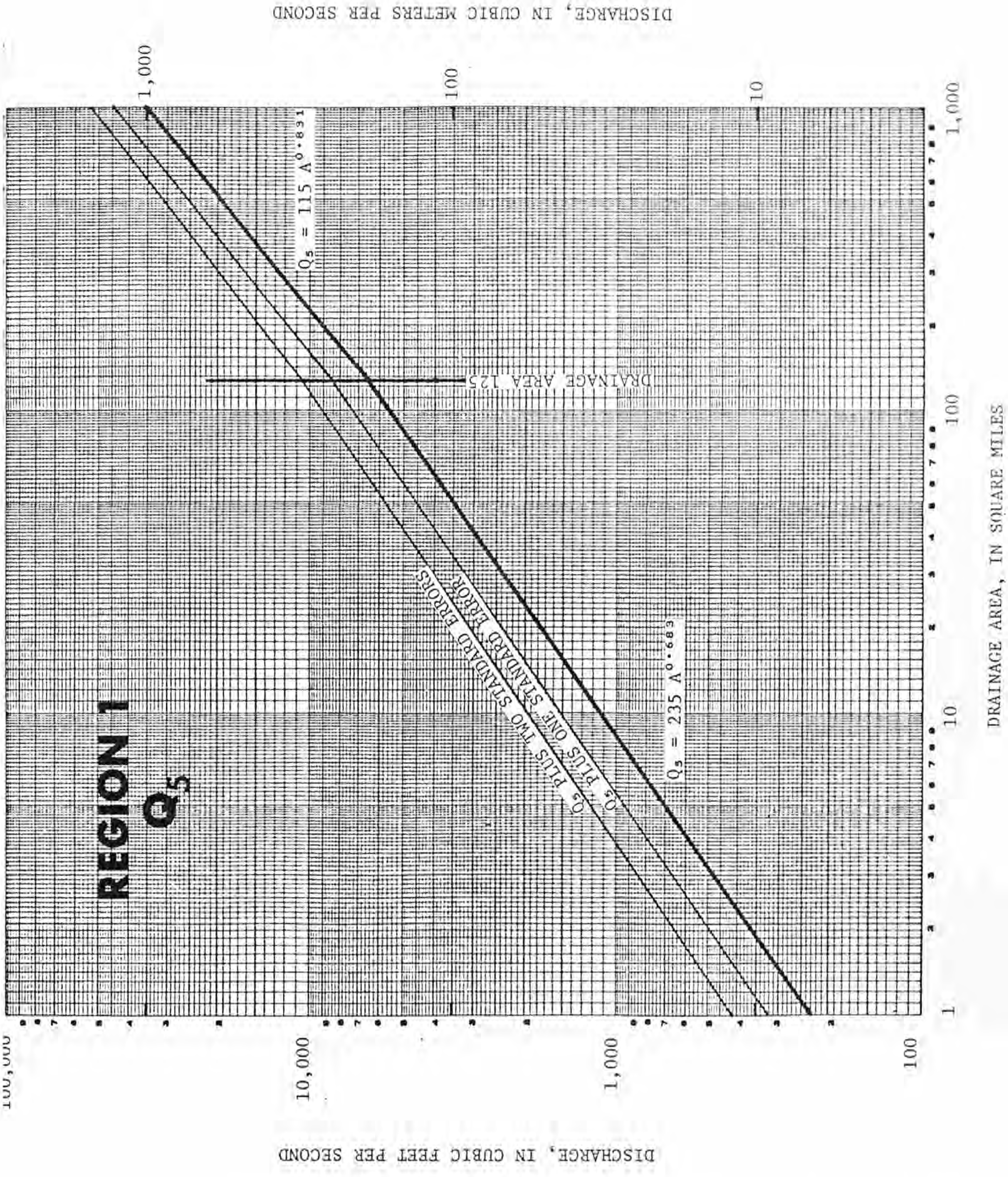

Figure 6.--Relation of 10-year peak discharge to drainage area, Region 1.

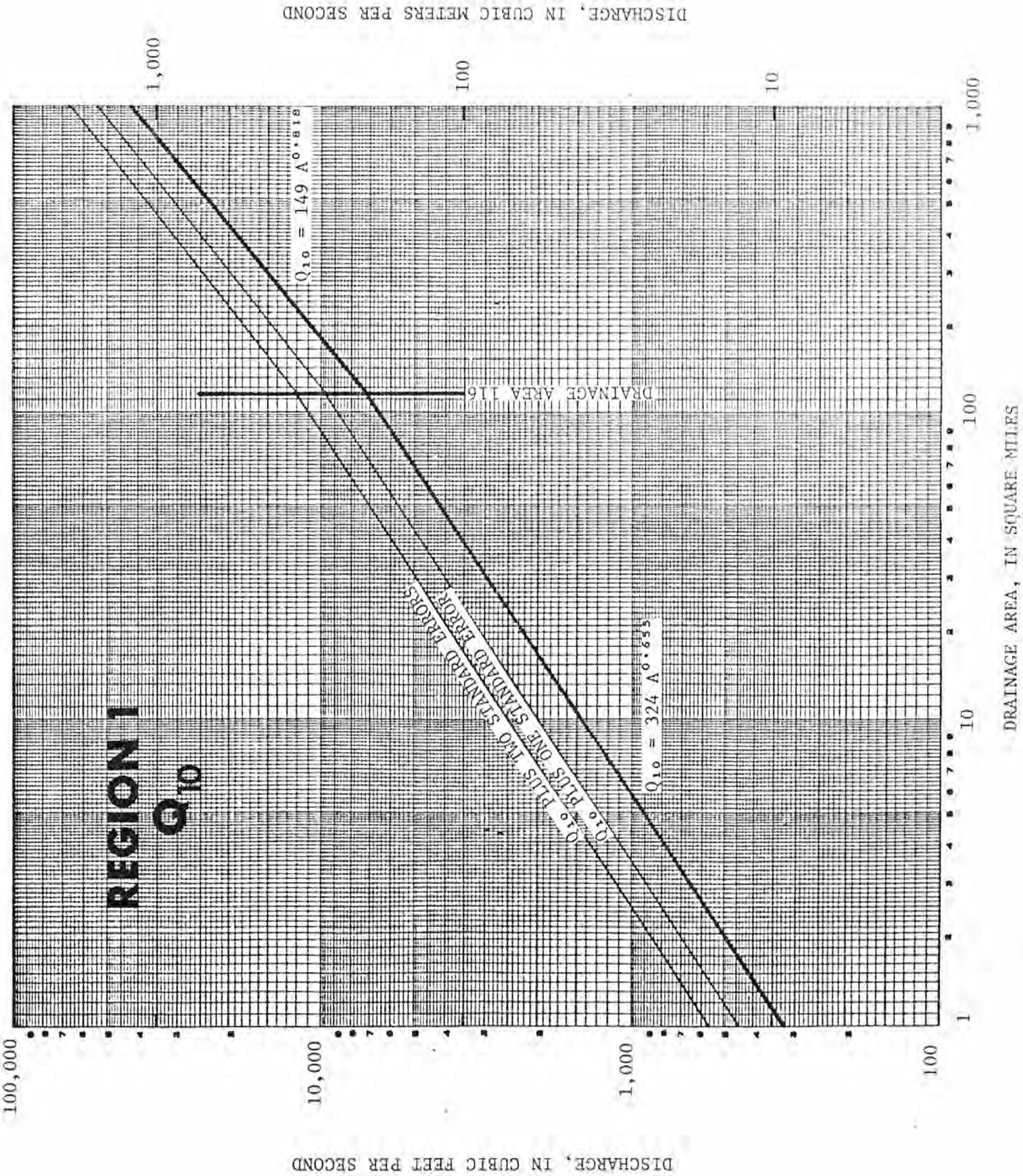

Figure 7.--Relation of 25-year peak discharge to drainage area, Region 1.

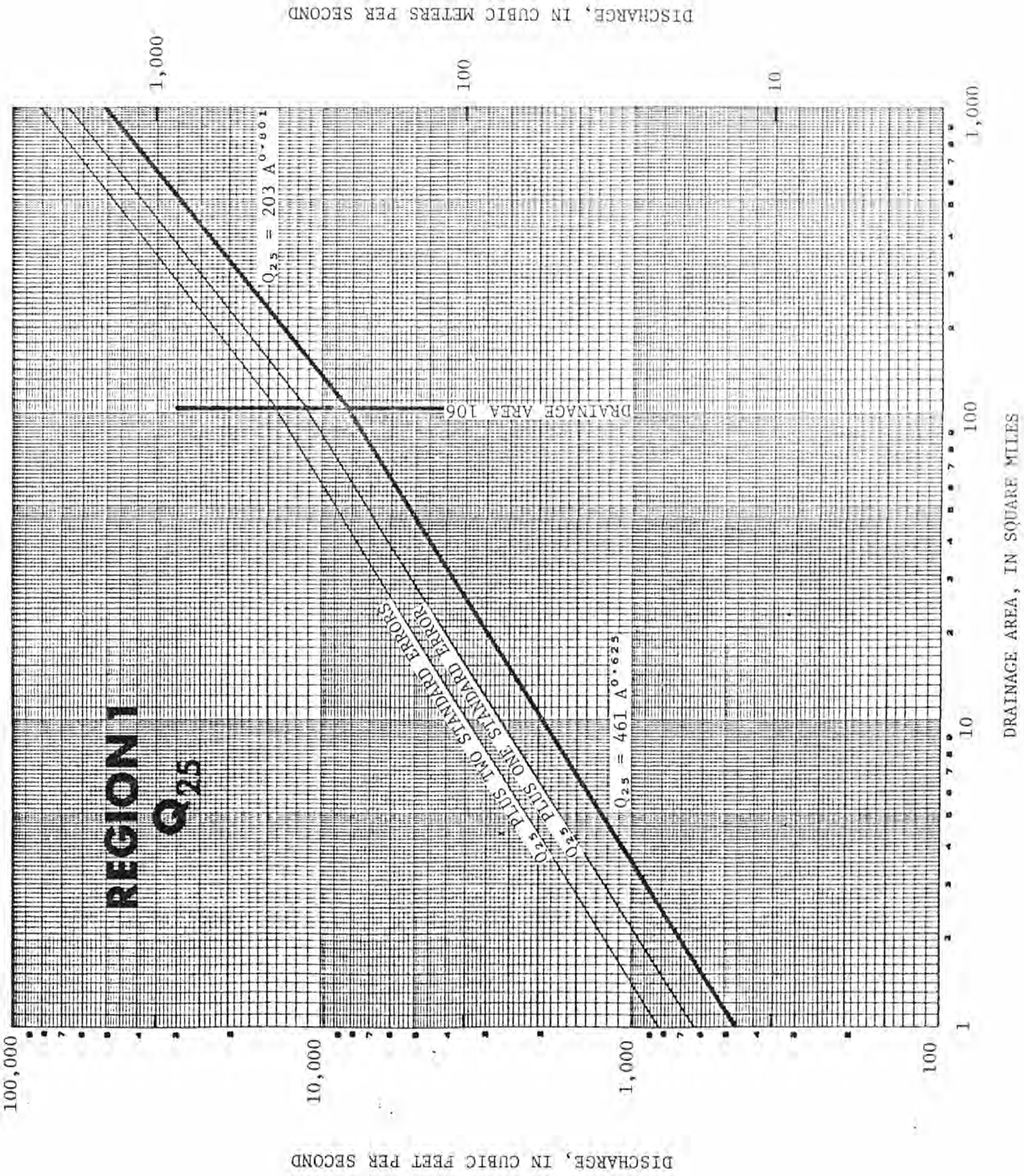

Figure 8.--Relation of 50-year peak discharge to drainage area, Region 1.

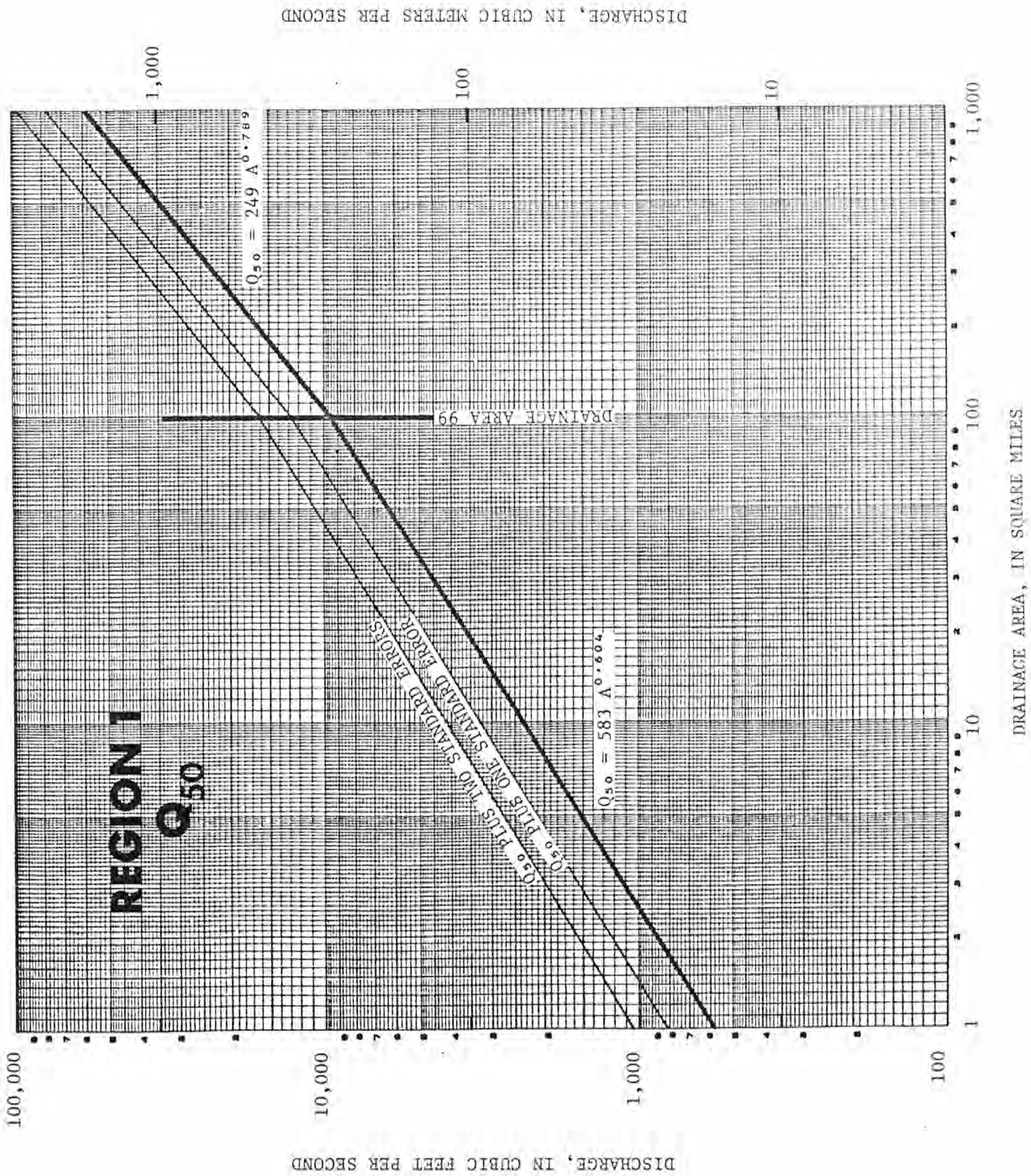

Figure 9.--Relation of 100-year peak discharge to drainage area, Region 1.

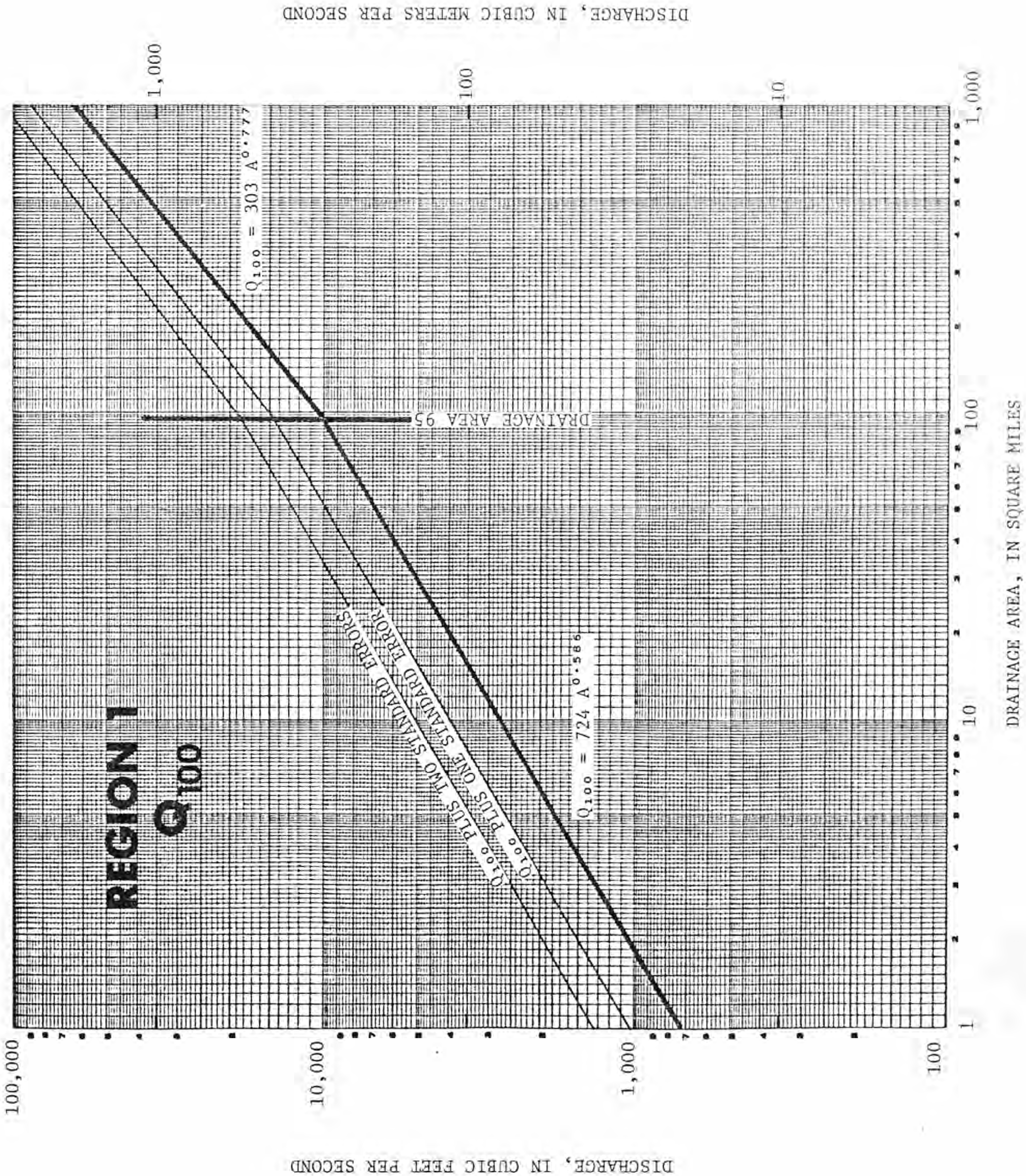

Figure 10--Relation of 500-year peak discharge to drainage area, Region 1.

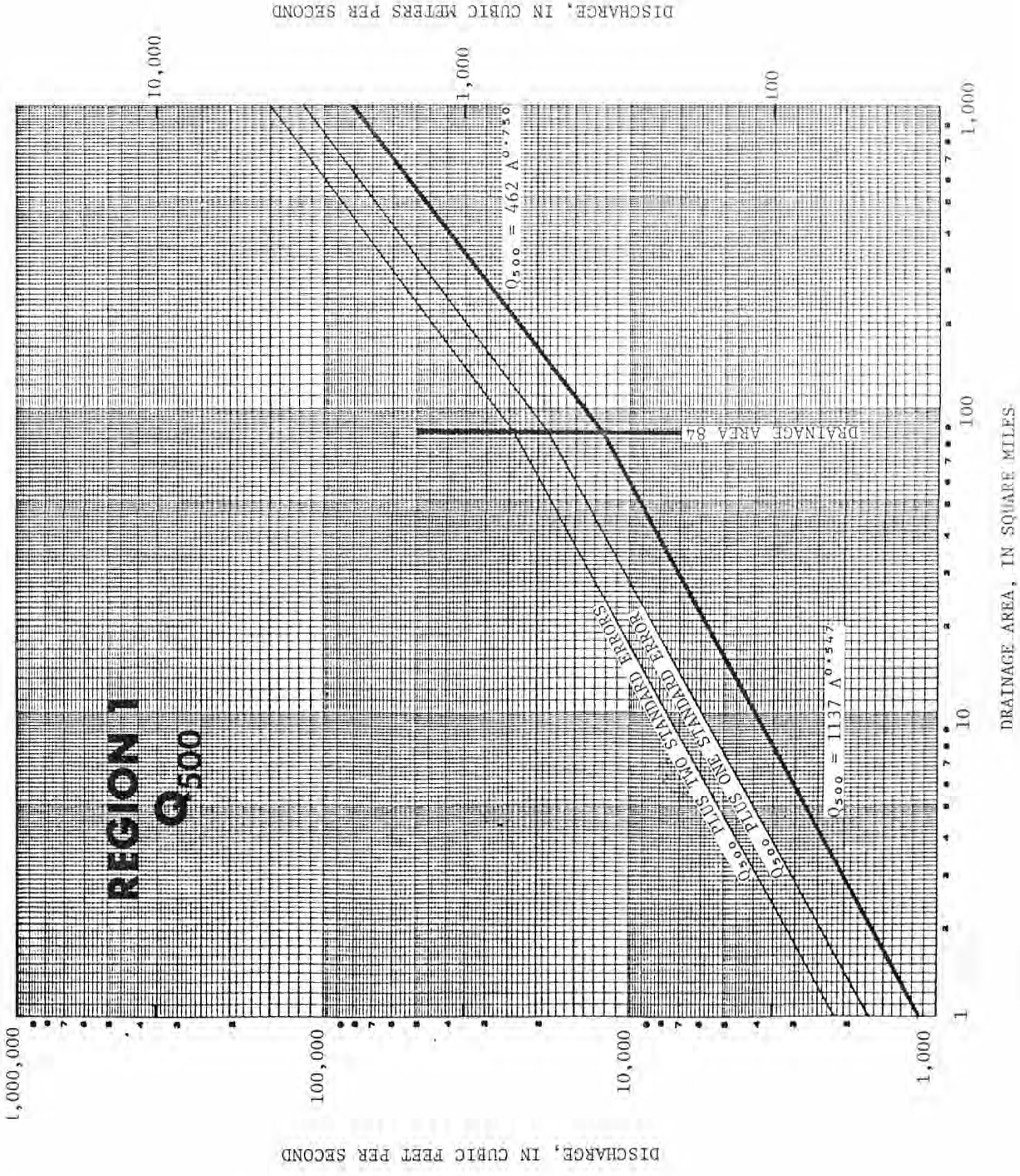

Figure 11.--Relation of 2-year discharge to drainage area, Region 2.

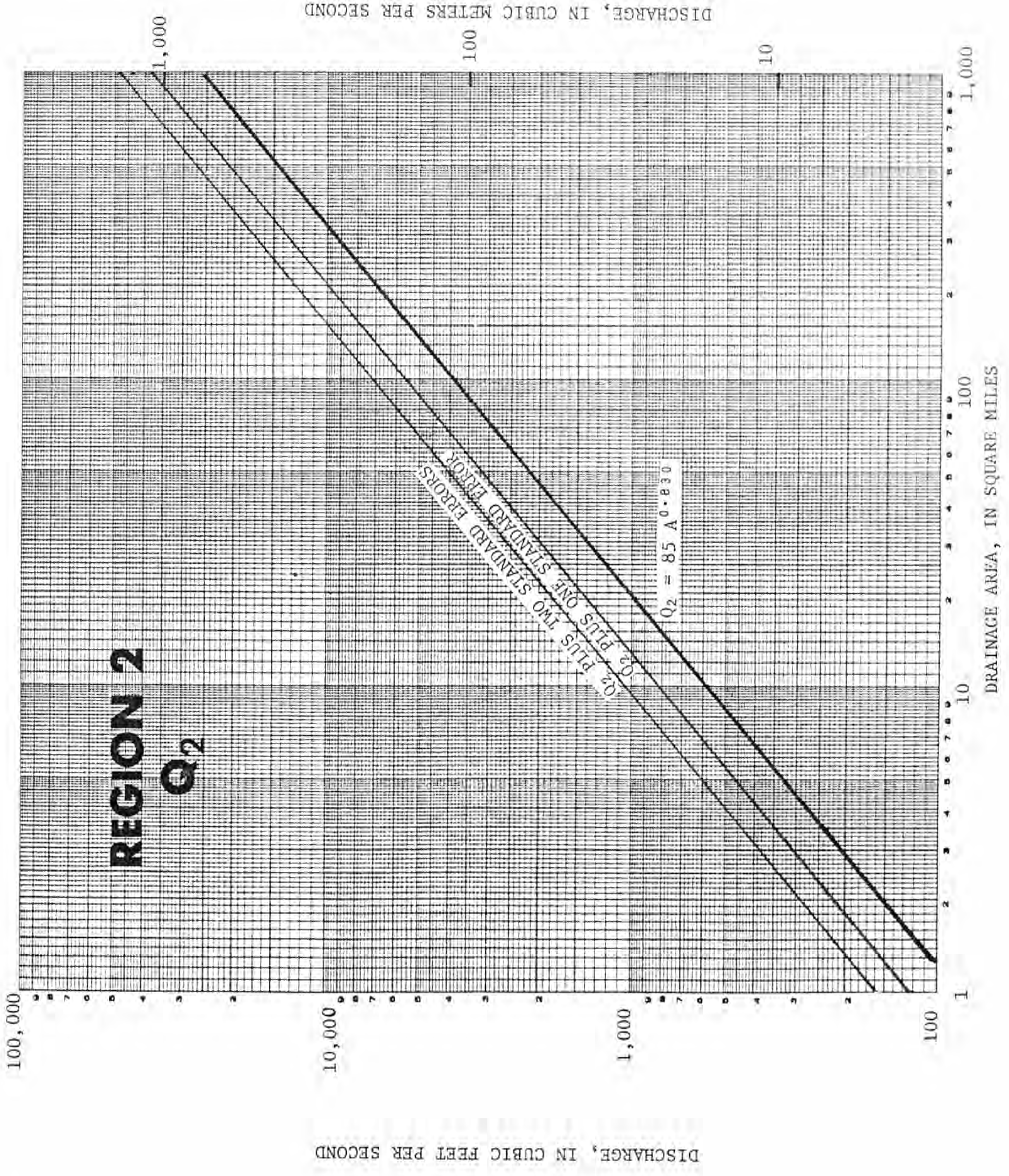

Figure 12.--Relation of 5-year peak discharge to drainage area, Region 2.

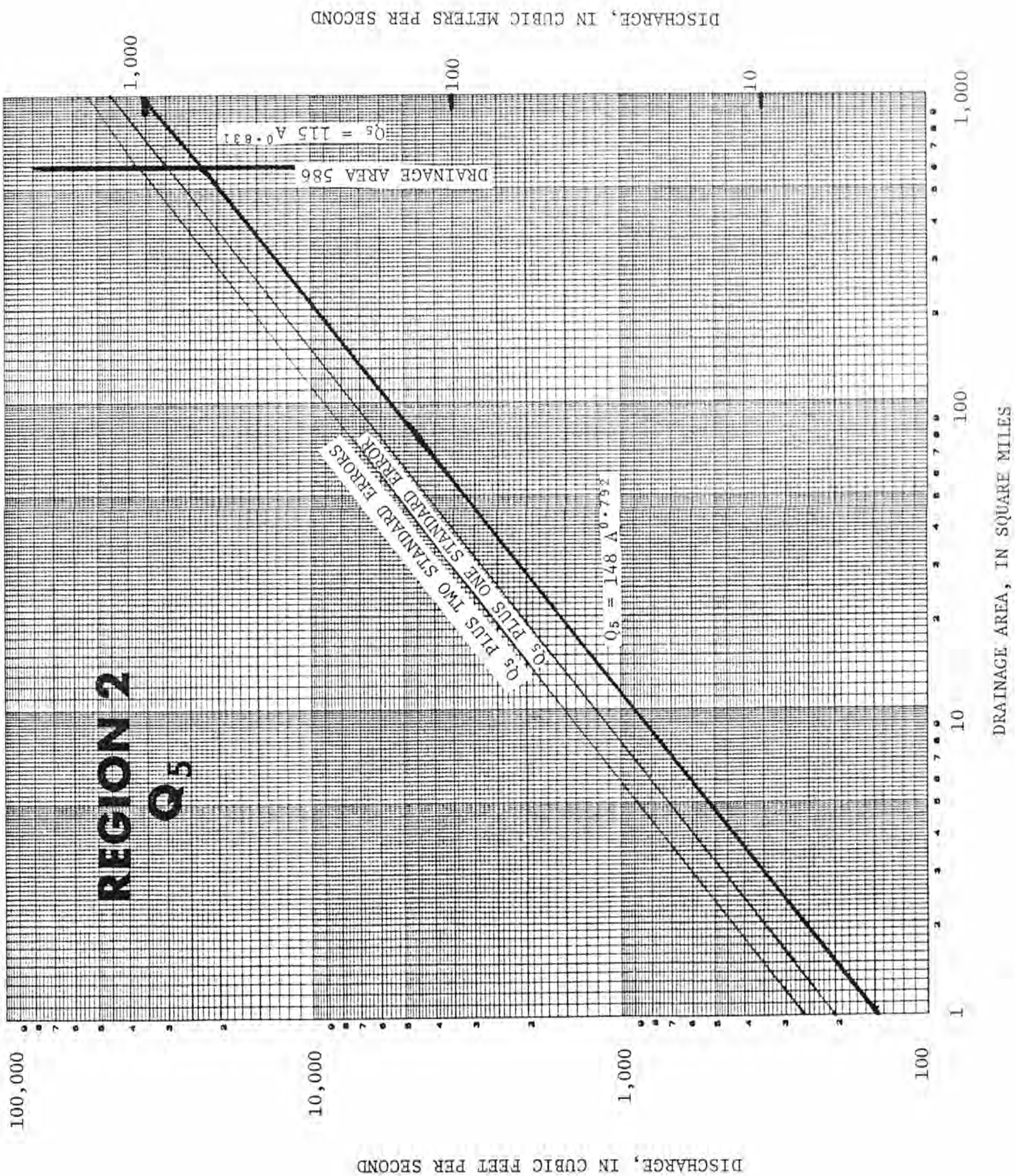

Figure 13.--Relation of 10-year peak discharge to drainage area, Region 2.

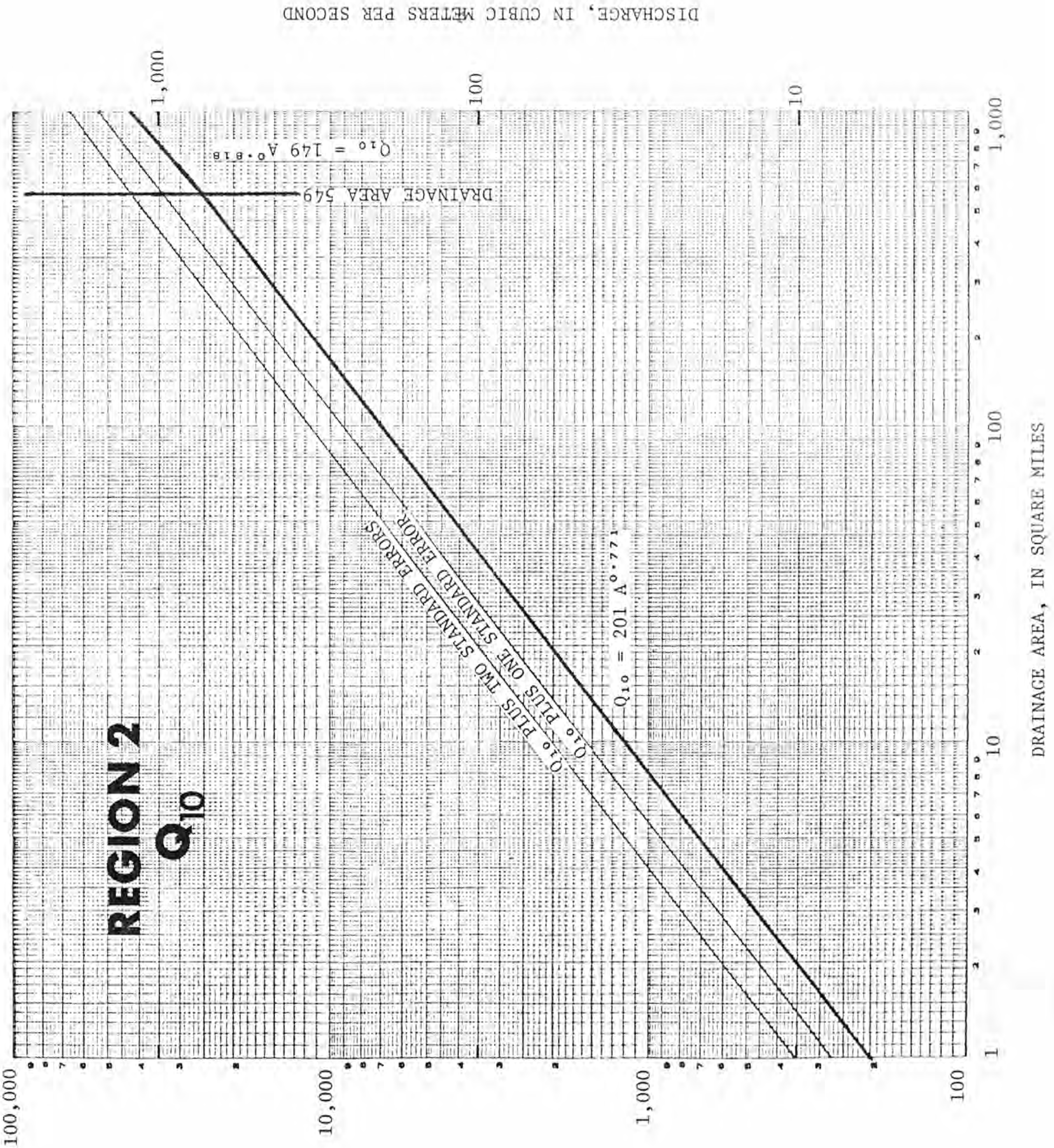

Figure 14.--Relation of 25-year peak discharge to drainage area, Region 2.

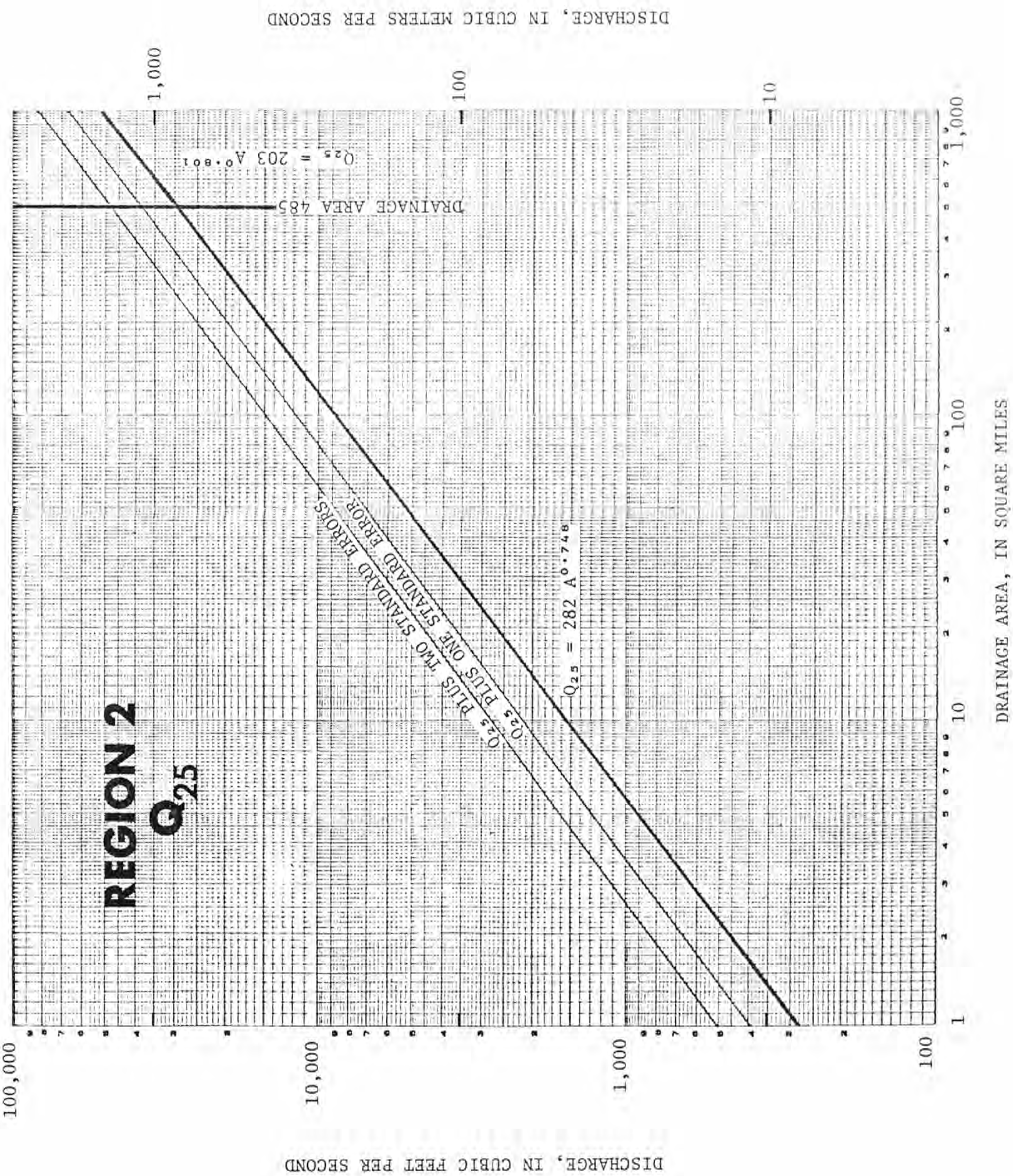

Figure 15.--Relation of 50-year peak discharge to drainage area, Region 2.

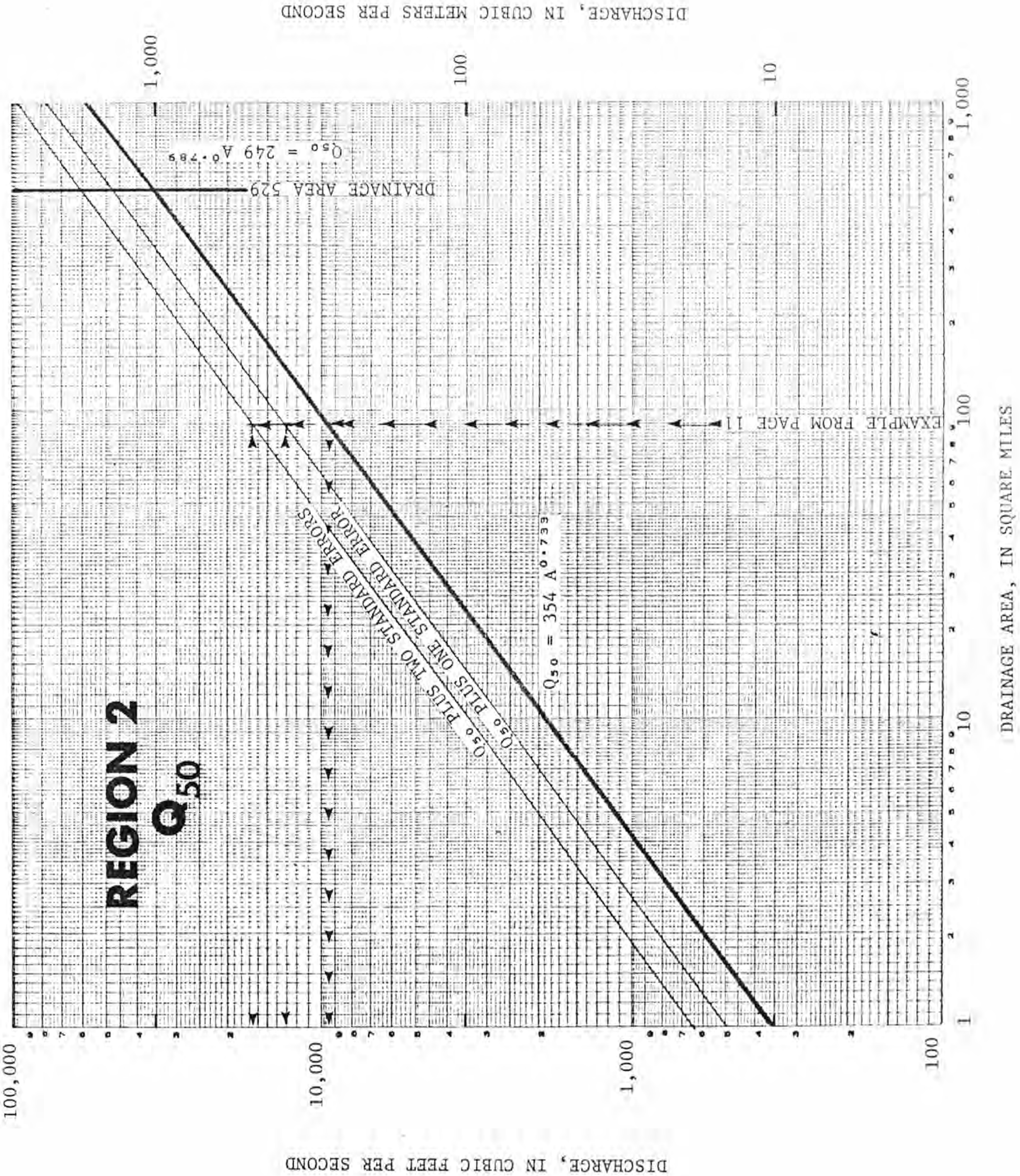

Figure 16.--Relation of 100-year peak discharge to drainage area, Region 2.

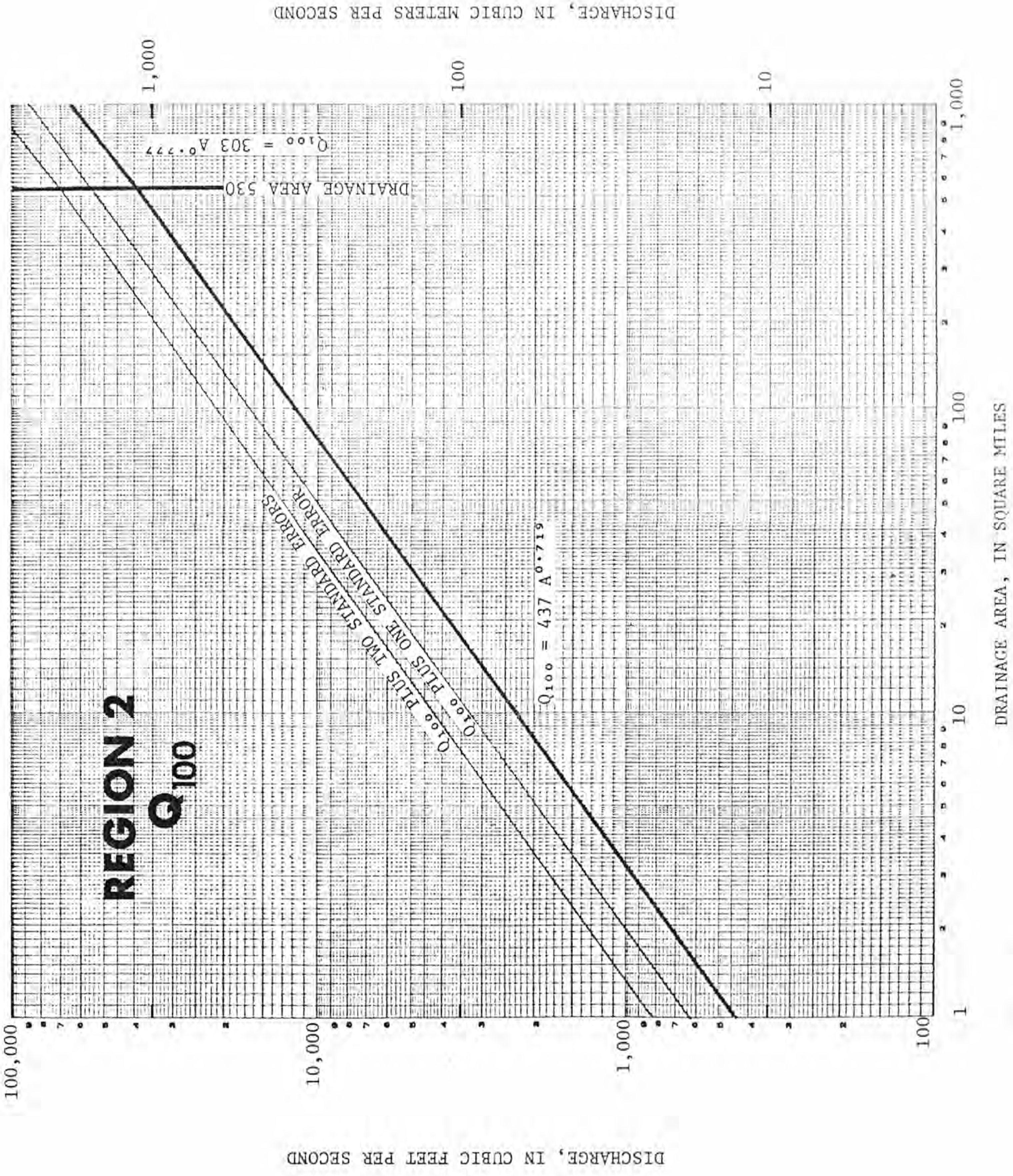

Figure 17.--Relation of 500-year peak discharge to drainage area, Region 2.

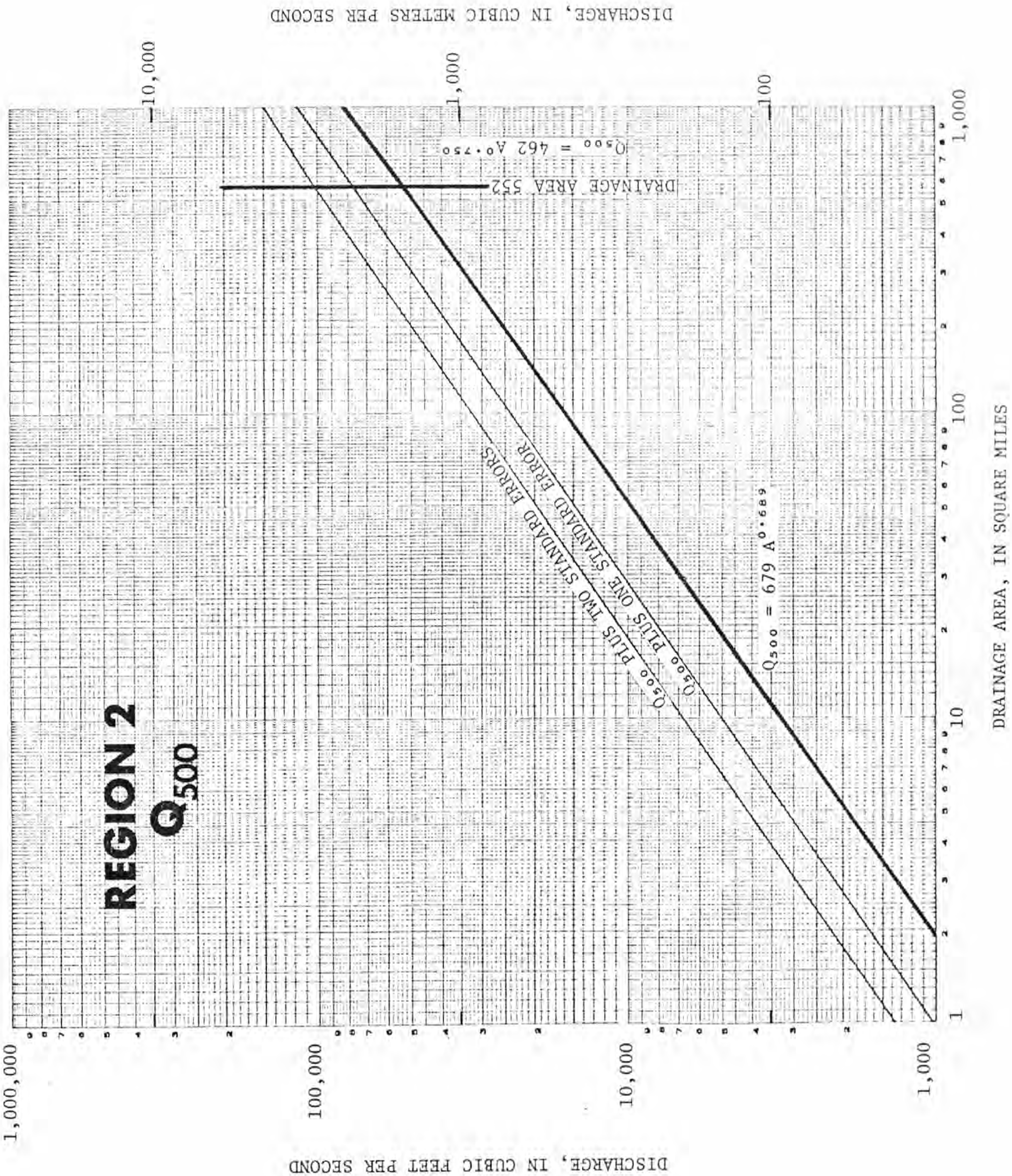

Figure 18.--Relation of 2-year peak discharge to drainage area, Region 3.

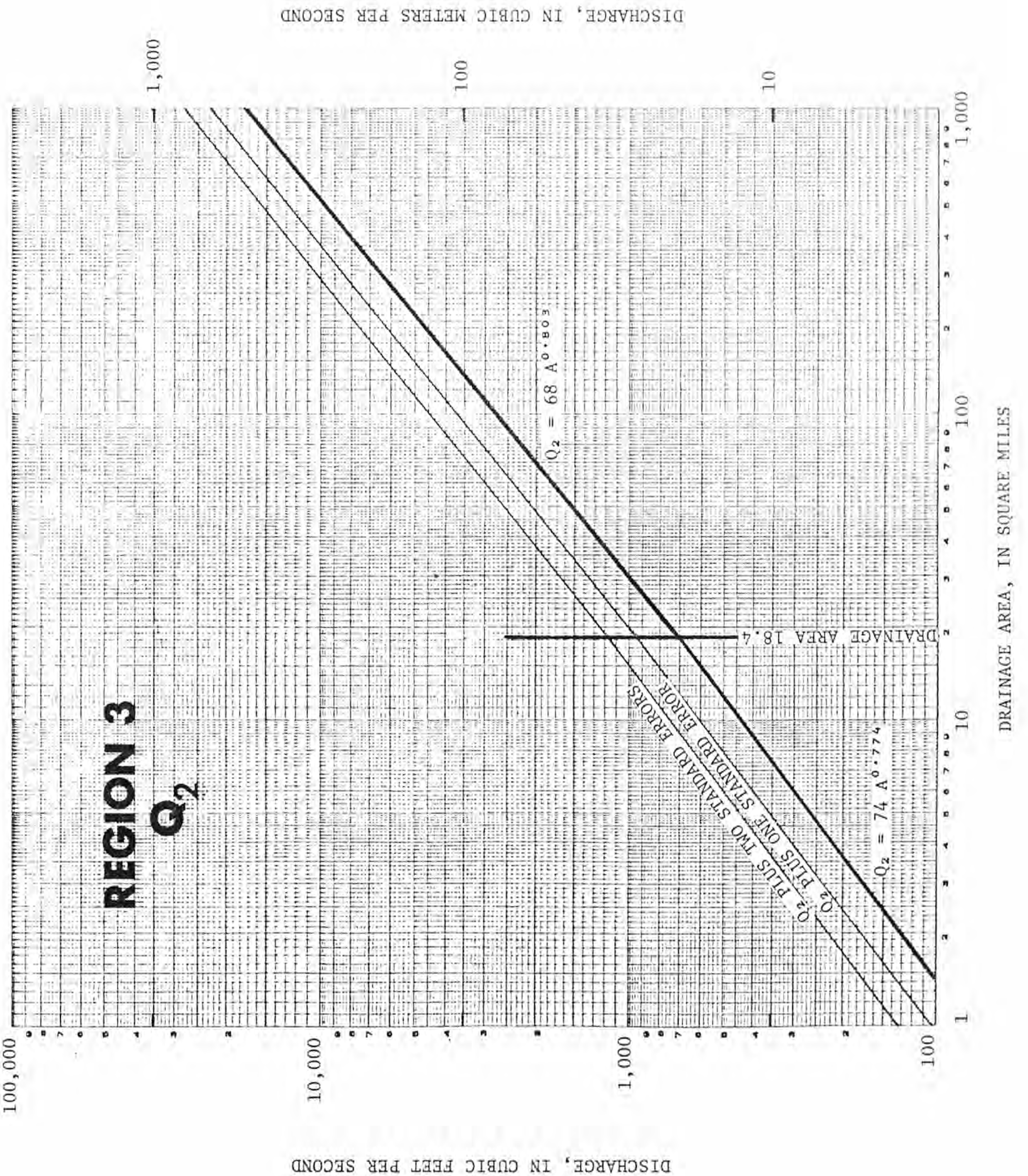

Figure 19.--Relation of 5-year peak discharge to drainage area, Region 3.

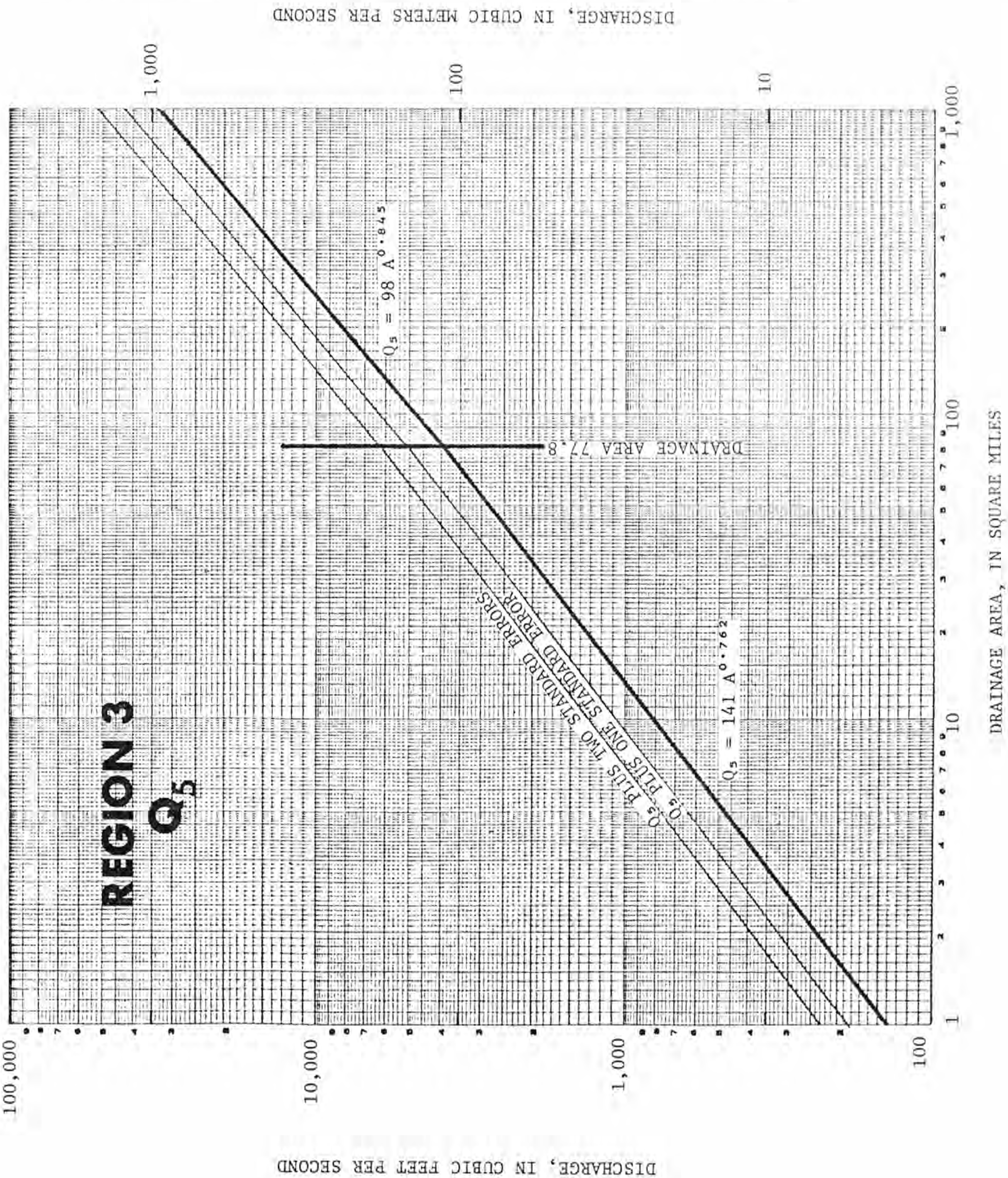

Figure 20.--Relation of 10-year peak discharge to drainage area, Region 3.

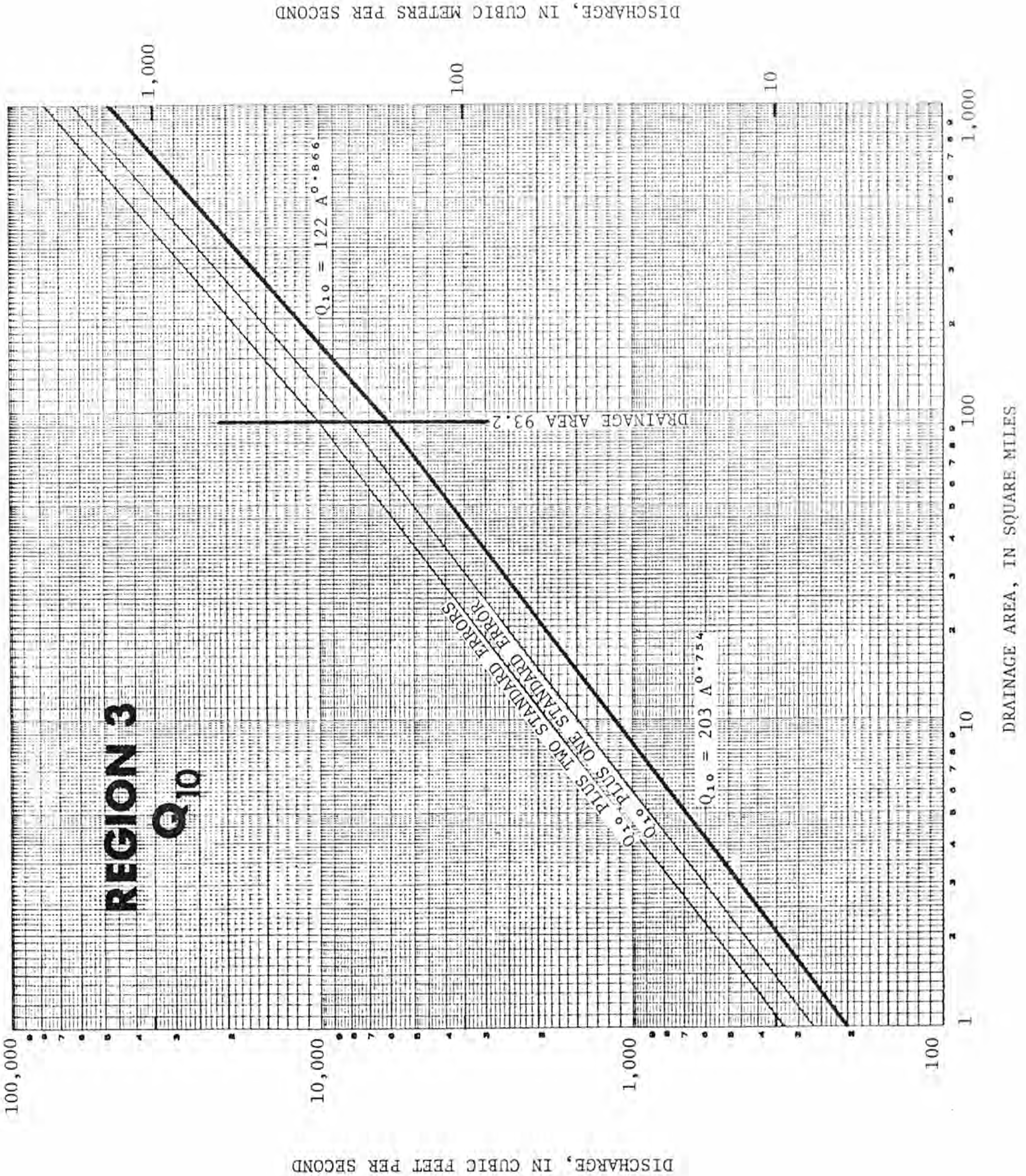

Figure 21.--Relation of 25-year peak discharge to drainage area, Region 3.

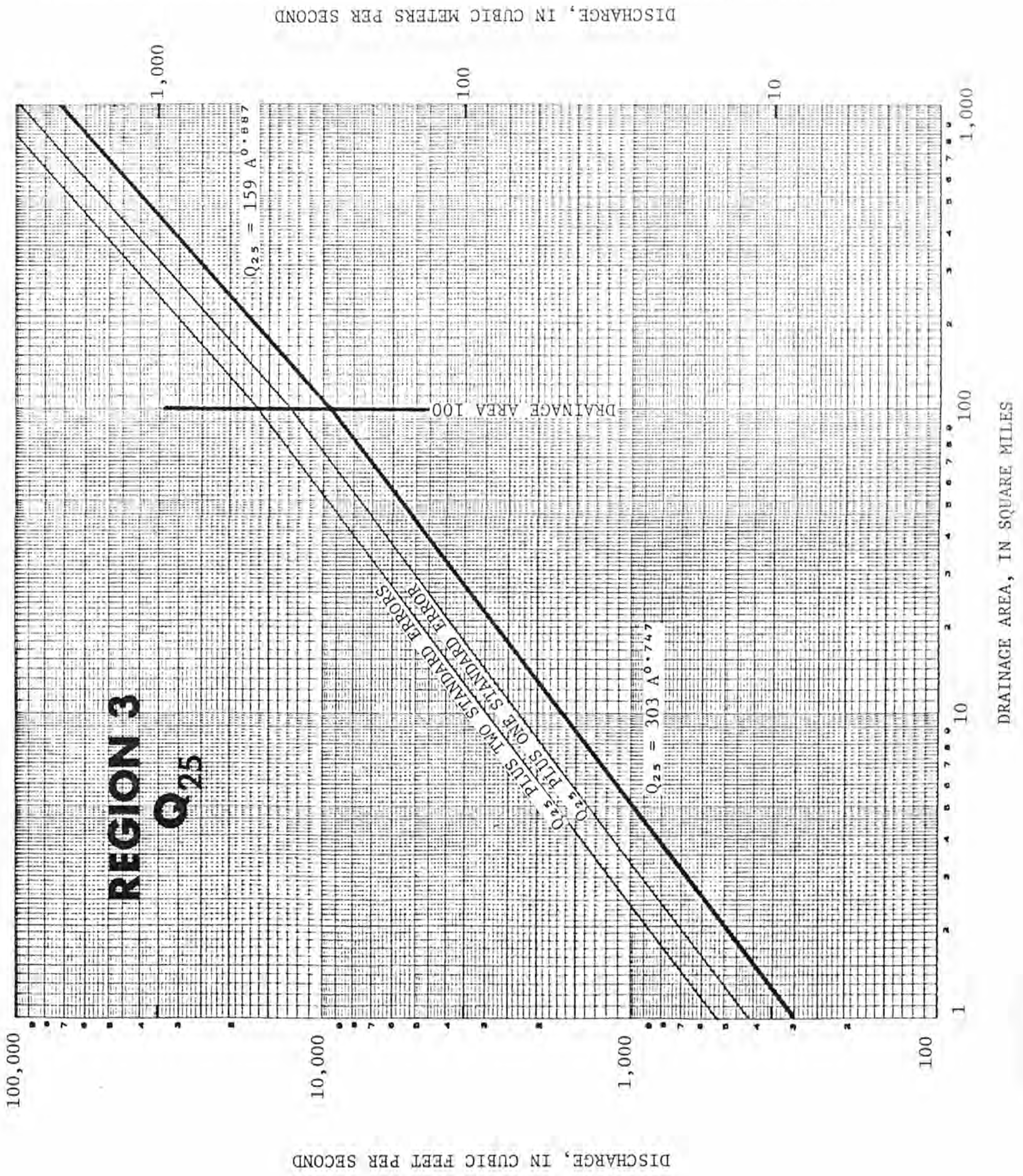

Figure 22.--Relation of 50-year peak discharge to drainage area, Region 3.

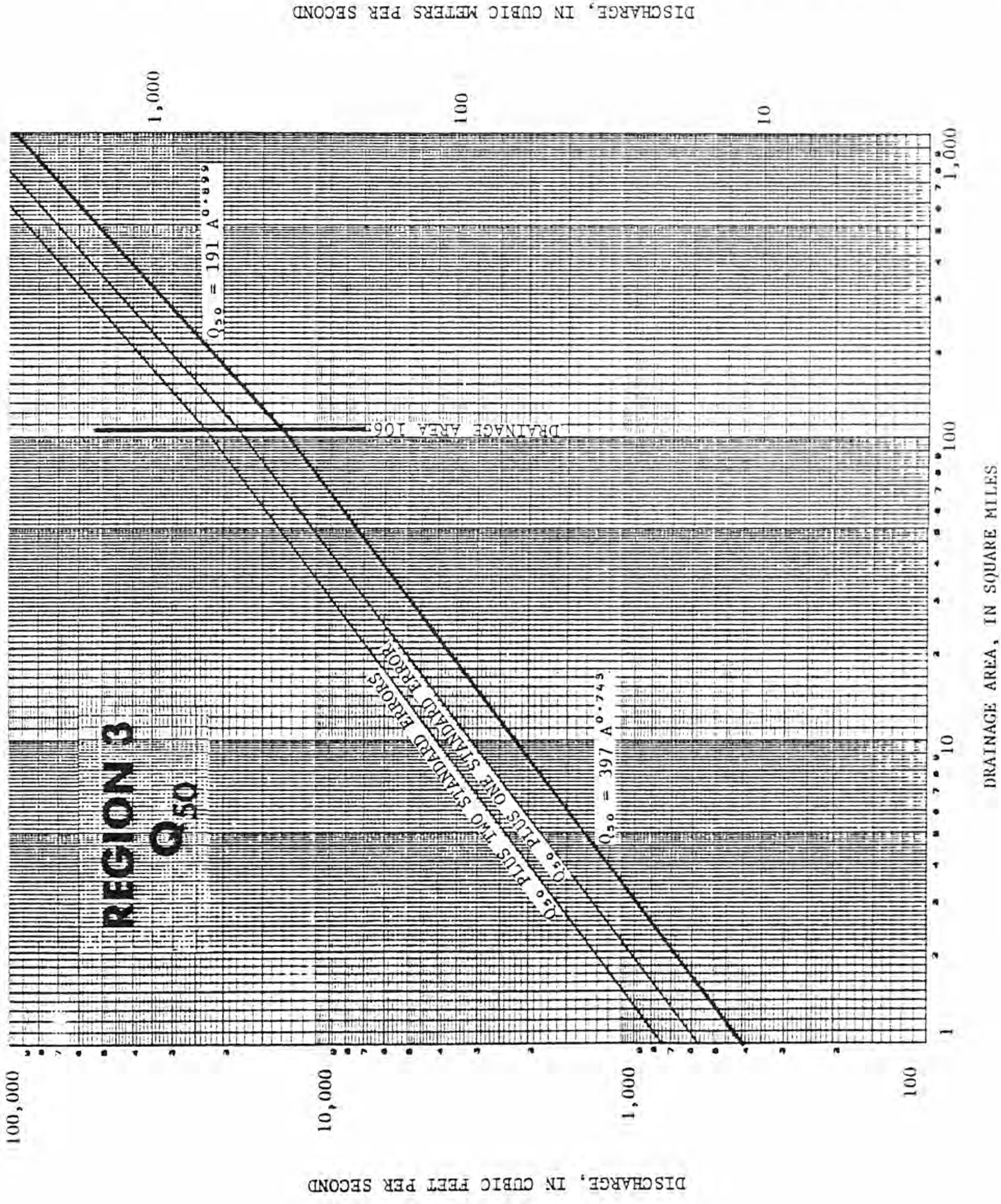

Figure 23.--Relation of 100-year peak discharge to drainage area, Region 3.

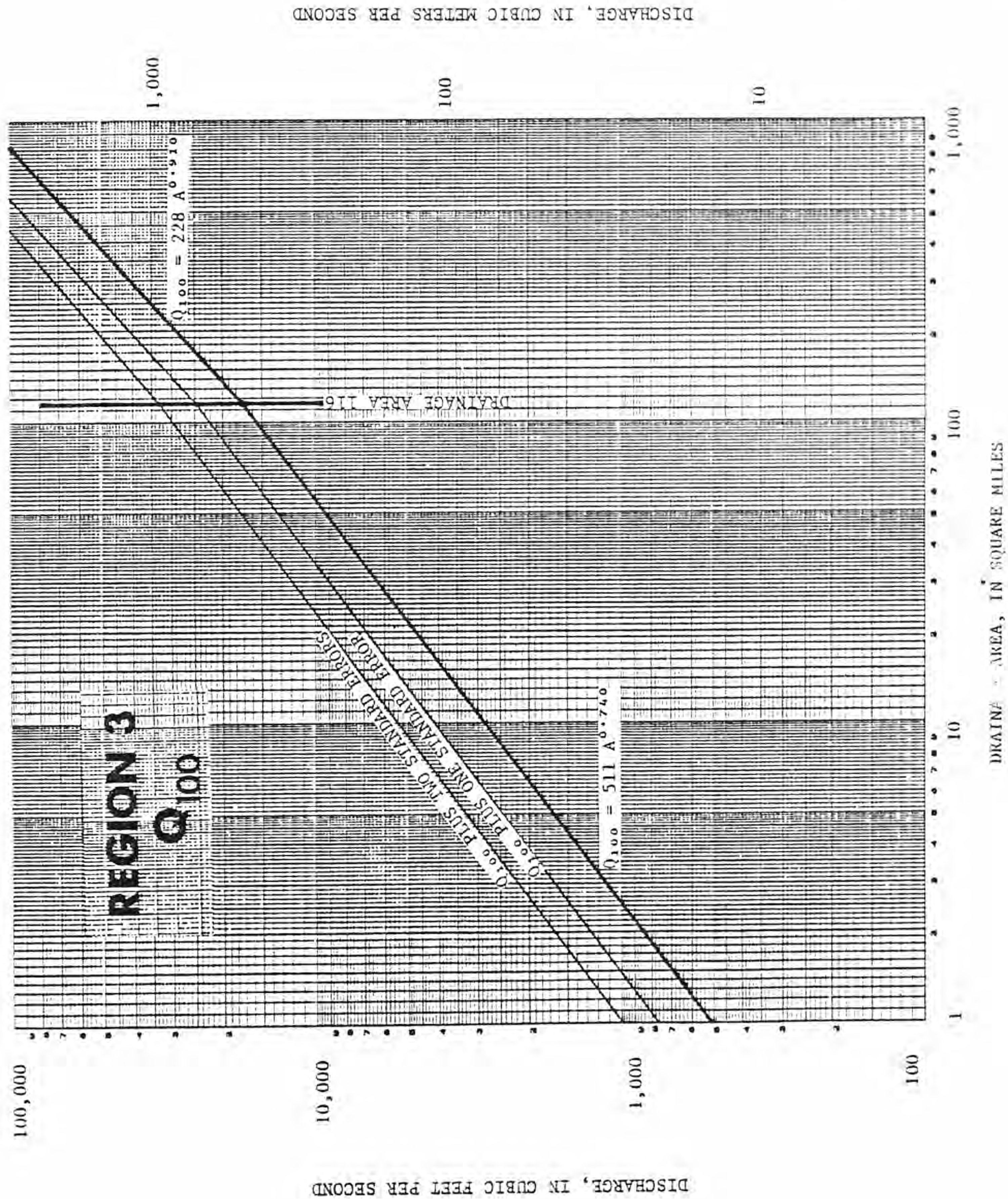

Figure 24.--Relation of 500-year peak discharge to drainage area, Region 3.