FLOODS IN KANSAS AND TECHNIQUES FOR ESTIMATING THEIR MAGNITUDE AND FREQUENCY ON UNREGULATED STREAMS

By R. W. Clement

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4008

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ERRATA

Floods in Kansas.and Techniques for Estimating Their Magnitude

and Frequency on Unregulated Streams, by R. W. Clement

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Page 34 (7 lines from the bottom) should read:

... basin shape (Sh), which is equal to the square of the main-channel length divided by the contributing-drainage area (CDA) ... .

Page 40 (fifteenth line in second paragraph) should read:

The dimensionless basin shape (SH) is equal to the square of the main-channel length, in miles, divided by the size of the contributing-drainage area (CDA), in square miles.

Page 50 (footnote number 3) should read as follows:

[3] Shape (Sh) - a dimensionless shape factor, which is the ratio of the square of the main-channel length to the contributing-drainage area (CDA), in square miles.

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Inch-pound units of measurement used in this report may be converted to metric (International System) units using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch	[1]25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
foot per mile	0.1894	meter per kilometer
inch per hour	[1]25.4	millimeter per hour
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

1 Exact conversion factor.

FLOODS IN KANSAS AND TECHNIQUES FOR ESTIMATING THEIR MAGNITUDE AND FREQUENCY ON UNREGULATED STREAMS

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ABSTRACT

Techniques are presented for generalizing the skewness coefficients of log-Pearson Type III distributions of annual maximum discharges and for flood magnitudes that have selected recurrence intervals from 2 to 100 years. A weighted least-squares (WLS) regression model was used to generalize the coefficients of station skewness that resulted in a root-mean-square error of prediction of 0.35 compared to 0.55 for the skewness map published in Bulletin 17B of the U.S. Water Resources Council. Estimates of generalized skewness were computed for each of 245 streamflow-gaging stations with a minimum of 10 years of record and a contributing-drainage area of less than 20,000 square miles. The WLS regression model also was used to develop equations for estimating flood magnitudes for selected recurrence intervals for ungaged stream locations by using data from 218 of the 245 streamflow-gaging stations that had contributing-drainage areas of less than 10,000 square miles. The errors of prediction of the most reliable WLS equations ranged from 28 to 42 percent. The WLS equations were compared statistically to previously developed equations and were determined to be different and more accurate than previously published equations.

Flood magnitudes and frequencies for 245 streamflow-gaging stations, based on data collected through the 1983 water year, are presented along with a summary of the seasonal distribution of annual maximum discharges and an analysis of the maximum observed discharges.

INTRODUCTION

There is a continuing need for flood-frequency data on Kansas streams. Information concerning magnitude and frequency of floods in rural areas is vital to the safe and economic design of transportation drainage structures, such as bridges and culverts, and flood-control structures, such as dams, levees, and floodways. Effective flood-plain management programs and flood-insurance rates also are based on the analysis of flood magnitude and frequency.

The study reported herein was conducted in cooperation with the Kansas Department of Transportation. Much of the data used in this study, especially that for many of the partial-record stations located on small streams, were collected by the U.S. Geological Survey as part of a cooperative program initiated with the Department in 1956.

Purpose and Scope

The purpose of this report is to present techniques that can be used to estimate the magnitude and frequency of floods on unregulated streams within the State. Presented are a summary of peak-discharge data used and descriptions of the techniques that contributed to the final results of the study. Annual peak-discharge data--recorded and synthesized--from 245 continuous- and partial-record streamflow-gaging stations located within the State formed the data base for the study.

The scope of the study included compiling peak-discharge data at all streamflow-gaging stations and miscellaneous measurement sites in Kansas, extending some of the systematic records in time by synthesizing long-term records of peak discharges through use of a rainfall-runoff model, defining the flood-frequency relations for each streamflow-gaging station, determining the generalized skewness coefficient for each station, and developing techniques for estimating the flood-frequency relations at ungaged locations not affected by regulation. In order to define the flood-frequency relation more reliably, the relation of the skewness coefficient to physical and climatic characteristics of the streamflow-gaging stations was analyzed.

Previous Studies

Since 1960, six studies have investigated various generalization techniques for estimating flood magnitude and frequency on Kansas streams. Studies by Ellis and Edelen (1960), Irza (1966), and Jordan and Irza (1975) analyzed flood magnitude and frequency by using then available data and techniques to develop regression equations to estimate peak discharges. Both Patterson (1964) and Matthai (1968) used the index-flood method, and Hedman and others (1974) used an active-channel-width concept to estimate the magnitude of floods for selected recurrence intervals.

The generalization technique presented in this report incorporates the most recent analytical developments for estimating flood magnitude and frequency and is considered more reliable than those previously reported on for use with unregulated streams in Kansas.

OCCURRENCE OF FLOODS ON KANSAS STREAMS

Systematically recorded streamflow data, including records of floods, have been collected on Kansas streams since 1895. These records are those recorded at established streamflow-gaging stations, both continuous and partial record, which have been operated by the U.S. Geological Survey in cooperation with several Federal, State, and local agencies. The records collected at continuous-record streamflow-gaging stations consist of stream stage mechanically recorded either graphically or digitally. The data at partial-record stations are records of peak stream stage recorded on crest-stage indicators, which are inspected periodically, generally 6 to 10 times per year. The crest-stage indicators were introduced in 1957 through a cooperative effort with the Kansas Department of Transportation.

There has been documentation of floods in addition to those systematically recorded. Records of long-term synthesized peak discharges have been developed at selected partial-record gaging stations through use of a rainfall-runoff model (Clement, 1983). Also available are records of floods whose peak discharges were determined at miscellaneous measurement (ungaged) locations by indirect methods.

Factors Affecting Occurrence of Floods

Generally, flooding on small streams in Kansas is the result of very intense thunderstorms that affect almost all of the watershed and produce rainfall so intense that the soil cannot infiltrate the excess moisture. Within large watersheds, flooding generally is the result of prolonged rainfall that affects a major part of the total drainage basin. The prolonged rainfall eventually saturates the soil to the point that only a small part of the subsequent rainfall can infiltrate the soil. Frequently, flooding is caused by runoff that is impeded by backwater from physical constrictions in the stream channel, such as excess debris on bridges or culverts, log or ice jams, or as a result of high flow in other interconnected channels. Kansas streams experience little flooding that results from snowmelt or dam breaks.

Physical features within the respective watersheds have a pronounced effect on the nature of flooding. Watersheds with different basin and channel slopes, shapes, and drainage patterns have varying effects on the potential for flooding. For example, steep slopes tend to allow excess rainfall to move more rapidly away from the headwater areas but to accumulate more rapidly at downstream locations where flood conditions occur. Varying watershed shapes also cause different responses to excess rainfall. Generally, long narrow watersheds are less affected by small, isolated storms because usually only a part of the watershed receives intense rainfall, and the timing of the peak discharges is affected by the longer travel time. On the other hand, compact-shaped watersheds have a greater chance to be entirely affected by storms of comparable size, and the dendritic (tree-like) stream pattern facilitates more rapid concentration of runoff at or near the watershed's outlet; this increases the likelihood of downstream flooding.

One of the most significant factors affecting the flood potential of watersheds is the types of soils and land-use and treatment practices within the watershed. For example, the flood potential from watersheds developed for commercial and urban uses is understandably greater than that from rural areas where vegetation and exposed soils tend to allow greater infiltration and less runoff. Land-treatment practices, such as contour-farming and construction of water-retention structures, reduce the amount of rapid runoff to the stream system.

Watersheds in Kansas exhibit a wide range of physical and climatic characteristics that affect flood magnitude and frequency. Generally, the climatic characteristics vary in an east-west direction, with some north-south variation.

Physiographically, Kansas is located almost entirely within the Interior Plains division as described by Schoewe (1949). The hydrologic characteristics of the physiographic provinces within the division are beyond the scope of this report, but the fact that there are significant variations denotes the complex nature of and difficulty in attempting to define the flood magnitude and frequency relations across the State.

Generally, it has been accepted that the nature of flooding follows one of two patterns, one typical of the eastern one-third of the State and one typical of the western two-thirds. The accepted arbitrary dividing line follows roughly the 98th meridian. Crippen and Bue (1977) identified a similarly located boundary within the State when dividing the conterminous United States into flood regions for a study of maximum floodflows. The topography of the western two-thirds of the State is typical of a high plains region, which extends from western Texas north to the Canadian border and is characterized by flat or gently sloping surfaces with little relief. However, the eastern one-third of the State is more complex, with alternating hills and lowlands and some glacial drift.

Land-surface elevations within the State range from about 700 feet above sea level at the Kansas-Oklahoma State line in southeast Kansas to about 4,135 feet above sea level at a point near the Kansas-Colorado State line in western Kansas, a vertical difference of about 3,435 feet.

The climatic characteristics also vary significantly within the State. The general climate of the western part of Kansas is semiarid with hot, dry summer months and cold, windy winter months. The eastern part of the State tends to be considerably more humid, with moderate but sultry summer months and numerous winter months that experience temperatures near or below zero. Average annual precipitation in the State varies from about 17 inches in the extreme western part to nearly 42 inches in the southeast (from map and information furnished by the Kansas State Extension Service, Manhattan, Kansas).

The average annual lake evaporation varies from 43 inches in the extreme northeastern part of the State to over 68 inches in the southwest (Farnsworth and others, 1982). Rainfall-depth frequency also varies in an east to west pattern. For example, the depth of rainfall over a 24-hour period that can be expected on an average return interval of 2 years varies from about 2.2 inches in the northwest corner of the State to about 4 inches in the southeast corner (Hershfield, 1961, chart 44).

Records of Recorded and Historic Floods

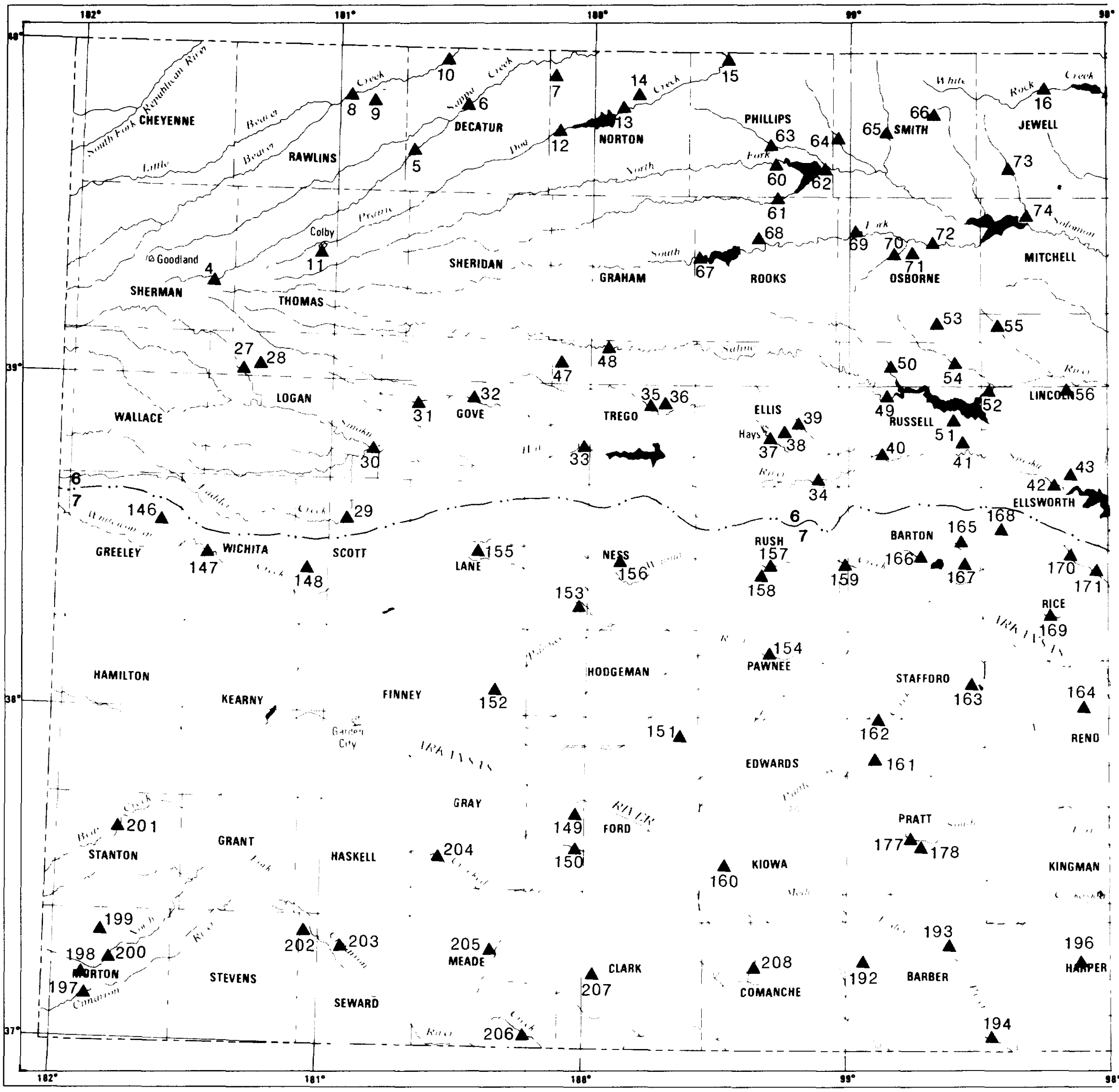
Streamflow records at continuous-record streamflow-gaging stations consist of continuously recorded stream stage from which the annual maximum discharge is determined. The flood records collected at partial-record stations consist of observations of flood peaks recorded on a crest-stage indicator from which the annual maximum discharges are determined. Parts of some systematic records contain peak discharges that are affected by streamflow regulation resulting from reservoir storage. Because the regulated part of a streamflow record constitutes an unnatural condition, only the unregulated part was used in the analysis of flood magnitude and frequency in this report.

Many streamflow records include additional historic information concerning floods that occurred before, during, or after the period of systematic record. Most of this information is documented from such sources as newspaper files, records of other agencies, and from local residents who have long-term knowledge of the flood plain. The historic information is useful in extending the period during which known flooding occurred, thus increasing the reliability of the estimate of flood magnitude and frequency.

Data used in this study also included synthesized long-term records of peak discharges at 19 streamflow-gaging stations. Thirteen of these records are from stations located in the eastern part of the State and were reported on in Clement (1983), which also explains the methodology used for the synthesis. Six of the records are successful results from application of the synthesis methodology to data collected during 1977-82 at 10 sites located in the western two-thirds of the State.

The streamflow-gaging stations whose records of unregulated flow were used in the study are listed in table 5 (at the end of this report), and their location is shown in figure 1. The length of gaging-station record for each gaging station listed in table 5 and the types of records, unregulated, regulated, or historic, are indicated in figure 2.

Additional flood information is afforded by measurement of peak discharges at miscellaneous (ungaged) locations. Generally, peak discharge at miscellaneous locations is determined by an indirect method, such as computations for slope-area, width constrictions, culvert, or flow-over-dam (Benson and Dalrymple, 1967; Dalrymple and Benson, 1967; Bodhaine, 1968; Matthai, 1967; and Hulsing, 1967). Because measurements at miscellaneous locations are not associated with a time series, the magnitudes of the peak discharges cannot be fitted to a frequency distribution for analysis. However, they do add significant information by expanding the flood data recorded at gaged locations for further analysis of selected extreme storms. On occasion an isolated, very intense storm will affect a watershed that is not monitored by any systematic stream gage. Hence, one or more measurements of the discharge at miscellaneous locations within the watershed will be the only record of the flood.



EXPLANATION

230▲ GAGING STATION AND MAP NUMBER

·· —— ·· BASIN BOUNDARY

DRAINAGE BASINS

6 Missouri River basin

7 Arkansas River basin

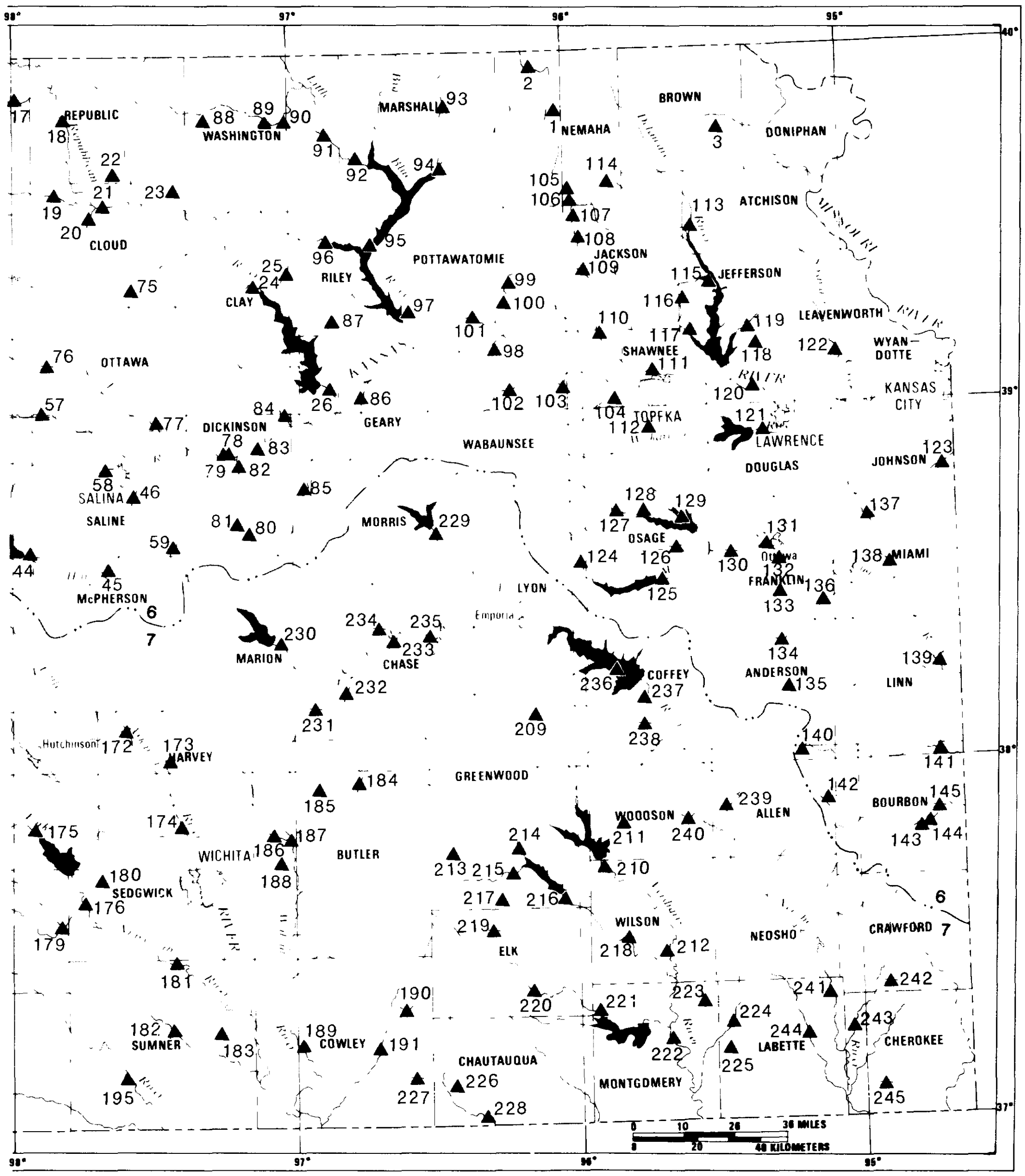
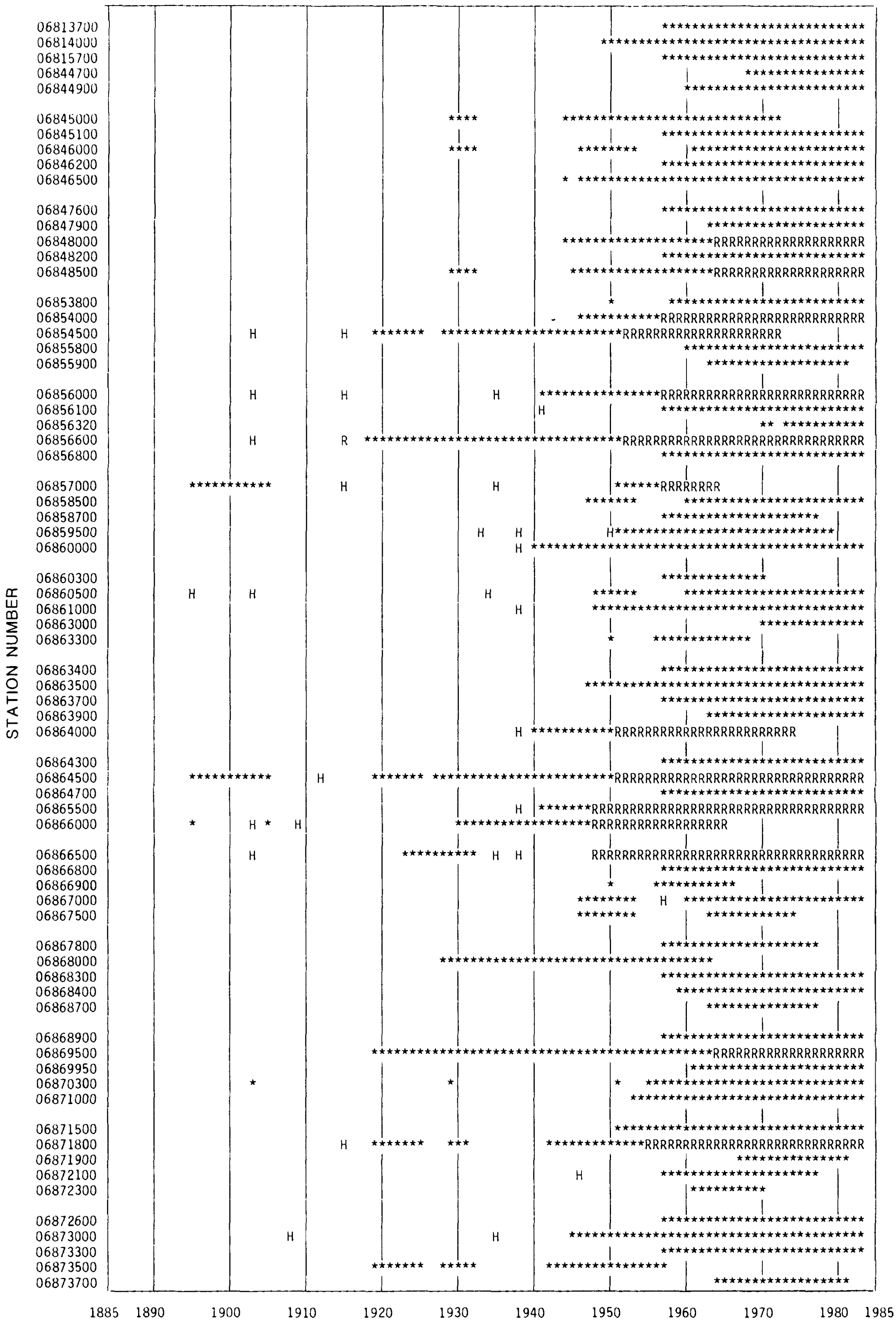
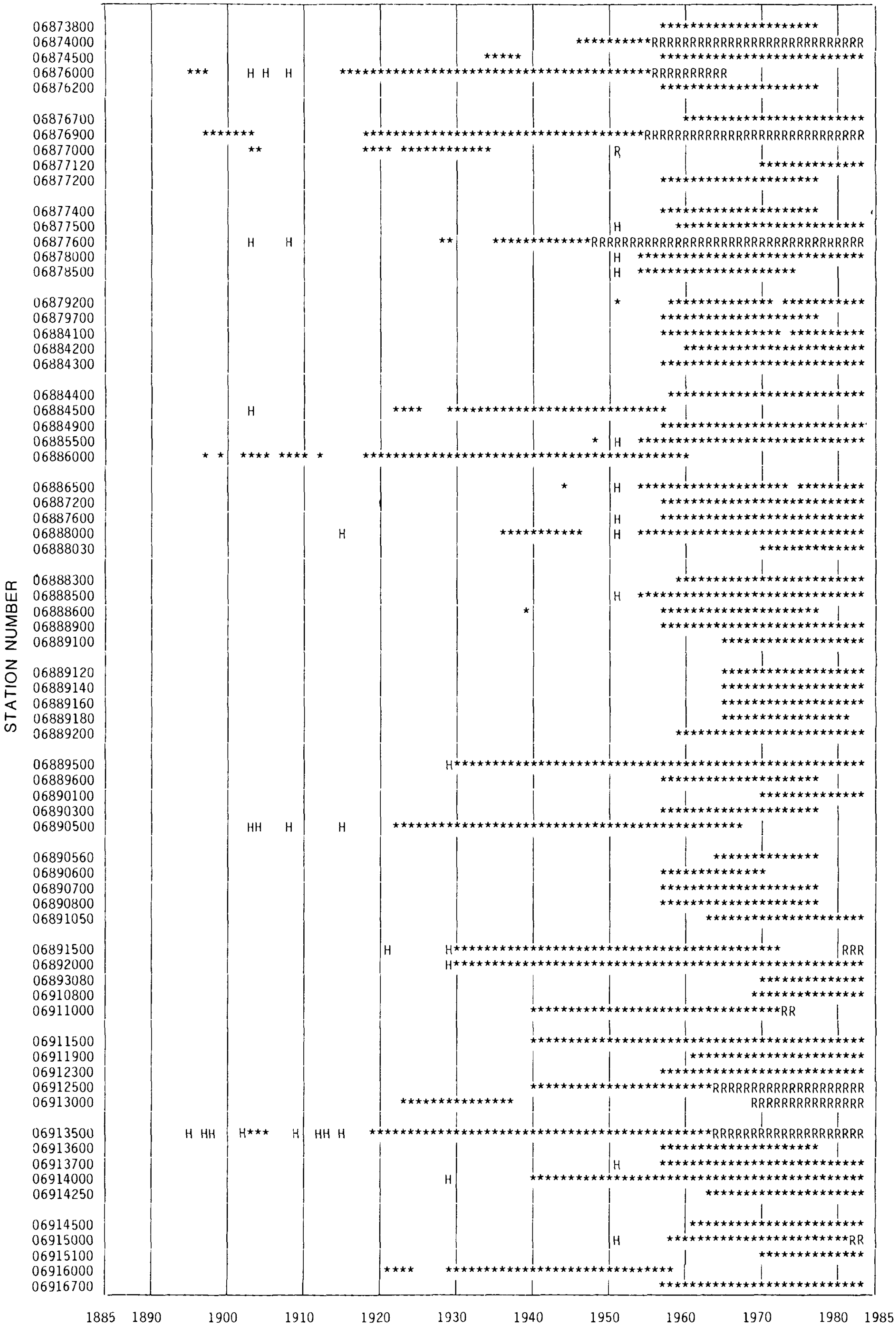


Figure 1.--Location of streamflow-gaging stations.



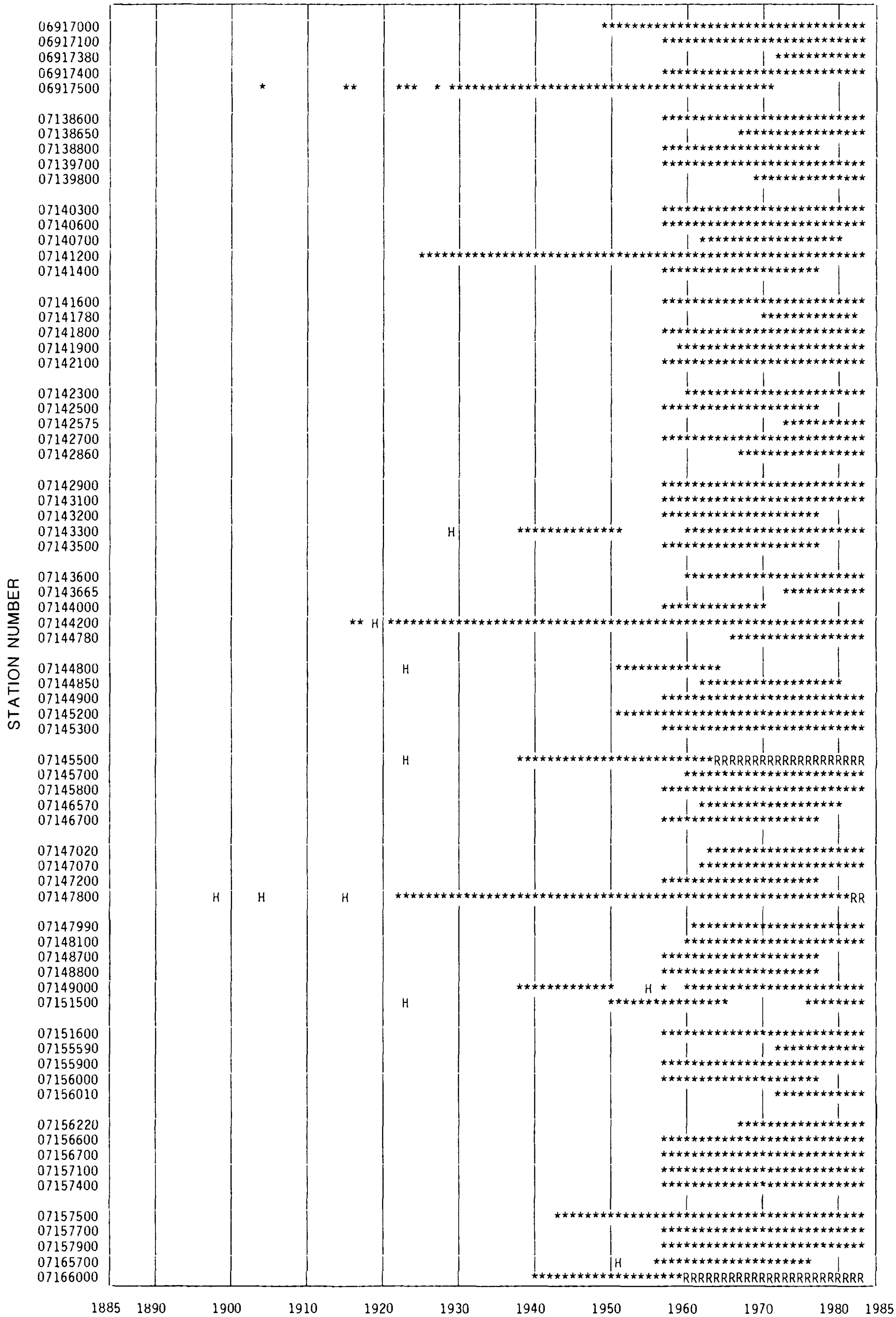
(Note: * - unregulated record; R - regulated record; H - additional historic flood information)

Figure 2.--Length and types of records collected at streamflow-gaging stations.



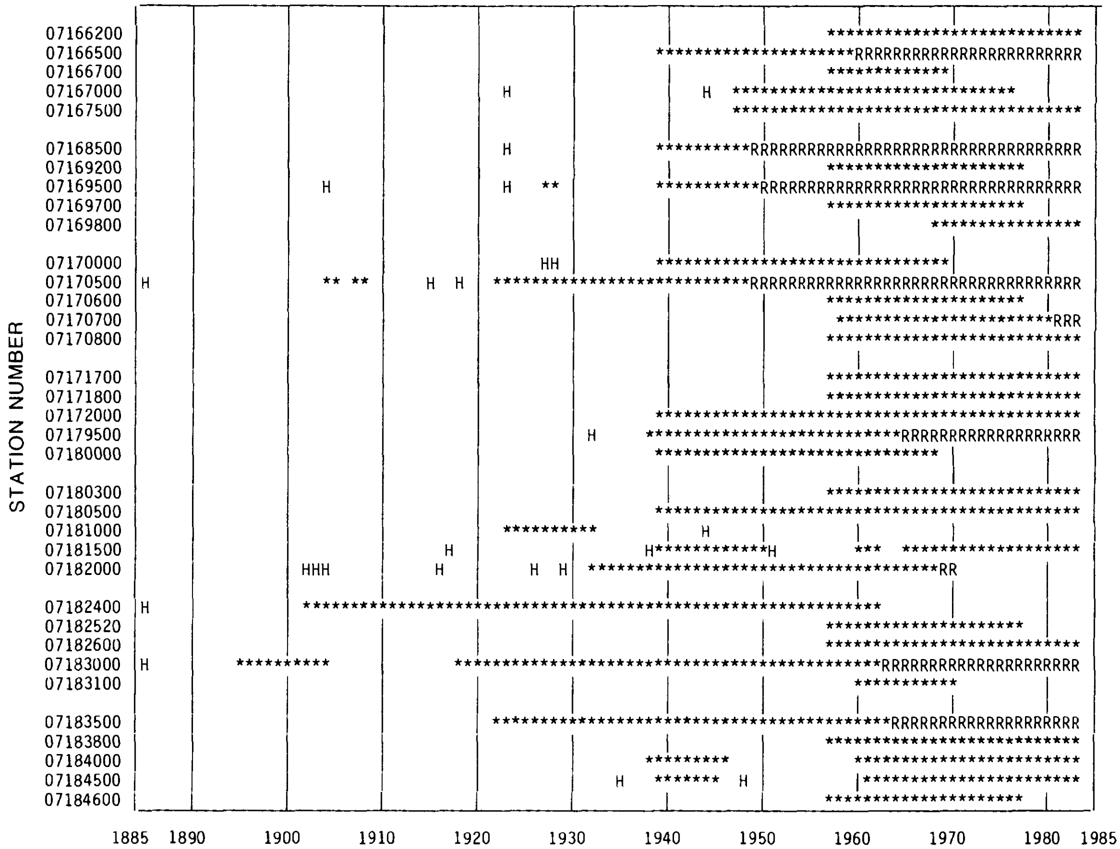
(Note: * - unregulated record; R - regulated record; H - additional historic flood information)

Figure 2.--Length and types of records collected at streamflow-gaging stations--Continued.



(Note: * - unregulated record; R - regulated record; H - additional historic flood information)

Figure 2.--Length and types of records collected at streamflow-gaging stations--Continued.



(Note: * - unregulated record; R - regulated record; H - additional historic flood information)

Figure 2.--Length and types of records collected at streamflow-gaging stations--Continued.

Seasonal Occurrence of Floods

Because the majority of flooding on Kansas streams results from thunderstorm activity, about 71 percent of the known flooding in the State occurs during the months of April through August when thunderstorms are most prevalent. In the eastern part of Kansas, the majority of floods occur from April through July, whereas the western part experiences the majority of its floods during May through August. The seasonal distribution of annual peak discharges on Kansas streams, by month, for the eastern and western parts of the State is shown in figure 3.

Occurrence of Extreme Floods

Moderate flooding is an annual occurrence in Kansas; however, the State has experienced several extreme floods. Notably, the floods of 1951 in river basins of eastern and north-central Kansas were the result of a large storm system. Likewise, the floods that occurred on the Elk River during 1976 were extreme. The Great Bend area experienced extreme flooding during June 1981, when an isolated but very intense storm system produced up to 20 inches of rain during a 12-hour period (Clement and Johnson, 1982). These are but a few of many floods that have been experienced on Kansas streams that were considerably larger than any floods

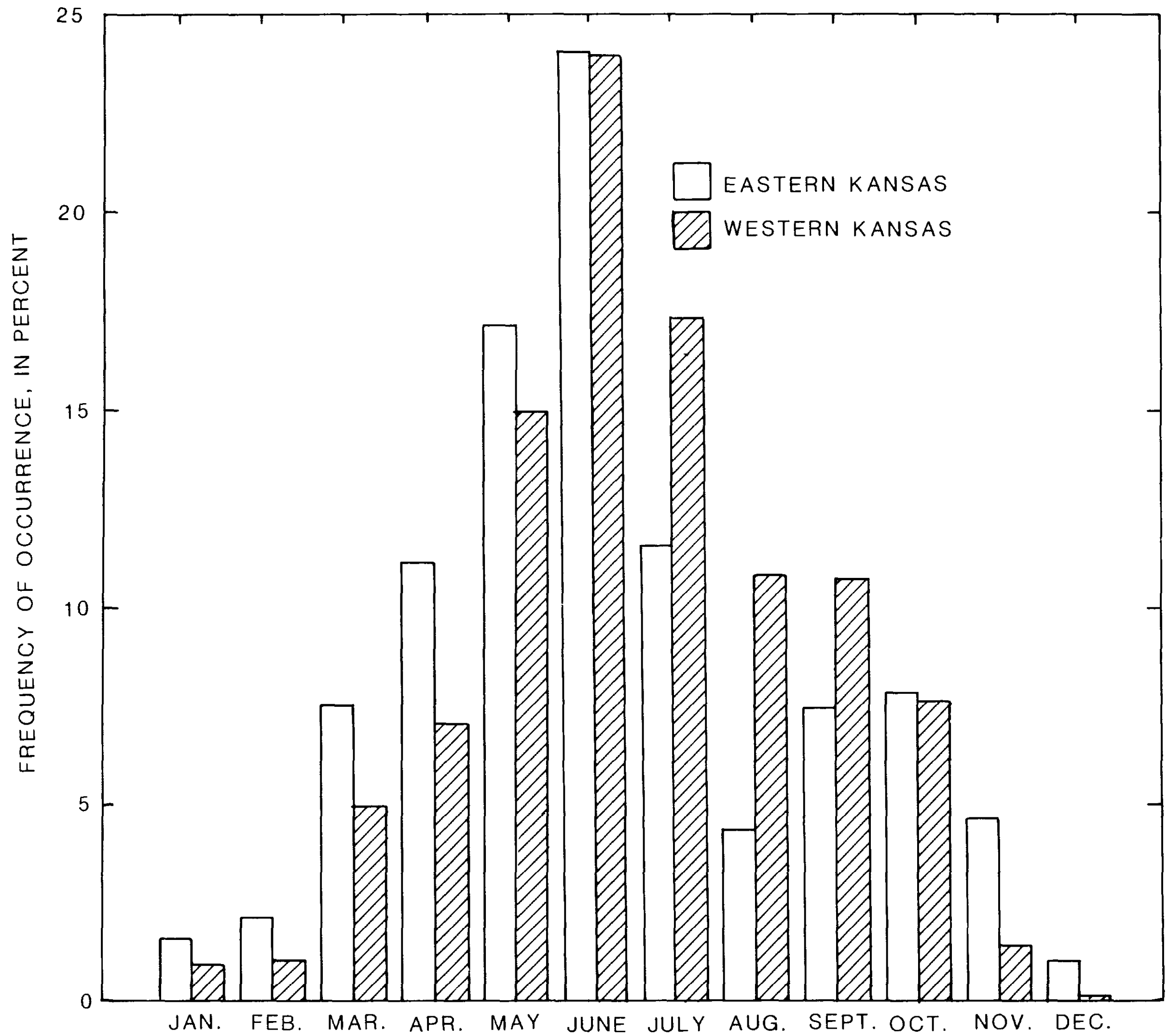


Figure 3.--Seasonal distribution of annual peak discharges in Kansas.

previously recorded. Generally, the peak discharges exceeded by 2 or 3 times the estimates of peaks having expected recurrence intervals of 100 years. The recorded peak discharges, which in relation to the respective contributing-drainage areas are the maximum observed in Kansas, are listed in table 1. The relation between peak discharge and contributing-drainage area for the data in table 1, in addition to other maximum observed discharges, are depicted graphically in figure 4. An envelope curve has been drawn through the highest points for both eastern and western Kansas. No recurrence interval can be assigned to the curves, although they represent peak discharges several times greater than those having 100-year recurrence intervals.

Crippen and Bue (1977) developed similar envelope curves to describe maximum floodflows in each of 17 regions in the conterminous United States. As discussed earlier in this report, their delineation of the boundary between eastern and western Kansas is very similar. However, the curve for western Kansas shown in figure 4 is lower than the curve

Table 1.--*Maximum observed discharges on Kansas streams*

Station number	Station name or location	Contributing-drainage area (square miles)	Maximum discharge Date	Maximum discharge (cubic feet per second)
	Eastern Kansas			
06815600*	Wolf River near Hiawatha	41	Aug. 9, 1968	40,000
06889100	Soldier Creek near Goff	2.06	May 10, 1970	7,080
06912300	Dragoon Creek tributary near Lyndon	3.76	June 11, 1981	8,200
07147020	Whitewater River tributary near Towanda	.17	June 5, 1965	510
07165700	Verdigris River near Madison	181	July 11, 1951	128,000
07166700	Burnt Creek at Reece	8.85	June 9, 1965	20,500
07167500	Otter Creek at Climax	129	July 3, 1976	107,000
07169800	Elk River at Elk Falls	220	July 3, 1976	200,000
07179500	Neosho River at Council Grove	250	July 11, 1951	121,000
07179600*	Four Mile Creek near Council Grove	55	June 26, 1969	68,100
07181500	Middle Creek near Elmdale	92	June 27, 1969	90,000
07182000	Cottonwood River at Cottonwood Falls	1,327	July 11, 1951	196,000
07182400	Neosho River at Strawn	2,933	July 11, 1951	400,000
07183000	Neosho River near Iola	3,818	July 13, 1951	436,000
07183500	Neosho River near Parsons	4,905	July 14, 1951	410,000
	Western Kansas			
06863900	North Fork Big Creek near Victoria	54	Aug. 9, 1974	26,400
06873500	South Fork Solomon River at Alton	1,720	July 12, 1951	91,900
06873800	Kill Creek tributary near Bloomington	1.45	May 21, 1961	2,000
06876200	Middle Pipe Creek near Miltonvale	10.2	Sept. 26, 1973	6,400
06876900	Solomon River at Niles	6,770	July 14, 1951	178,000
06878000	Chapman Creek near Chapman	300	July 1951	46,700
06878500	Lyon Creek near Woodbine	230	July 1951	93,000
06879650*	Kings Creek near Manhattan	4.09	July 1, 1982	4,530
07142100	Rattlesnake Creek tributary near Mullinville	10.3	Sept. 26, 1973	7,000
07143800*	Black Kettle Creek tributary near Halstead	1.65	June 2, 1962	2,440
07144000	East Emma Creek near Halstead	58	Aug. 25, 1960	18,000
07144780	North Fork Ninnescah River above Cheney Reservoir	787	Oct. 30, 1979	87,000
*	Dry Walnut Creek tributary near Great Bend	2.28	June 15, 1981	5,720
*	do.	1.19	do.	3,080
*	do.	.92	do.	1,870
*	do.	.66	do.	1,340

* Indicates that station is not listed in table 5 and is not plotted in figure 1.

for region 12 (Crippen and Bue, 1977) because region 12 includes larger peak discharges for stations located along the eastern slopes of the Rocky Mountains. Conversely, the curve for eastern Kansas is higher than Crippen and Bue's (1977) curve for region 9 because figure 4 includes data for larger, more recent peak discharges. Therefore, the envelope curves (fig. 4) showing the maximum observed peak discharges are more realistic for Kansas.

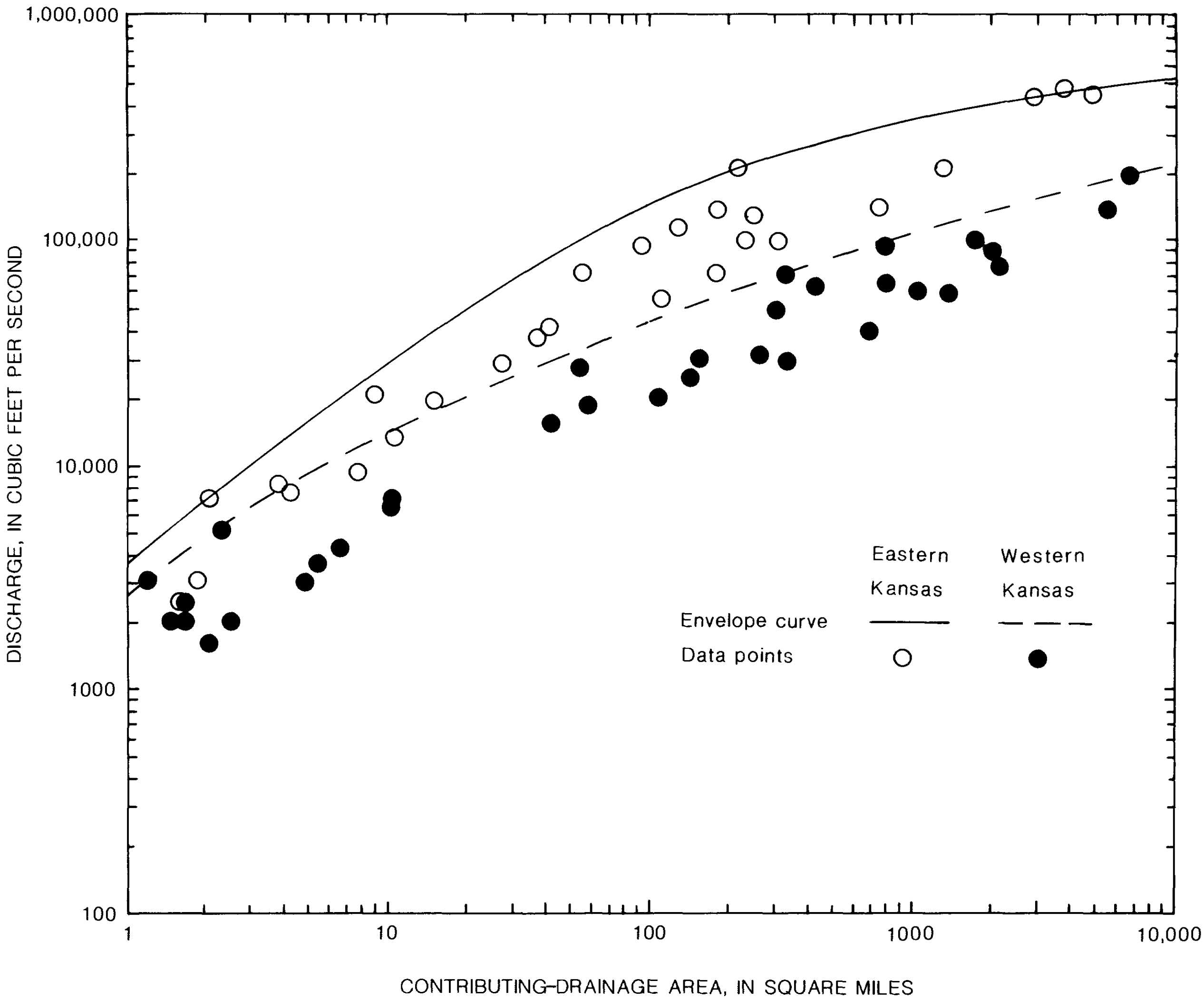


Figure 4.--Relation between maximum observed discharge and drainage area.

ESTIMATING FLOOD MAGNITUDE AND FREQUENCY BY USE OF DATA FROM GAGED SITES

Use of Log-Pearson Type III Techniques

Since about 1914, numerous techniques have been developed for flood-frequency analysis (Benson, 1962a). However, many of the techniques produced conflicting results causing considerable misunderstanding and confusion in their interpretation due to the nonuniform and dissimilar techniques used. In 1966, under authority of House Document 465 (1966), the U.S. Water Resources Council investigated various techniques for the analysis of flood magnitude and frequency and in 1967 recommended that the log-Pearson Type III frequency distribution be adopted as the standard technique to be used in Federal practice (U.S. Water Resources Council, 1967). Subsequently, the U.S. Water Resources Council conducted additional studies that resulted in improvements to the initial log-Pearson Type III technique. The improvements were reported on in Bulletins 17, 17A, and 17B (U.S. Water Resources Council, 1976, 1977, and 1981, respectively).

The log-Pearson Type III technique uses logarithmic transformation of the natural values of the data to compute by the method of moments three statistics of a distribution--mean, standard deviation, and skewness. The skewness coefficient is adjusted by weighting the computed skewness coefficient with an areally distributed, generalized skewness coefficient.

The log-Pearson Type III distribution is sensitive to data that are uncharacteristic of the sample data used to compute the statistics, particularly to extreme data, including data values of zero, that do not fit the general trend of the log-Pearson Type III distribution. These data are considered to be "outliers" and can be deleted or adjusted depending on whether they are extremely low or extremely high. Low outliers, including zero values, are excluded from the computation, and the distribution is adjusted by the method of conditional probability. High outliers are adjusted by assigning a longer recurrence interval to the data based on historic information.

The reliability of estimates of flood magnitude and frequency is based on the assumption that the model used to determine the distribution is correct and that the data (annual maximum peak discharges) are accurate and drawn from a representative sample of random and independent events. Hence, length of the period used to compute the estimates of flood magnitude and the at-site variability are the principal measures of the reliability. Specifically, the longer the record the more reliable the estimates become because the size of the sampling error is a function of the inverse of the square root of the length of record used to make the estimate. It follows, therefore, that the error in estimating a peak discharge having a long recurrence interval by using data from a short record would be much greater than the error in estimating a peak discharge having a short recurrence interval using data from a longer record. The general relation between the error of estimate for selected recurrence intervals and the length of record used to compute the estimates for Kansas streams is depicted in figure 5 (modified from Hardison, 1969).

Use of Historic Data

As mentioned previously, many of the records of maximum discharges used in this study also contained additional information relating to peak discharges that occurred before, during, or after the period of systematic record collection and represented maximum occurrences during an extended period. For example, it may be known that the maximum peak discharge recorded during the systematic collection was the largest since a point in time significantly before or after the beginning or ending of the recorded period. Likewise, a peak discharge that occurred outside of the period of systematic record may be known to be larger than any peak discharge that occurred during that period. This "historic data" can be used to make adjustments to the original distribution of the data by assigning a historic period of record that is longer than the systematic period, thereby adjusting the recurrence intervals of the peak discharges.

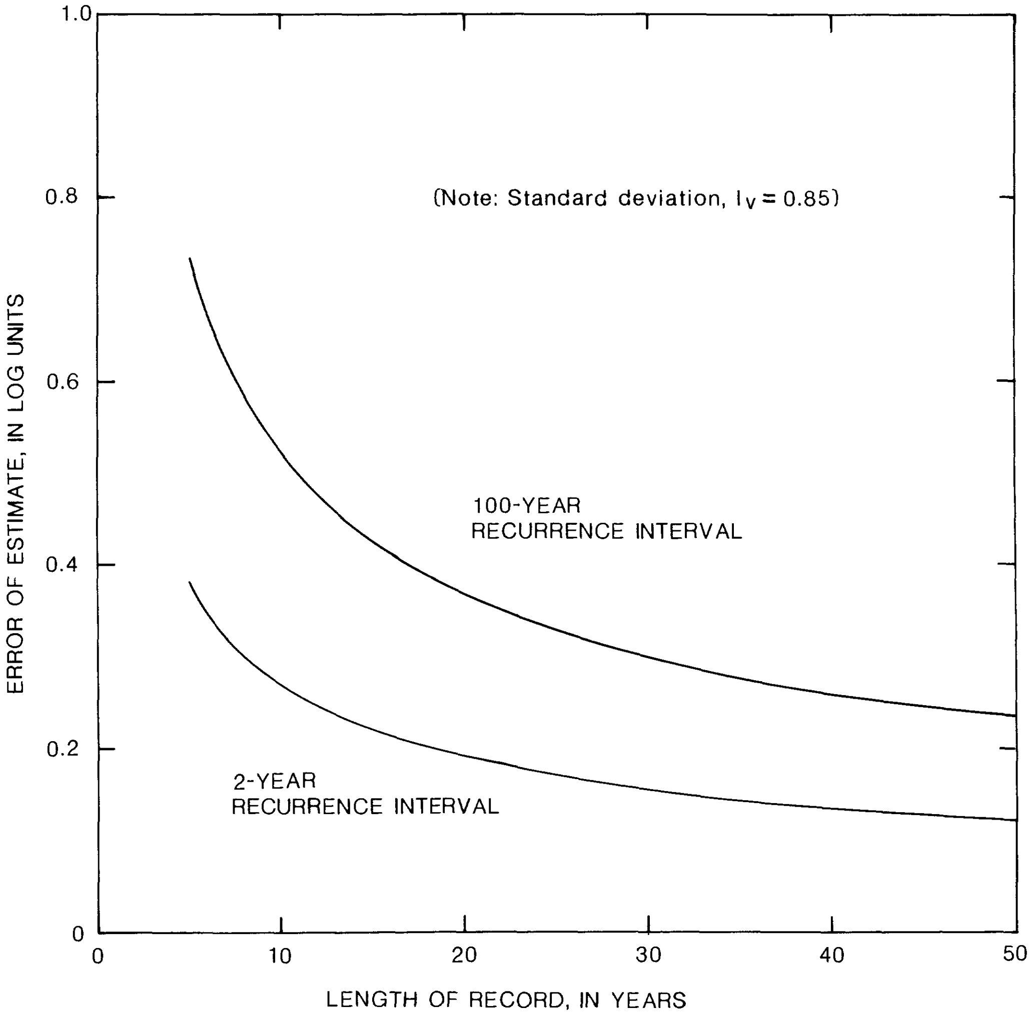


Figure 5.--Relation of errors of estimate to length of record for Kansas data (modified from Hardison, 1969).

Generalized Skewness Coefficients

The U.S. Water Resources Council Bulletin 17 (1976) recommended that the skewness coefficient computed from station records be weighted with a generalized skewness coefficient to reduce the bias caused primarily by records having relatively short lengths. The suggested method entailed picking the generalized skewness coefficient from a map showing lines of equal skewness for the entire United States. The map of equal skewness was based on the skewness coefficients computed from station records collected through 1973 at 2,972 streamflow-gaging stations having 25 or more years of unregulated record and contributing-drainage areas of less than 3,000 square miles. The root-mean-square error between the isolines and the station data is 0.55. The same skewness map is presented in Bulletins 17, 17A, and 17B of U.S. Water Resources Council (1976; 1978; 1981).

Although using the U.S. Water Resources Council's map of regional skewness probably improves most flood-frequency computations, the spatial position of the lines of equal skewness can be questioned. McCuen (1979) showed that more than one map can be determined from the data and that the spatial variability can lead to ambiguous results. As an alternative, the U.S. Water Resources Council suggested that skewness coefficients could be regionalized by one of three techniques--averaging the station skewness coefficients within a specific area (not less than 25 stations), developing a local skewness map, or relating the coefficients to predictor variables, such as physical and climatic characteristics of the drainage basins.

The greatest problem encountered in estimating the value of the skewness coefficient is the large error of computations from short-term gaging-station records. McCuen (1979) suggested that a weighting technique be used whereby more records could be utilized, including values of skewness computed from shorter records. Stedinger and Tasker (1985) have adapted a weighted least-squares regression model for use with hydrologic data. This modified weighted least-squares (WLS) model weights the error variances based on the length of the data record and variability in the data. The WLS model is well adapted for analysis of hydrologic data having variable accuracy because of its ability to separate the error of prediction into the sampling error and model error and to treat each error separately based on the length of the peak-discharge record at the streamflow-gaging station. The sampling error is a function of the length of record and the degree of deviation from the average predictor variables. The model error, in this case, is the error associated with the formulation of the model. The error that can be expected when using the regression equation is the error of prediction which includes both the sampling and model errors.

Tasker and Stedinger (1986) further modified the WLS model specifically to estimate generalized skewness coefficients by weighting each unbiased estimate of skewness based on the length of the record of annual peak discharges. The technique relates the station skewness coefficient determined from the log-Pearson Type III distribution to one or more physical and climatic characteristics of the drainage basins. The result of the computations yields the coefficients and constants of a regression equation, as well as their significance to the equation, that can be used to estimate the generalized skewness coefficient.

The WLS regression model was used with the station skewness coefficient computed from 245 streamflow-gaging-station records in Kansas as the dependent variable and several physical and climatic characteristics for each station as independent (predictor) variables. A summary, including description and dimensions, of the various physical and climatic characteristics for each streamflow-gaging station used in the analysis is listed and described in table 5 (at the end of this report).

The computation for generalized skewness coefficients was limited to those stations having contributing-drainage areas of less than 20,000 square miles. The length of record, including historical data, ranged from 10 years to 142 years, and the value of station skewness ranged from -1.62 to 1.44. Contributing-drainage area (CDA) and latitude (Lat) were the independent variables that yielded the best fit based on the magnitude of the model error. The latitude apparently serves as a surrogate for a combination of physical and climatic characteristics. The resulting root-mean-square error of prediction was 0.35, which included root-mean-square sampling and model errors of 0.061 and 0.348, respectively.

The equation used in the regression for estimating the skewness coefficient took the form:

$$G_s = a + b_1 \log CDA + b_2 \log (Lat-36) , \tag{1}$$

where

G_s = station skewness coefficient (table 2);
a = regression constant;
b_1 and b_2 = regression coefficients for the respective independent variables;
CDA = contributing-drainage area, in square miles; and
Lat = latitude of the streamflow-gaging station, in degrees.

The resulting equation for estimating the generalized skewness coefficient at streamflow-gaging stations is:

$$G_g = -0.658 + 0.140 \log_{10} CDA + 0.614 \log_{10} (Lat-36), \tag{2}$$

where

G_g = generalized skewness coefficient for the selected streamflow-gaging station to be used in lieu of the U.S. Water Resources Council map of equal skewness.

The resulting estimates of generalized skewness coefficients (G_g) are listed in table 2. The mean, standard deviation, and station skewness coefficients (G_s) of the log-Pearson Type III distributions for each streamflow-gaging station used in the analysis also are listed in table 2.

The skewness coefficient used to compute the magnitude and frequency of peak discharges were the result of weighting estimates of the station (G_s) and generalized (G_g) skewness coefficients where the weights were inversely proportional to the root-mean-square errors of the respective estimates as recommended by the U.S. Water Resources Council (1981, p. 12-13). In this case, the error associated with the generalized (G_g) skewness is the error of prediction of the estimating equation.

Flood Magnitude and Frequency at Gaged Sites

Using the unregulated annual maximum discharges recorded at 245 streamflow-gaging stations whose lengths of record were equal to or greater than 10 years, log-Pearson Type III distributions were computed for the period of record. Adjustments then were made to account for data that represented low or high outliers and for historic data where necessary. Final estimates of magnitude and frequency were computed using the generalized skewness coefficients (G_g) obtained for each station using equation 2 and weighted with the station skewness coefficient (G_s) as recommended by U.S. Water Resources Council (1981).

Table 2.--*Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*

[Values of the mean, standard deviation, and coefficient of skewness are in logarithmic units. All streamflows were unregulated during the period of record used in the analysis; * indicates those streams where flows presently are regulated]

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness		
				Station (G_s)	Generalized (G_g)	Weighted (G_w)
1	06813700	2.358	0.485	-0.677	-0.308	-0.511
2	06814000	3.727	.395	-.468	.049	-.161
3	06815700	3.310	.126	.298	-.225	.098
4	06844700	1.533	1.200	-.697	-.080	-.235
5	06844900	2.601	.598	.169	.049	.092
6	06845000	2.939	.548	.224	.110	.158
7	06845100	2.512	.486	-.508	-.085	-.234
8	06846000	2.716	.458	-.178	.127	-.008
9	06846200	2.480	.492	-1.625	-.160	-.436
10	06846500	2.736	.445	.901	.147	.420
11	06847600	2.171	.625	-.603	-.210	-.375
12	06847900	2.809	.524	-.165	.083	.000
13	06848000*	3.443	.491	.757	.095	.280
14	06848200	2.207	.383	-1.130	-.297	-.518
15	06848500*	3.368	.398	.690	.130	.302
16	06853800	3.150	.319	.147	.034	.113
17	06854000*	3.462	.287	.686	.058	.403
18	06854500*	4.155	.357	.992	.283	.553
19	06855800	3.206	.358	1.401	.036	.424
20	06855900	2.954	.348	-.157	-.077	-.102
21	06856000*	4.230	.379	.298	.270	.285
22	06856100	2.863	.520	.516	-.085	.282
23	06856320	2.772	.499	.490	-.057	.070
24	06856600*	4.131	.341	.604	.256	.462
25	06856800	2.560	.464	-.642	-.256	-.470
26	06857000*	4.157	.371	.893	.241	.536
27	06858500	2.543	.858	-.096	.029	-.024
28	06858700	2.516	.320	.279	-.355	-.180
29	06859500	2.799	.725	.066	.052	.061
30	06860000	3.304	.679	-.153	.109	-.024
31	06860300	2.576	.590	.330	-.134	-.028
32	06860500	2.738	.802	-.228	-.003	-.146
33	06861000	3.475	.611	-.497	.137	-.251
34	06863000*	3.170	.499	.037	.137	.083
35	06863300	3.109	.633	-.010	-.028	-.023

Table 2.-- *Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*--Continued

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness		
				Station (G_s)	Generalized (G_g)	Weighted (G_w)
36	06863400	2.244	0.678	0.141	-0.276	-0.114
37	06863500	3.208	.357	.580	.005	.317
38	06863700	1.813	.641	.025	-.268	-.150
39	06863900	2.314	.833	-.600	-.134	-.495
40	06864000*	3.874	.371	-.712	.151	-.230
41	06864300	2.232	.496	.080	-.277	-.136
42	06864500*	3.815	.456	-.621	.151	-.217
43	06864700	2.723	.476	-.339	-.251	-.283
44	06865500*	4.082	.285	.667	.142	.242
45	06866000*	3.775	.308	.699	.139	.449
46	06866500*	3.731	.366	.768	.164	.425
47	06866800	2.269	.663	-.092	-.292	-.213
48	06866900	3.487	.541	-.586	.041	-.088
49	06867000	3.463	.502	-.382	.076	-.175
50	06867500	2.955	.641	-.545	-.034	-.185
51	06867800	2.106	.289	.428	-.372	-.121
52	06868000*	3.684	.418	-.351	.087	-.100
53	06868300	2.574	.548	-.107	-.236	-.185
54	06868400	3.185	.409	-.442	-.051	-.185
55	06868700	2.512	.625	-.344	-.154	-.204
56	06868900	2.021	.392	-.223	-.309	-.277
57	06869500*	3.481	.404	-.255	.117	-.127
58	06869950	3.371	.345	-.321	-.044	-.138
59	06870300	3.381	.330	.062	-.108	-.037
60	06871000	3.290	.524	-.299	.098	-.061
61	06871500	3.021	.516	.209	.034	.109
62	06871800*	3.610	.448	.273	.126	.222
63	06871900	3.063	.556	-.978	-.050	-.252
64	06872100	2.768	.452	.946	-.058	.268
65	06872300	2.875	.319	-.337	-.044	-.102
66	06872600	2.027	.580	.311	-.208	-.015
67	06873000	3.225	.506	-.535	.087	-.097
68	06873300	1.472	.622	-.072	-.336	-.231
69	06873500*	3.518	.591	-.040	.123	.010
70	06873700	2.228	.979	-.473	-.094	-.201

Table 2.--*Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*--Continued

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness		
				Station (G_s)	Generalized (G_g)	Weighted (G_w)
71	06873800	2.341	0.475	0.230	-0.309	-0.132
72	06874000*	3.513	.433	.437	.132	.279
73	06874500	2.751	.398	-.080	-.113	-.099
74	06876000*	3.917	.355	.532	.193	.382
75	06876200	2.723	.452	.351	-.195	-.021
76	06876700	3.124	.602	-.400	.008	-.238
77	06876900*	3.825	.327	.539	.167	.392
78	06877000*	3.965	.225	.573	.223	.425
79	06877120	3.358	.354	-.679	-.101	-.236
80	06877200	3.063	.332	-1.102	-.198	-.413
81	06877400	2.446	.562	-.142	-.340	-.273
82	06877500	3.480	.440	-.110	-.082	-.100
83	06877600*	4.167	.266	-.133	.225	.004
84	06878000	3.574	.331	.532	-.016	.315
85	06878500	3.805	.544	-.550	-.046	-.349
86	06879200	3.719	.334	.070	-.043	.000
87	06879700	2.959	.410	-.558	-.180	-.295
88	06884100	2.171	.601	-.078	-.271	-.196
89	06884200	3.650	.315	-.431	.054	-.110
90	06884300	2.624	.303	.727	-.231	.085
91	06884400	4.102	.268	-.062	.188	.033
92	06884500	4.067	.373	.008	.192	.087
93	06884900	3.292	.376	-.526	-.074	-.200
94	06885500	3.878	.400	-.056	.055	.003
95	06886000*	4.378	.278	.110	.225	.168
96	06886500	3.667	.471	-.894	-.013	-.485
97	06887200	3.141	.443	-.164	-.186	-.176
98	06887600	2.331	.446	-.561	-.362	-.475
99	06888000	3.763	.372	-.846	-.003	-.462
100	06888030	3.836	.194	.073	.004	.021
101	06888300	3.780	.278	-.149	-.048	-.086
102	06888500	3.988	.362	-.578	-.011	-.349
103	06888600	3.229	.311	.438	-.194	.163
104	06888900	2.507	.363	-.525	-.347	-.450
105	06889100	2.562	.314	.458	-.271	.180

Table 2.-- *Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*--Continued

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness		
				Station (G_s)	Generalized (G_g)	Weighted (G_w)
106	06889120	3.079	0.264	0.552	-0.174	0.262
107	06889140	3.224	.228	.614	-.148	.301
108	06889160	3.586	.206	-.918	-.090	-.524
109	06889180	3.651	.260	-.883	-.068	-.270
110	06889200	3.604	.218	-.006	-.040	-.016
111	06889500	3.715	.375	-.524	-.012	-.260
112	06889600	2.882	.333	.236	-.286	-.114
113	06890100	4.113	.206	-.404	.046	-.065
114	06890300	3.214	.422	.836	-.129	.142
115	06890500	4.145	.350	-.197	.078	-.107
116	06890560	2.635	.331	-.375	-.299	-.318
117	06890600	3.294	.180	.143	-.161	-.001
118	06890700	2.227	.515	-.651	-.359	-.521
119	06890800	3.553	.188	.467	-.138	.151
120	06891050	3.258	.389	-.837	-.204	-.382
121	06891500*	3.777	.353	-.490	-.006	-.304
122	06892000	3.745	.291	.067	.009	.049
123	06893080	3.599	.197	-.505	-.150	-.236
124	06910800	3.948	.305	.889	-.093	.314
125	06911000*	3.835	.478	-.712	-.057	-.296
126	06911500	3.600	.424	-.587	-.117	-.321
127	06911900	3.739	.348	.387	-.105	.059
128	06912300	2.920	.484	-.792	-.314	-.566
129	06912500*	3.831	.409	-.910	-.048	-.502
130	06913000*	3.975	.419	.425	.017	.121
131	06913500*	4.057	.412	.200	.031	.143
132	06913600	2.863	.489	-.484	-.267	-.394
133	06913700	3.470	.223	.352	-.177	.161
134	06914000	4.057	.315	.050	-.080	-.007
135	06914250	2.306	.283	.122	-.508	-.294
136	06914500	4.119	.334	.523	-.041	.140
137	06915000*	3.847	.369	.373	-.097	.170
138	06915100	3.779	.227	.012	-.076	-.028
139	06916000*	4.307	.349	.320	.041	.158
140	06916700	2.752	.407	-.671	-.423	-.560

Table 2.--*Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*--Continued

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness		
				Station (G_s)	Generalized (G_g)	Weighted (G_w)
141	06917000	3.883	0.240	0.316	-0.126	0.062
142	06917100	2.296	.289	-.509	-.494	-.499
143	06917380	4.138	.128	.881	-.154	.058
144	06917400	2.911	.275	-.953	-.440	-.593
145	06917500	4.062	.353	-.519	-.127	-.305
146	07138600	1.826	.633	-.446	-.288	-.345
147	07138650	2.533	.826	-.641	-.014	-.179
148	07138800	1.926	.392	-1.102	-.405	-.572
149	07139700	2.433	.312	-.161	-.384	-.297
150	07139800	2.360	.555	-.313	-.272	-.283
151	07140300	2.235	.709	.129	-.324	-.095
152	07140600	2.445	.450	.091	-.348	-.175
153	07140700*	2.596	.592	-.325	-.190	-.231
154	07141200	3.411	.336	.461	.014	.243
155	07141400	1.711	.378	-1.352	-.429	-.614
156	07141600	1.927	.823	-.483	-.217	-.311
157	07141780	3.037	.480	-.776	.010	-.177
158	07141800	2.608	.490	-.366	-.252	-.294
159	07141900	3.204	.369	-.200	.017	-.064
160	07142100	2.572	.570	-.282	-.394	-.321
161	07142300	2.619	.654	.477	-.134	.074
162	07142500	2.448	.727	-.226	-.318	-.269
163	07142575	2.900	.426	.804	-.081	.297
164	07142700	3.074	.331	-.271	-.209	-.232
165	07142860	2.797	.544	-.119	-.183	-.164
166	07142900	3.009	.457	-.579	-.161	-.305
167	07143100	2.110	.262	.137	-.395	-.188
168	07143200	2.720	.312	.366	-.225	.066
169	07143300	3.334	.457	.296	-.058	.127
170	07143500	2.956	.208	-1.312	-.223	-.448
171	07143600	3.062	.347	1.435	-.165	.151
172	07143665	3.802	.284	-.175	-.063	-.088
173	07144000	3.514	.517	-.194	-.223	-.216
174	07144200	3.744	.442	-.616	-.064	-.348
175	07144780	3.522	.584	.001	-.112	-.014

Table 2.--*Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*--Continued

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness		
				Station (G_s)	Generalized (G_g)	Weighted (G_w)
176	07144800*	3.550	0.477	-0.373	-0.125	-0.238
177	07144850	2.764	.424	-.355	-.350	-.353
178	07144900	2.476	.325	-.651	-.497	-.548
179	07145200	3.778	.413	-.422	-.157	-.263
180	07145300	2.759	.285	-.751	-.425	-.531
181	07145500*	4.057	.267	.131	-.103	.055
182	07145700	3.540	.455	-.567	-.293	-.419
183	07145800	2.079	.298	.077	-.647	-.360
184	07146570	3.272	.415	.010	-.274	-.119
185	07146700	3.108	.332	.087	-.334	-.190
186	07147020	1.881	.434	-.479	-.602	-.564
187	07147070	3.847	.473	-.447	-.135	-.235
188	07147200	2.343	.270	.253	-.526	-.271
189	07147800*	4.283	.358	-.121	-.147	-.129
190	07147990	2.611	.655	-.449	-.531	-.504
191	07148100	3.880	.384	.307	-.292	.074
192	07148700	2.393	.678	-.145	-.491	-.375
193	07148800	2.073	.738	-.730	-.543	-.597
194	07149000	3.624	.302	-.105	-.235	-.164
195	07151500	3.917	.418	-.337	-.221	-.284
196	07151600	3.030	.369	-.357	-.447	-.414
197	07155590	3.431	.321	-.079	-.154	-.114
198	07155900	2.166	1.026	-.235	-.350	-.306
199	07156000	2.852	.623	-.176	-.339	-.284
200	07156010	2.949	.653	.024	-.224	-.089
201	07156220	2.974	.752	-.138	-.120	-.126
202	07156600	2.671	.610	-.902	-.402	-.557
203	07156700	2.447	.421	.086	-.541	-.293
204	07157100	2.780	.552	-.280	-.309	-.298
205	07157400	2.478	.856	-.587	-.475	-.514
206	07157500	3.200	.552	-.288	-.243	-.264
207	07157700	2.530	.377	-.372	-.397	-.388
208	07157900	2.679	.525	-.181	-.373	-.299
209	07165700	3.891	.438	-.390	-.140	-.298
210	07166000*	4.258	.448	-.039	-.114	-.089

Table 2.--*Summary of statistics of log-Pearson Type III distributions for streamflow-gaging stations on unregulated streams in Kansas*--Continued

Map number (fig. 1)	Station number	Mean	Standard deviation	Coefficient of skewness: Station (G_s)	Generalized (G_g)	Weighted (G_w)
211	07166200	3.102	0.324	-0.364	-0.378	-0.370
212	07166500*	4.209	.366	-.068	-.125	-.105
213	07166700	3.125	.369	.151	-.368	-.018
214	07167000	4.042	.483	-.264	-.156	-.213
215	07167500	3.868	.483	-.558	-.221	-.409
216	07168500*	4.202	.354	-.370	-.139	-.222
217	07169200	3.418	.265	-.431	-.407	-.421
218	07169500*	4.266	.293	-.294	-.141	-.215
219	07169700	2.691	.416	-.640	-.506	-.580
220	07169800	4.028	.340	-.126	-.246	-.165
221	07170000	4.103	.470	-.567	-.210	-.364
222	07170500*	4.517	.276	.090	-.121	.004
223	07170600	3.349	.281	-.026	-.425	-.148
224	07170700*	3.532	.271	.844	-.376	.289
225	07170800	3.040	.252	.135	-.524	-.078
226	07171700	2.823	.535	-1.167	-.561	-.717
227	07171800	2.064	.441	-1.001	-.666	-.763
228	07172000	4.110	.377	-1.212	-.287	-.683
229	07179500*	4.008	.410	.479	-.062	.271
230	07180000*	3.799	.337	-.264	-.079	-.200
231	07180300	1.993	.571	-.941	-.486	-.623
232	07180500	3.741	.358	-.522	-.163	-.397
233	07181000*	3.994	.266	.334	-.006	.163
234	07181500	3.852	.316	-.692	-.151	-.561
235	07182000*	4.018	.443	.231	.010	.160
236	07182400*	4.310	.385	.160	.044	.122
237	07182520	2.989	.401	-.440	-.320	-.391
238	07182600	3.484	.234	.184	-.227	-.069
239	07183000*	4.372	.342	.078	.012	.057
240	07183100	3.838	.378	.206	-.180	-.096
241	07183500*	4.417	.312	-.066	-.070	-.067
242	07183800	3.435	.404	-.416	-.417	-.417
243	07184000	3.768	.340	.117	-.272	-.102
244	07184500	3.857	.273	-.804	-.287	-.573
245	07184600	3.608	.512	-.145	-.432	-.335

The estimates of peak discharges having selected recurrence intervals for each of the 245 streamflow-gaging stations are shown in table 3. In some cases there appears to be inconsistencies in the values of peak discharges listed in table 3 for selected recurrence intervals for stations on the same stream. In particular, for some stations the discharges listed for selected recurrence intervals are less than the discharge listed for the same recurrence interval at stations located upstream. The primary reason for these differences is that data used to compute the distributions were collected during periods that are not completely concurrent. For example, records collected at the upstream station may contain an extremely large peak discharge that was not included in the other record.

ESTIMATING FLOOD MAGNITUDE FOR SELECTED FREQUENCIES AT UNGAGED SITES

Although information concerning flood magnitude and frequency is available at many streamflow-gaging-station locations in Kansas, often such information is needed at stream locations where insufficient or no data are available. Hence, there is a need to generalize the information on flood magnitude and frequency in order to extend the information to and facilitate estimates at ungaged locations. Regression analysis was used in this study to relate the magnitude of floods having selected recurrence intervals to various physical and climatic characteristics.

Regression Analysis

Based primarily on the results of studies by Benson (1962b) and Thomas and Benson (1970), multiple regression analysis has been the standard approach used by investigators to regionalize estimates of flood magnitude and frequency. These studies used an ordinary least-squares regression model (OLS). The OLS model minimizes the variance in a distribution of peak discharges having a selected recurrence interval as a function of selected physical and climatic characteristics. The OLS model is insensitive to the intercorrelation of the peak discharges at nearby stream locations and to the variations in accuracy of values of the dependent variable. Hence, use of the OLS model assumes that the peak discharges are not correlated and that the values of the dependent variable have no sampling error. It is acknowledged that the standard error of estimate computed by the OLS model is multifaceted and represents the sum of all the errors, including the sampling error and the model error.

Until recently, a technique was not available that could separate and evaluate these errors. However, Stedinger and Tasker (1985) have adapted the weighted least-squares model (WLS) for use with hydrologic data. As discussed earlier, the WLS model basically weights the error variances based on the length of station record. The WLS model is well adapted for analysis of flood magnitude and frequency because of its ability to separate the sampling error and the model error based on length of record. Hence, a WLS model was used to develop the final regression equations for estimating flood magnitudes for selected recurrence intervals.

Table 3.--*Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*

[All streamflows were unregulated during the period of record used in the analysis; * indicates those streams where flows presently are regulated]

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
1	06813700	251	594	887	1,310	1,650	2,010
2	06814000	5,460	11,500	16,800	24,900	31,800	39,600
3	06815700	2,030	2,600	2,960	3,420	3,750	4,080
4	06844700	38	358	1,090	3,420	6,980	13,100
5	06844900	391	1,260	2,360	4,640	7,210	10,800
6	06845000	841	2,480	4,460	8,450	12,900	18,900
7	06845100	340	842	1,320	2,100	2,800	3,610
8	06846000	521	1,260	2,010	3,290	4,510	6,010
9	06846200	328	796	1,210	1,830	2,350	2,920
10	06846500	507	1,250	2,100	3,770	5,590	8,070
11	06847600	162	507	877	1,520	2,120	2,820
12	06847900	645	1,780	3,030	5,340	7,690	10,700
13	06848000*	2,630	7,060	12,200	22,300	33,400	48,500
14	06848200	174	343	470	639	766	894
15	06848500*	2,230	4,960	7,750	12,700	17,700	24,100
16	06853800	1,390	2,610	3,650	5,250	6,660	8,270
17	06854000*	2,770	4,970	6,910	10,000	12,900	16,300
18	06854500*	13,200	27,600	42,500	69,500	97,400	134,000
19	06855800	1,520	3,140	4,760	7,620	10,500	14,100
20	06855900	912	1,770	2,490	3,560	4,460	5,460
21	06856000*	16,300	34,800	53,100	84,800	116,000	155,000
22	06856100	690	1,960	3,500	6,650	10,200	15,200
23	06856320	584	1,550	2,600	4,540	6,530	9,080
24	06856600*	12,700	25,600	38,200	60,200	81,900	109,000
25	06856800	395	907	1,340	1,960	2,470	3,000
26	06857000*	13,300	28,500	44,500	74,000	105,000	145,000
27	06858500	352	1,850	4,370	10,900	19,700	33,400
28	06858700	335	613	830	1,140	1,390	1,650
29	06859500	620	2,560	5,410	12,100	20,500	33,000
30	06860000	2,030	7,520	14,900	30,700	49,000	74,600
31	06860300	379	1,190	2,140	4,020	6,020	8,660
32	06860500	572	2,620	5,650	12,600	20,900	32,900
33	06861000	3,170	9,890	17,400	30,900	44,200	60,600
34	06863000*	1,460	3,870	6,510	11,400	16,500	23,000
35	06863300	1,290	4,390	8,290	16,300	25,200	37,200

Table 3.--*Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*--Continued

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
36	06863400	180	657	1,270	2,530	3,930	5,810
37	06863500	1,550	3,180	4,740	7,420	10,000	13,200
38	06863700	67	228	421	798	1,200	1,710
39	06863900	241	1,070	2,130	4,180	6,260	8,810
40	06864000*	7,720	15,500	21,800	31,100	38,800	47,100
41	06864300	175	450	725	1,190	1,640	2,170
42	06864500*	6,790	16,000	24,500	38,000	50,000	63,700
43	06864700	557	1,350	2,080	3,230	4,240	5,390
44	06865500*	11,700	20,800	28,400	40,100	50,500	62,400
45	06866000*	5,650	10,600	15,200	22,800	30,100	39,000
46	06866500*	5,080	10,700	16,400	26,400	36,600	49,500
47	06866800	196	679	1,260	2,390	3,570	5,080
48	06866900	3,120	8,800	15,000	26,200	37,400	51,400
49	06867000	3,000	7,740	12,500	20,400	27,900	36,700
50	06867500	943	3,160	5,790	10,900	16,100	22,900
51	06867800	129	224	297	398	480	566
52	06868000*	4,900	10,900	16,400	25,100	33,000	42,100
53	06868300	390	1,090	1,840	3,140	4,400	5,930
54	06868400	1,580	3,410	5,020	7,500	9,650	12,100
55	06868700	341	1,100	1,990	3,640	5,320	7,440
56	06868900	109	227	324	467	585	713
57	06869500*	3,080	6,650	9,830	14,800	19,200	24,100
58	06869950	2,390	4,610	6,430	9,100	11,300	13,800
59	06870300	2,410	4,560	6,350	9,010	11,300	13,800
60	06871000	1,980	5,400	9,070	15,700	22,300	30,500
61	06871500	1,030	2,830	4,880	8,780	12,900	18,300
62	06871800*	3,920	9,580	15,600	26,800	38,200	53,100
63	06871900	1,220	3,440	5,730	9,680	13,400	17,900
64	06872100	560	1,390	2,290	3,990	5,770	8,110
65	06872300	760	1,400	1,910	2,640	3,250	3,920
66	06872600	107	328	588	1,090	1,630	2,340
67	06873000	1,710	4,500	7,370	12,400	17,300	23,200
68	06873300	31	100	179	323	468	649
69	06873500*	3,290	10,300	18,900	35,800	54,200	78,800
70	06873700	182	1,150	2,880	7,460	13,600	22,900

Table 3.--*Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*--Continued

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
71	06873800	225	554	876	1,410	1,920	2,510
72	06874000*	3,110	7,410	12,000	20,400	29,100	40,400
73	06874500	572	1,220	1,800	2,710	3,510	4,430
74	06876000*	7,850	16,100	24,300	38,300	52,200	69,600
75	06876200	530	1,270	2,000	3,250	4,430	5,860
76	06876700	1,410	4,330	7,570	13,400	19,200	26,300
77	06876900*	6,360	12,400	18,000	27,500	36,600	47,700
78	06877000*	8,890	14,100	18,200	24,500	29,900	36,000
79	06877120	2,350	4,550	6,320	8,850	10,900	13,100
80	06877200	1,220	2,230	2,970	3,940	4,690	5,430
81	06877400	297	842	1,410	2,370	3,290	4,370
82	06877500	3,070	7,120	10,900	17,200	22,900	29,600
83	06877600*	14,700	24,600	32,200	43,000	51,800	61,300
84	06878000	3,600	7,020	10,200	15,400	20,300	26,300
85	06878500	6,870	18,600	30,100	48,900	65,800	85,000
86	06879200	5,230	9,990	14,000	20,100	25,300	31,300
87	06879700	953	2,030	2,950	4,300	5,430	6,650
88	06884100	155	480	845	1,520	2,190	3,030
89	06884200	4,530	8,260	11,200	15,500	19,000	22,800
90	06884300	417	754	1,030	1,450	1,820	2,220
91	06884400	12,600	21,300	28,000	37,600	45,500	54,100
92	06884500	11,500	24,000	35,400	54,000	71,100	91,200
93	06884900	2,010	4,090	5,820	8,390	10,500	12,900
94	06885500	7,550	16,400	24,600	37,900	50,100	64,500
95	06886000*	23,500	40,700	54,800	75,800	94,000	114,000
96	06886500	5,070	11,800	17,400	25,600	32,200	39,200
97	06887200	1,430	3,290	5,010	7,750	10,200	13,000
98	06887600	232	516	749	1,080	1,350	1,620
99	06888000	6,180	12,100	16,500	22,400	27,000	31,600
100	06888030	6,850	9,980	12,200	15,000	17,200	19,500
101	06888300	6,090	10,400	13,600	18,200	21,800	25,700
102	06888500	10,200	19,800	27,300	37,700	45,900	54,400
103	06888600	1,660	3,080	4,290	6,170	7,840	9,760
104	06888900	342	657	893	1,210	1,450	1,700
105	06889100	357	666	934	1,350	1,730	2,160

Table 3.-- *Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*--Continued

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
106	06889120	1,170	1,980	2,660	3,670	4,550	5,550
107	06889140	1,630	2,580	3,330	4,430	5,360	6,380
108	06889160	4,020	5,790	6,850	8,060	8,890	9,650
109	06889180	4,600	7,450	9,450	12,000	14,000	16,000
110	06889200	4,020	6,130	7,630	9,640	11,200	12,800
111	06889500	5,390	10,800	15,300	21,800	27,100	32,800
112	06889600	773	1,460	2,010	2,830	3,510	4,250
113	06890100	13,000	19,400	23,800	29,500	33,900	38,300
114	06890300	1,600	3,680	5,760	9,380	12,900	17,300
115	06890500	14,200	27,600	38,900	55,600	69,800	85,500
116	06890560	450	827	1,110	1,500	1,810	2,120
117	06890600	1,970	2,790	3,350	4,070	4,620	5,170
118	06890700	187	466	711	1,070	1,370	1,680
119	06890800	3,530	5,130	6,260	7,790	9,000	10,300
120	06891050	1,920	3,900	5,470	7,680	9,450	11,300
121	06891500*	6,240	12,000	16,500	22,700	27,800	33,000
122	06892000	5,520	9,750	13,200	18,200	22,400	27,100
123	06893080	4,040	5,840	7,020	8,470	9,520	10,600
124	06910800	8,540	15,800	22,200	32,500	42,000	53,200
125	06911000*	7,210	17,500	26,900	41,700	54,700	69,300
126	06911500	4,190	9,140	13,400	19,600	24,800	30,500
127	06911900	5,440	10,700	15,400	22,700	29,200	36,600
128	06912300	924	2,160	3,190	4,650	5,800	6,970
129	06912500*	7,330	15,200	21,300	29,600	36,000	42,600
130	06913000*	9,270	21,100	32,900	53,200	72,900	97,100
131	06913500*	11,200	25,200	39,000	62,800	86,000	114,000
132	06913600	786	1,910	2,920	4,470	5,780	7,220
133	06913700	2,910	4,530	5,740	7,450	8,850	10,300
134	06914000	11,400	21,000	28,900	40,600	50,500	61,500
135	06914250	209	353	456	592	696	801
136	06914500	12,900	25,000	35,600	52,400	67,500	85,000
137	06915000*	6,860	14,200	21,200	32,600	43,400	56,300
138	06915100	6,020	9,340	11,700	14,900	17,500	20,100
139	06916000*	19,800	39,600	57,500	86,400	113,000	144,000
140	06916700	617	1,260	1,750	2,400	2,890	3,380

Table 3.--*Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*--Continued

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
141	06917000	7,600	12,100	15,600	20,300	24,200	28,300
142	06917100	209	350	445	563	647	729
143	06917380	13,700	17,600	20,100	23,100	25,400	27,600
144	06917400	868	1,400	1,740	2,150	2,430	2,690
145	06917500	12,000	23,100	31,700	43,800	53,400	63,500
146	07138600	73	233	408	717	1,010	1,370
147	07138650	361	1,720	3,760	8,450	14,100	22,100
148	07138800	92	183	250	338	404	469
149	07139700	281	501	664	884	1,060	1,230
150	07139800	243	682	1,130	1,890	2,600	3,430
151	07140300	176	685	1,370	2,840	4,530	6,860
152	07140600	287	672	1,030	1,600	2,120	2,720
153	07140700*	416	1,260	2,180	3,840	5,470	7,460
154	07141200	2,490	4,890	7,070	10,600	13,900	17,900
155	07141400	56	108	146	194	228	262
156	07141600	93	426	892	1,890	3,000	4,480
157	07141780	1,130	2,790	4,390	7,050	9,490	12,300
158	07141800	429	1,060	1,650	2,600	3,430	4,380
159	07141900	1,610	3,280	4,730	6,960	8,910	11,100
160	07142100	401	1,150	1,910	3,200	4,400	5,800
161	07142300	408	1,470	2,900	6,030	9,730	15,000
162	07142500	303	1,170	2,270	4,490	6,840	9,890
163	07142575	756	1,780	2,870	4,860	6,920	9,600
164	07142700	1,220	2,270	3,090	4,240	5,160	6,140
165	07142860	648	1,820	3,050	5,230	7,350	9,940
166	07142900	1,080	2,510	3,780	5,750	7,440	9,320
167	07143100	131	215	275	355	417	481
168	07143200	521	959	1,330	1,880	2,360	2,890
169	07143300	2,110	5,200	8,430	14,300	20,100	27,500
170	07143500	936	1,360	1,620	1,930	2,140	2,340
171	07143600	1,130	2,240	3,250	4,870	6,350	8,090
172	07143665	6,410	11,000	14,600	19,500	23,600	27,800
173	07144000	3,410	9,000	14,600	24,000	32,800	43,100
174	07144200	5,890	13,200	19,600	29,000	36,900	45,500
175	07144780	3,340	10,300	18,600	34,800	52,200	75,000

Table 3.--*Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*--Continued

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
176	07144800*	3,710	9,050	14,100	22,200	29,400	37,700
177	07144850	615	1,340	1,950	2,840	3,580	4,370
178	07144900	320	568	739	953	1,110	1,260
179	07145200	6,250	13,500	19,700	28,900	36,800	45,400
180	07145300	608	1,010	1,270	1,590	1,820	2,040
181	07145500*	11,300	19,100	25,200	33,900	41,100	48,900
182	07145700	3,730	8,500	12,600	18,500	23,400	28,700
183	07145800	125	215	280	364	428	492
184	07146570	1,910	4,200	6,280	9,570	12,500	15,900
185	07146700	1,310	2,450	3,360	4,640	5,690	6,810
186	07147020	83	179	254	355	433	512
187	07147070	7,340	17,800	27,500	43,200	57,200	73,200
188	07147200	226	374	479	616	720	825
189	07147800*	19,500	38,600	54,500	78,200	98,300	120,000
190	07147990	464	1,490	2,560	4,340	5,950	7,770
191	07148100	7,500	15,900	23,700	36,500	48,300	62,300
192	07148700	272	938	1,700	3,080	4,420	6,050
193	07148800	140	508	912	1,590	2,210	2,910
194	07149000	4,290	7,590	10,100	13,700	16,500	19,500
195	07151500	8,650	18,800	27,500	40,500	51,500	63,400
196	07151600	1,140	2,220	3,050	4,180	5,060	5,970
197	07155590	2,730	5,040	6,890	9,550	11,800	14,100
198	07155900	165	1,100	2,780	7,090	12,700	21,000
199	07156000	762	2,420	4,270	7,590	10,900	14,800
200	07156010	908	3,170	6,020	11,800	18,100	26,600
201	07156220	977	4,090	8,460	18,100	29,300	45,000
202	07156600	533	1,560	2,550	4,110	5,440	6,880
203	07156700	294	640	937	1,380	1,760	2,170
204	07157100	643	1,780	2,940	4,880	6,680	8,770
205	07157400	356	1,630	3,290	6,530	9,830	13,900
206	07157500	1,680	4,680	7,750	13,000	17,900	23,700
207	07157700	358	711	987	1,370	1,670	1,990
208	07157900	507	1,340	2,150	3,480	4,690	6,080
209	07165700	8,180	18,400	27,300	40,800	52,400	65,000
210	07166000*	18,400	43,400	67,400	107,000	144,000	187,000

Table 3.--*Magnitude of peak discharges, in cubic feet per second, on unregulated streams in Kansas for selected recurrence intervals*--Continued

Map number (fig. 1)	Station number	Recurrence interval, in years					
		2	5	10	25	50	100
211	07166200	1,320	2,390	3,180	4,220	5,030	5,840
212	07166500*	16,400	33,100	47,300	68,700	87,300	108,000
213	07166700	1,340	2,730	3,950	5,870	7,570	9,510
214	07167000	11,500	28,400	44,600	71,100	95,300	123,000
215	07167500	7,960	19,100	28,900	43,800	56,300	69,800
216	07168500*	16,400	31,900	44,300	62,300	77,000	92,900
217	07169200	2,730	4,420	5,550	6,950	7,970	8,960
218	07169500*	18,900	32,800	43,100	57,100	68,200	79,600
219	07169700	538	1,120	1,550	2,140	2,580	3,020
220	07169800	10,900	20,700	28,700	40,200	49,700	60,000
221	07170000	13,500	32,000	48,300	73,100	94,200	117,000
222	07170500*	32,900	56,100	74,200	100,000	121,000	144,000
223	07170600	2,270	3,860	5,060	6,700	8,000	9,360
224	07170700*	3,300	5,690	7,690	10,800	13,500	16,500
225	07170800	1,100	1,790	2,290	2,970	3,510	4,080
226	07171700	770	1,910	2,850	4,130	5,100	6,060
227	07171800	132	277	381	512	605	693
228	07172000	14,200	27,100	36,000	47,100	55,000	62,400
229	07179500*	9,760	22,200	35,000	57,800	80,900	110,000
230	07180000*	6,470	12,200	16,700	23,200	28,500	34,200
231	07180300	113	304	475	727	930	1,140
232	07180500	5,820	11,100	15,200	20,700	25,000	29,300
233	07181000*	9,710	16,400	21,800	29,800	36,500	44,000
234	07181500	7,610	13,300	17,100	21,900	25,300	28,600
235	07182000*	10,100	24,400	39,200	65,800	92,500	126,000
236	07182400*	20,100	42,800	64,300	99,900	133,000	174,000
237	07182520	1,040	2,150	3,040	4,300	5,320	6,380
238	07182600	3,070	4,820	6,070	7,750	9,070	10,400
239	07183000*	23,400	45,600	64,900	94,800	121,000	152,000
240	07183100	6,980	14,400	20,800	30,700	39,400	49,100
241	07183500*	26,300	47,900	65,300	90,500	111,000	134,000
242	07183800	2,900	6,030	8,540	12,100	14,900	17,800
243	07184000	5,940	11,400	15,900	22,500	28,100	34,200
244	07184500	7,630	12,300	15,300	18,900	21,400	23,700
245	07184600	4,330	11,100	17,500	27,700	36,700	46,900

The WLS regression model in this study used base-10 logarithmic transformation for both dependent and independent variables. The form of the model equation is:

$$\log Q_T = \log a + b_1 \log X_1 + b_2 \log X_2 \; . \; . \; . \; . + b_n \log X_n, \qquad (3)$$

which is equivalent to:

$$Q_T = a \, X_1^{b_1} \, X_2^{b_2} \; . \; . \; . \; . \; X_n^{b_n} \, , \qquad (4)$$

where

Q_T is peak discharge for recurrence interval, T, in years (dependent variable);

X_1- X_n are the physical characteristics (independent variables);

a is the regression constant; and

b_1- b_n are the regression coefficients.

Variables Used in the Regression

The dependent variables used in the regression analysis were the peak discharges for selected recurrence intervals resulting from the analysis of flood magnitude and frequency at gaged stations, as discussed in a preceding section of this report and listed in table 3. Data for 218 of the 245 stations listed in table 3 that had contributing-drainage areas of less than 10,000 square miles were used in the regression analysis. Several pairs of gaging stations listed in table 3 are located on the same stream and in close proximity to each other. In this case, only the data for the station that had the longer, more reliable record were used in the analysis. The recurrence intervals selected were the 2, 5, 10, 25, 50, and 100 years, respectively. Separate equations were developed for each of the dependent variables.

The independent variables initially included in the regression equations were those physical and climatic characteristics identified as having a logical influence on the magnitude and frequency of floods and which were significantly important to regression equations developed in previous studies. The initial set of independent variables included contributing-drainage-area size (CDA), main-channel length, main-channel slope (S1), basin shape (Sh), which is equal to the square of the main-channel length divided by the contributing-drainage area (CDA) divided by the square of the main-channel length, gage latitude, gage longitude, mean annual precipitation, 2-year, 24-hour rainfall depth (I2), mean annual lake evaporation, and the soil-permeability index (SP). Distribution of the 2-year, 24-hour rainfall depth and generalized soil permeability are shown in figures 6 and 7, respectively.

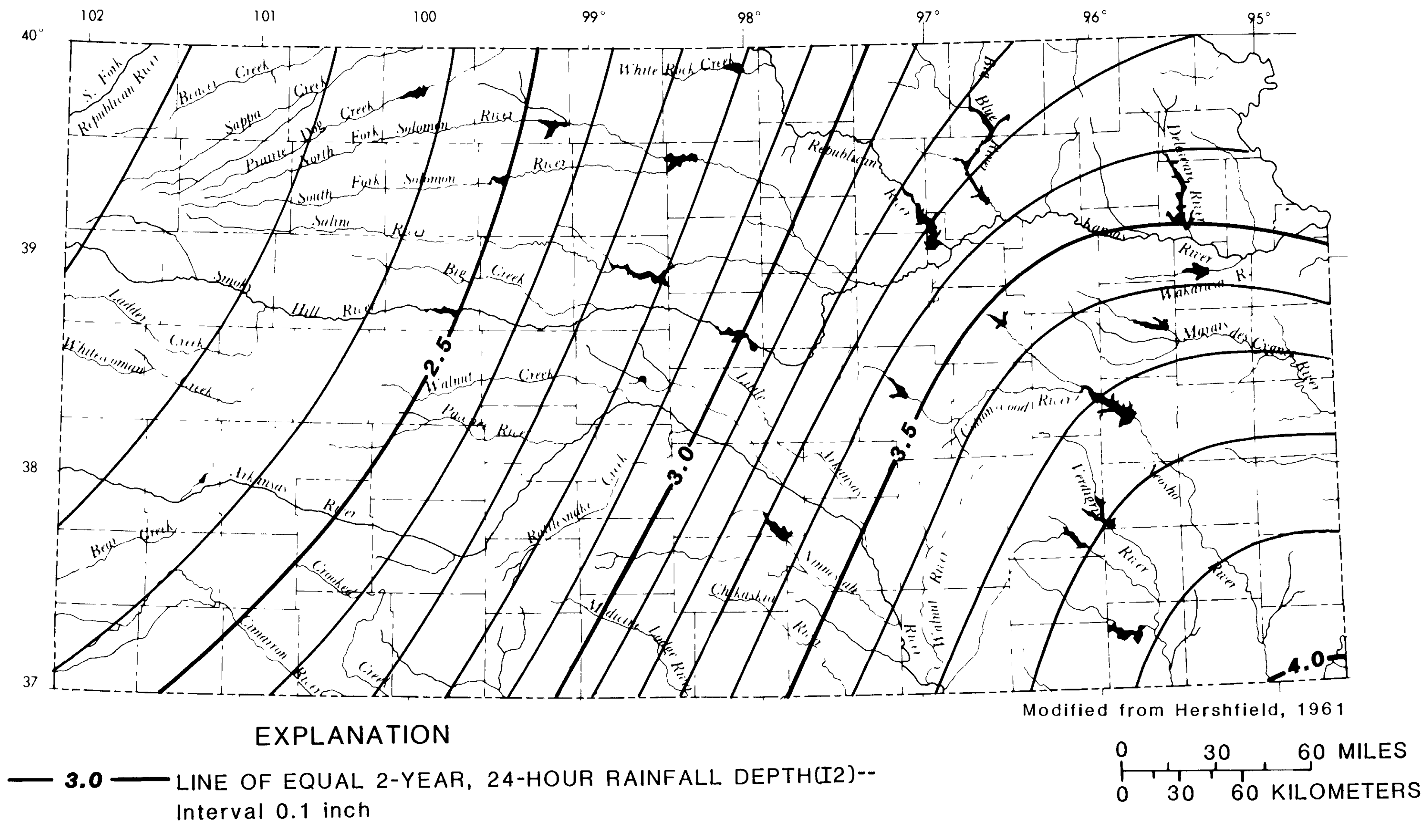


Figure 6.--Distribution of 24-hour rainfall for 2-year recurrence interval for Kansas.

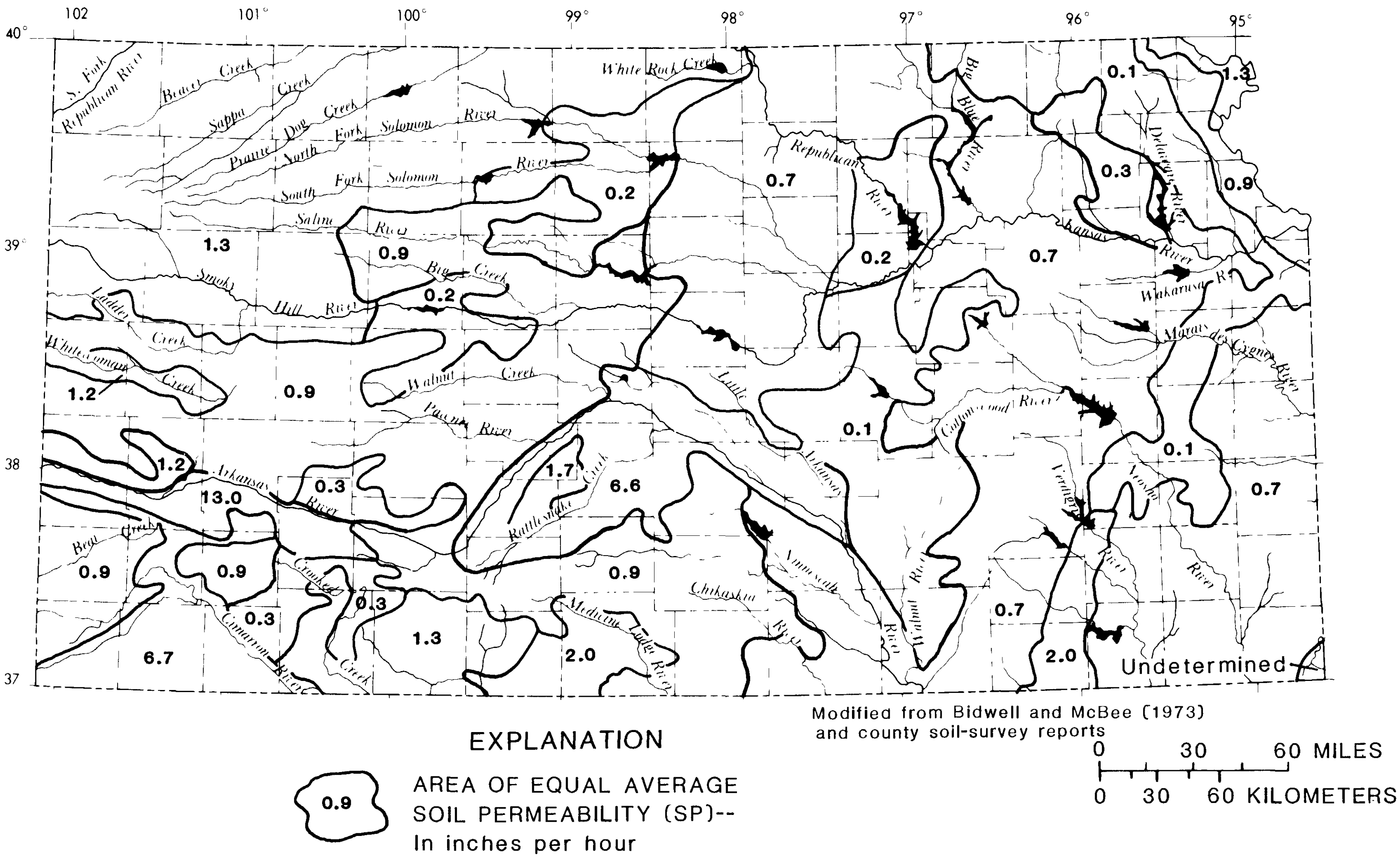


Figure 7.--Generalized soil-permeability values for Kansas.

Regression analysis relies on the assumption that independent variables are not greatly interrelated with each other. Violation of this rule generally results in regression coefficients that are unstable, and it becomes difficult to evaluate the interrelated variables' importance to the respective equations. Hence, a simple cross-correlation matrix was computed for all independent variables and was used in the analysis to identify variables that might pose problems if included in the same analyses. Pairs of variables having coefficients greater than 0.8 were considered greatly interrelated, were evaluated further in the initial analysis, and only the most significant variable was included in the final analysis.

Past experience of many investigators when analyzing streamflow discharges indicates that the relation between discharges and physical and climatic characteristics is more linear when the logarithms of the values are used in lieu of the normal (untransformed) values. This assumption is correct when analyzing the data for Kansas streams, as indicated from plots of peak discharges for selected recurrence intervals against the more significant physical and climatic characteristics. Hence, all variables used in the regression analysis, both dependent and independent, were converted to base-10 logarithms before the equations were computed.

Hauth (1974) found that the base-10 transformations did not linearize completely the relation between peak discharges and contributing-drainage area and, thus, used an additional transformation for drainage area. The resulting equation took the form:

$$\log Q_T = \log a + b_1 CDA^c \log CDA + \ldots \quad , \tag{5}$$

or

$$Q_T = a\ CDA^{b_1 CDA^c} \ldots \quad , \tag{6}$$

where the best results were obtained for Missouri stations by using $c = -0.02$.

Equation 5 was used with Kansas data in an attempt to further linearize the independent variable for contributing-drainage area in the regression. The results indicated that a value of $c = -0.04$ resulted in a smaller model error; hence, it was used in regressions for all recurrence intervals.

The ability of a regression equation to reliably estimate the magnitude of peak discharges having selected recurrence intervals is measured by the error of prediction. The error of prediction is the measure of confidence in the estimated peak discharge and describes the range where an estimate would fall two-thirds of the time. Computed in logarithmic units, the root-mean-square error of prediction can be expressed as a percentage.

Results of Regression Analysis

Regression analysis was performed and equations developed for peak-discharge magnitudes having recurrence intervals of 2, 5, 10, 25, 50, and 100 years. The results of the analysis are shown in table 4, which lists all of the equations for each of the six dependent variables (peak discharges). The root-mean-square errors of prediction for the most reliable equations ranged from 0.118 (28 percent) for the 10-year recurrence interval to 0.155 (36 percent) for the 100-year recurrence interval and 0.183 (42 percent) for the 2-year recurrence interval. Table 4 indicates all of the independent variables that were significant in each equation, their coefficients, the regression constant, and the errors of prediction.

The resulting WLS equations were compared to the equations previously developed by Jordan and Irza (1975). The errors of prediction for the WLS equations ranged from 28 to 42 percent, whereas the standard errors of estimate for the equations developed by Jordan and Irza (1975) ranged from 40.5 to 57 percent.

The two sets of equations were tested further to determine whether the WLS equations were significantly different than those computed by Jordan and Irza (1975). The previous equations used four independent variables, all of which were common to the independent variables used in the WLS equations. The method used in the test involved computing an F statistic for pairs of equations--WLS equations versus previous equations (1975) as applied to the same set of data.

$$F = \frac{(SSE_{T.75} - SSE_{T.c})/(NP1 - NP2)}{(SSE_{T.c})/(NS - NP1 - 1)} \qquad (7)$$

where

$SSE_{T.75}$ = sum of the squares of the differences (residuals) between Q_T and $\hat{Q}_{T.75}$;

$SSE_{T.c}$ = sum of the squares of the differences (residuals) between Q_T and $\hat{Q}_{T.c}$;

Q_T = peak magnitude having recurrence interval T, in years (table 3);

$\hat{Q}_{T.75}$ = peak magnitude having recurrence interval T, in years, estimated from equations of Jordan and Irza (1975);

$\hat{Q}_{T.c}$ = peak magnitude having recurrence interval T, in years, estimated from WLS equations (table 4);

NS = number of stations used to compute the residuals = 218;

NP1 = number of independent variables in WLS equations = 5; and

NP2 = number of independent variables in equations developed by Jordan and Irza (1975) = 4.

Table 4.--*Weighted least-squares regression equations for describing the magnitude of peak discharges for selected recurrence intervals on unregulated streams in Kansas*

[All variables are significant to the following equation at the 5-percent level except where noted: a, 10-percent level; b, 25-percent level; and c, greater than 50-percent level

$$(Q_T = a\ CDA^{b_1 CDA^{-0.04}}\ I2^{b_2}\ Sl^{b_3}\ SP^{b_4}\ Sh^{b_5}).$$

Q is the magnitude of peak discharges having recurrence interval, T, in years]

Q_T	Regression constant a	Regression coefficients b_1	b_2	b_3	b_4	b_5	Error of prediction (percent)
Q_2	0.054	0.867	5.771	0.344	-	-	43
	.067	.873	5.496	.343	-0.149	-	42
	.135	.878	5.321	.286	- .147	-0.134	42
Q_5	2.33	0.704	4.368	-	-	-	34
	.500	.842	4.653	0.315	-	-	32
	.571	.855	4.405	.327	-0.159	-	30
	1.000	.860	4.195	.282	- .157	-0.112	30
Q_{10}	6.34	0.707	3.838	-	-	-	32
	1.40	.843	4.120	0.305	-	-	30
	1.56	.868	3.885	.319	-0.158	-	28
	2.51	.862	3.710	.281	- .156	-0.094 a	28
Q_{25}	17.8	0.714	3.282	-	-	-	34
	4.12	.848	3.556	0.293	-	-	32
	4.43	.864	3.339	.310	-0.156	-	29
	6.48	.867	3.201	.279	- .153	-0.075 b	30
Q_{50}	34.1	0.721	2.922	-	-	-	36
	8.23	.852	3.186	0.284	-	-	34
	8.69	.869	2.980	.303	-0.156	-	33
	12.1	.871	2.863	.276	- .153	-0.065 c	33
Q_{100}	61.0	0.727	2.597	-	-	-	40
	15.3	.856	2.851	0.275	-	-	38
	16.0	.873	2.651	.295	-0.156	-	36
	21.2	.874	2.552	.272	- .154	-0.056 c	36

The F statistic was computed for peak magnitudes having recurrence intervals listed in table 3 and used the equation that had the smallest standard error of estimate in the case of the 1975 equations and the equation that had the smallest error of prediction in the case of the WLS results for each recurrence interval. The resulting F statistics ranged from 34.8 to 50.5, and all were greater than the critical F value of 7.9 for 1 and 212 degrees of freedom at the 0.5-percent level of significance. Hence, the analyses indicated that the WLS equations are more reliable and significantly different than those developed by Jordan and Irza (1975).

Use of Regression Equations

The WLS regression equations shown in table 4 may be used to estimate the magnitude of peak discharges for specific recurrence intervals at ungaged sites by determining the values of the physical and climatic characteristics relative to the site and substituting the values into the respective equation. The value for contributing-drainage area (CDA) can be determined from topographic maps by planimetric or grid-counting methods. The values for the 2-year, 24-hour rainfall depth (I2) and for soil permeability (SP) can be determined from figures 6 and 7, respectively. Main-channel slope (Sl), and basin shape (Sh) are computed as a function of main-channel length, which is the length of the main channel, in miles, from the site to the basin divide of the contributing drainage. The main-channel slope (Sl), in feet per mile, is equal to the difference in elevations, in feet, between points located 85- and 10-percent of the main-channel distance. The dimensionless basin shape (Sh) is equal to the square of the main-channel length, in miles, divided by the size of the contributing-drainage area (CDA), in square miles. Values for elevation and main-channel length should be determined from topographic maps.

The equations shown in table 4 were developed using data from streams that are located in rural settings, whose contributing-drainage areas range in size from 0.17 to about 10,000 square miles, and whose flows were unregulated during the period of record used for the study. Hence, the equations should not be used to estimate flood magnitudes if the watershed is not predominately rural, if the contributing-drainage area is larger than 10,000 square miles, or if the present streamflow is affected by regulation.

At times, estimates of flood magnitude and frequency may be desired at a site located on the same stream and in the vicinity of a streamflow-gaging station where flood-frequency characteristics have been determined from available streamflow data. In order to make the most accurate estimate possible, it is desirable to use information from both the streamflow data and that provided by the regression equation by weighting the respective estimates. Jordan (1986) has developed a technique that computes a weighted estimate based on ratios of contributing-drainage areas and of the estimates of peak discharge computed from the streamflow data and from the regression equation as applied to the gaged location. The algorithm suggested by Jordan (1986) is:

$$Q_{wu} = W_E\ Q_{Eu} + W_g\ R_g\ Q_{Eu}, \qquad (8)$$

where

Q_{wu} = weighted estimate of discharge at the ungaged location;

$$W_E = 0.5 - 0.5 \cos\left(4.53 \ln \frac{A_u}{A_g}\right) \qquad (9)$$

is a weighting factor for Q_{Eu}, where A_u and A_g are the contributing-drainage areas at the ungaged and gaged locations, respectively, and where the ratio A_u/A_g is greater than 0.5 and less than 2.0 and the expression in parentheses is interpreted as an angle in radians.

W_E can be determined directly from curve shown in figure 8;

Q_{Eu} = the peak discharge computed from the regression equation (table 4) at the ungaged location;

W_g = 1.0 - W_E, weighting factor for R_g; and

R_g = Q_{gg}/Q_{Eg}, is an adjustment factor equal to the peak discharge, Q_{gg}, computed from the streamflow data (table 3) divided by the peak discharge, Q_{Eg}, computed from the regression equation (table 4) for the gaged location.

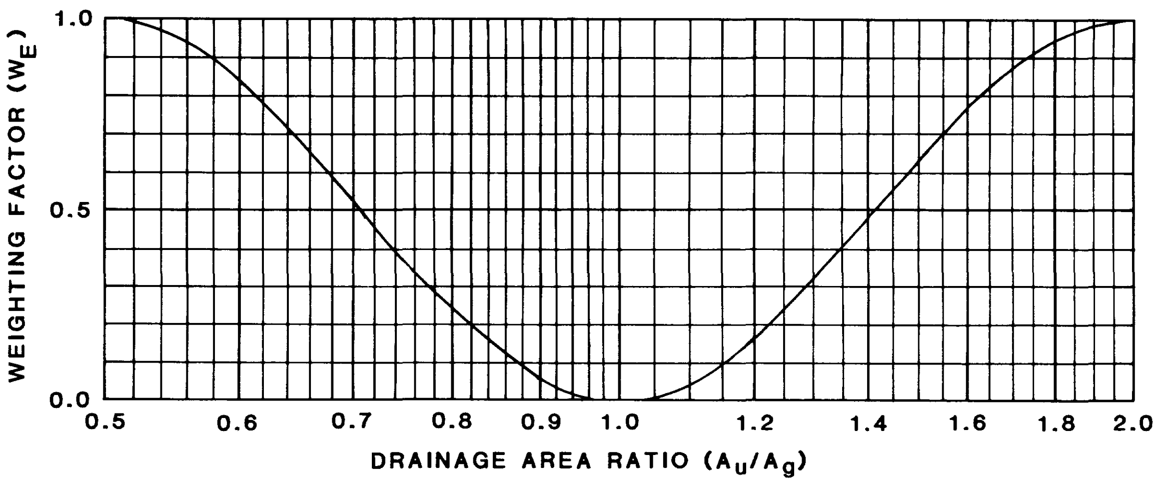


Figure 8.--Graph for interpolating weighting factor for an ungaged site on a gaged stream (from Jordan, 1986).

SUMMARY

Estimates of flood magnitudes for selected recurrence intervals were computed by using data collected through the 1983 water year for 245 streamflow-gaging stations in Kansas. Log-Pearson Type III distributions were computed by using techniques recommended by the U.S. Water Resources Council. The distributions were adjusted for the effects of low- and highoutlier data and for historic data. The computed values of station skewness from the adjusted distributions were generalized by using a weighted least-squares regression model (WLS) that adjusts for the bias caused by varying lengths of streamflow-gaging-station records. The root-mean-square error of the estimates of generalalized skewness was 0.35 compared to the root-mean-square error of 0.55 from the U.S. Water Resources Council skewness map. Finally, flood magnitudes were computed for selected recurrence intervals. The final computations used estimates of general skewness from the WLS regression equation and weighted them with the station skewness.

Regression equations were computed for flood magnitudes that have selected recurrence intervals by using the WLS model to relate the flood magnitudes to selected physical and climatic characteristics. The errors of prediction of the most reliable regression equations ranged from 28 percent for floods that have a recurrence interval of 10 years to 36 percent for a recurrence interval of 100 years and 42 percent for a recurrence interval of 2 years.

The WLS regression equations were compared to those developed by Jordan and Irza (1975) by evaluating the errors of estimate and the respective errors as the equations were applied to the same set of data. The analysis indicated that the WLS equations resulted in smaller errors than did the equations developed by Jordan and Irza (1975). An additional analysis was conducted to determine if there was significant difference in the two sets of equations. An analysis of the F statistic indicated that the two sets of equations were significantly different at the 0.5-percent level. Hence, the set of WLS equations presented in this report are considered to be more reliable than any previous methods for estimating flood magnitudes for selected recurrence intervals at ungaged sites in Kansas.

REFERENCES CITED

Benson, M.A., 1962a, Evolution of methods for evaluating the occurrence of floods: U.S. Geological Survey Water-Supply Paper 1580-A, 30 p.

_____1962b, Factors influencing the occurrence of floods in a humid region of diverse terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Benson, M.A., and Dalrymple, Tate, 1967, General field and office procedures for indirect discharge measurements: U.S. Geological Survey Techniques Water-Resources Investigations, Book 3, Chapter A1, 30 p.

Bidwell, O.W., and McBee, C.W., 1973, Soils of Kansas (map): Kansas Agriculture Experiment Station Contribution No. 1359, scale 1:1,125,000, 1 sheet.

Bodhaine, G.L., 1968, Measurement of peak discharge at culverts by indirect methods: U.S. Geological Survey Techniques Water-Resources Investigations, Book 3, Chapter A3, 60 p.

Clement, R.W., 1983, Improvement of flood-frequency estimates for selected small watersheds in eastern Kansas using a rainfall-runoff model: U.S. Geological Survey Water-Resources Investigations Report 83-4110, 22 p.

Clement, R.W., and Johnson, D.G., 1982, Flood of June 15, 1981, in Great Bend and vicinity, central Kansas: U.S. Geological Survey Water-Resources Investigations Report 82-4123, 9 p.

Crippen, J.R., and Bue, C.D., 1977, Maximum floodflows in the conterminous United States: U.S. Geological Survey Water-Supply Paper 1887, 52 p.

Dalrymple, Tate, and Benson, M.A., 1967, Measurement of peak discharge by the slope-area method: U.S. Geological Survey Techniques Water-Resources Investigations, Book 3, Chapter A2, 12 p.

Ellis, D.W. and Edelen, G.W., Jr., 1960, Kansas streamflow characteristics part 3, Flood frequency: Kansas Water Resources Board Technical Report No. 3, 221 p.

Farnsworth, R.K., Thompson, E.S., and Peck, E.L., 1982, Evaporation atlas for the contiguous 48 United States: U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Report NWS 33, 26 p.

Foster, H.A., 1924, Theoretical frequency curves: Transactions of American Society of Civil Engineers, v. 89, p. 142-203.

Hardison, C.H., 1969, Accuracy of streamflow characteristics, _in_ Geological Survey Research, 1969: U.S. Geological Survey Professional Paper 650-D, p. D210-214.

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

Hedman, E.R., Kastner, W.M., and Hejl, H.R., 1974, Kansas streamflow characteristics--Part 10, Selected streamflow characteristics as related to active-channel geometry of streams in Kansas: Kansas Water Resources Board Technical Report No. 10, 21 p.

Hershfield, D.M., 1961, Rainfall frequency atlas of the United States: U.S. Department of Commerce, Weather Bureau Technical Paper 40, 115 p.

House Document 465, 1966, A unified national program for managing flood losses, 89th Congress, 2d session: U.S. Government Printing Office, 47 p.

Hulsing, Harry, 1967, Measurement of peak discharge at dams by indirect methods: U.S. Geological Survey Techniques Water-Resources Investigations, Book 3, Chapter A5, 29 p.

Irza, T.J., 1966, Preliminary flood-frequency relations for small streams in Kansas: U.S. Geological Survey open-file report, 19 p.

Jordan, P.R., 1986, Magnitude and frequency of high flows of unregulated streams in Kansas: U.S. Geological Survey Water-Supply Paper 2280, 35 p.

Jordan, P.R., and Irza, T.J., 1975, Kansas streamflow characteristics--Magnitude and frequency of floods in Kansas, unregulated streams: Kansas Water Resources Board Technical Report No. 11, 34 p.

Matthai, H.F., 1967, Measurement of peak discharge at width contractions by indirect methods: U.S. Geological Survey Techniques Water-Resources Investigations, Book 3, Chapter A4, 44 p.

_____1968, Magnitude and frequency of floods in the United States--part 6-B, Missouri River basin below Sioux City, Iowa: U.S. Geological Survey Water-Supply Paper 1680, 491 p.

McCuen, R.H., 1979, Map skew ???: American Society of Civil Engineers, Journal of the Water Resources Planning and Management Division, v. 105, no. WR2, p. 269-277.

Patterson, J.L., 1964, Magnitude and frequency of floods in the United States--part 7, Lower Mississippi River basin: U.S. Geological Survey Water-Supply Paper 1681, 636 p.

Schoewe, W.H., 1949, The geography of Kansas--part 2, Physical geography: Transactions of the Kansas Academy of Science, v. 52, no. 3, p. 261-333.

Stedinger, J.R., and Tasker, G.D., 1985, Regional hydrologic regression--1. Regression analysis with ordinary, weighted, and generalized least squares compared: Water Resources Research, v. 21, no. 9, p. 1421-1432.

Tasker, G.D., and Stedinger, J.R., 1986, Regional skew with weighted least squares regression: American Society of Civil Engineers, Journal of Water Resources Planning and Management, v. 112, no. 2, p. 225-237.

Thomas, D.M., and Benson, M.A., 1970, Generalization of streamflow characteristics from drainage-basin characteristics: U.S. Geological Survey Water-Supply Paper 1975, 55 p.

U.S. Geological Survey, Water resources data for Kansas: U.S. Geological Survey Water-Data Report (published annually).

U.S. Water Resources Council, 1967, A uniform technique for determining flood flow frequency: Washington, D.C., Bulletin 15 of the Hydrology Committee, 15 p.

______1976, Guidelines for determining flood flow frequency: Washington, D.C., Bulletin 17 of the Hydrology Committee, 26 p.

______1977, Guidelines for determining flood flow frequency: Washington, D.C., Bulletin 17A of the Hydrology Committee, 26 p.

______1981, Guidelines for determining flood flow frequency: Washington, D.C., Bulletin 17B of the Hydrology Committee, 28 p.

Table 5.--*Physical and climatic characteristics used in regression analyses for streamflow-gaging stations used in the study*

[All gaging stations are located in Kansas; * indicates stations whose records of annual peak discharges were synthesized using a rainfall-runoff model]

Map number (fig.1)	Station number	Station name	CDA[1/] (square miles)	Sl[2/] (feet per mile)	Sh[3/] (dimensionless)	Lat[4/] (degrees)	I2[5/] (inches)	SP[6/] (inches per hour)
1	06813700*	Tennessee Creek tributary near Seneca	0.9	62.1	3.44	39.812	3.30	0.1
2	06814000	Turkey Creek near Seneca	276	5.89	11.1	39.947	3.20	.1
3	06815700*	Buttermilk Creek near Willis	3.74	67.2	3.27	39.754	3.40	.9
4	06844700	South Fork Sappa Creek near Brewster	74	10.8	8.17	39.285	2.25	1.3
5	06844900	South Fork Sappa Creek near Achilles	378	7.00	35.0	39.676	2.30	1.3
6	06845000	Sappa Creek near Oberlin	900	7.33	19.5	39.785	2.29	1.3
7	06845100	Long Branch Draw near Norcatur	31.7	12.8	8.48	39.901	2.40	1.3
8	06846000	Beaver Creek at Ludell	1,117	8.11	13.5	39.848	2.20	1.3
9	06846200	Beaver Creek tributary near Ludell	10.2	33.2	3.79	39.814	2.30	1.3
10	06846500	Beaver Creek at Cedar Bluffs	1,324	7.72	20.2	39.985	2.24	1.3
11	06847600*	Prairie Dog Creek tributary at Colby	7.53	16.7	3.45	39.391	2.30	1.3
12	06847900	Prairie Dog Creek above Keith Sebelius Lake	590	7.11	33.1	39.770	2.30	1.3
13	06848000	Prairie Dog Creek at Norton	689	7.03	35.5	39.810	2.37	1.3
14	06848200	Prairie Dog Creek tributary near Norton	1.02	67.8	5.64	39.854	2.40	.7
15	06848500	Prairie Dog Creek near Woodruff	1,000	5.61	45.0	39.985	2.37	1.3
16	06853800	White Rock Creek near Burr Oak	227	6.95	7.15	39.898	2.70	1.3
17	06854000	White Rock Creek at Lovewell	345	6.12	9.75	39.886	2.80	1.0
18	06854500	Republican River at Scandia	15,403	--	8.60	39.797	2.90	--
19	06855800	Buffalo Creek near Jamestown	330	6.15	7.57	39.615	2.90	.6
20	06855900	Wolf Creek near Concordia	56	8.79	6.44	39.543	3.00	.7
21	06856000	Republican River at Concordia	16,060	--	9.33	39.590	2.30	--
22	06856100	West Creek near Talmo	42	7.07	29.3	39.666	3.00	.7
23	06856320	Elk Creek at Clyde	73	11.0	9.02	39.594	3.00	.7
24	06856600	Republican River at Clay Center	17,042	--	11.3	39.355	2.30	--
25	06856800*	Moll Creek near Green	3.6	20.4	6.66	39.380	3.20	.2
26	06857000	Republican River at Milford	17,400	--	12.1	39.164	2.30	--
27	06858500	North Fork Smoky Hill River near McAllaster	650	7.84	49.4	39.016	2.20	1.3
28	06858700	North Fork Smoky Hill River tributary near Winona	1.13	69.2	2.77	39.030	2.30	1.3
29	06859500	Ladder Creek below Chalk Creek near Scott City	1,333	6.87	34.1	38.788	2.30	1.2
30	06860000	Smoky Hill River at Elkader	3,390	13.2	6.27	38.792	2.24	1.3
31	06860300	South Branch Hackberry Creek near Orion	49.6	9.34	20.2	38.941	2.40	1.3
32	06860500	Hackberry Creek near Gove	421	6.71	26.5	38.954	2.30	1.3
33	06861000	Smoky Hill River near Arnold	5,220	11.4	7.20	38.808	2.30	1.2
34	06863000	Smoky Hill River at Pfeifer	6,070	10.3	10.7	38.714	2.67	--
35	06863300	Big Creek near Ogallah	297	5.50	48.5	38.911	2.40	.9
36	06863400	Big Creek tributary near Ogallah	4.81	15.8	13.1	38.933	2.50	.9
37	06863500	Big Creek near Hays	594	5.82	51.0	38.812	2.49	.6
38	06863700	Big Creek tributary near Hays	6.19	14.8	18.5	38.852	2.60	.7
39	06863900	North Fork Big Creek near Victoria	54	8.30	14.3	38.886	2.60	.9
40	06864000	Smoky Hill River near Russell	6,965	9.70	11.2	38.776	2.30	--
41	06864300*	Smoky Hill River tributary at Dorrance	5.39	24.8	3.35	38.847	2.80	.9
42	06864500	Smoky Hill River at Ellsworth	7,580	8.95	14.1	38.726	2.37	1.0
43	06864700*	Spring Creek near Kanopolis	9.84	17.8	8.80	38.739	3.00	.7
44	06865500	Smoky Hill River near Langley	7,857	8.28	16.2	38.610	2.40	--
45	06866000	Smoky Hill River at Lindsborg	8,110	7.41	19.1	38.565	2.40	.9
46	06866500	Smoky Hill River near Mentor	8,358	6.65	22.3	38.798	2.40	--
47	06866800	Saline River tributary at Collyer	3.13	33.2	4.37	39.046	2.40	.2
48	06866900	Saline River near WaKeeney	696	7.17	38.1	39.106	2.30	1.1
49	06867000	Saline River near Russell	1,502	6.86	51.4	38.966	2.40	.8
50	06867500	Paradise Creek near Paradise	212	7.29	27.0	39.073	2.70	.3
51	06867800	Cedar Creek tributary near Bunker Hill	.99	99.3	1.89	38.934	2.80	.9
52	06868000	Saline River near Wilson	1,900	6.28	52.0	38.933	2.48	.8
53	06868300	Coon Creek tributary near Luray	6.53	43.2	4.46	39.175	2.70	.2
54	06868400	Wolf Creek near Lucas	163	16.4	2.91	39.058	2.80	.7
55	06868700	North Branch Spillman Creek near Ash Grove	26.1	14.0	8.16	39.152	2.80	.8

Table 5.--*Physical and climatic characteristics used in regression analyses for streamflow-gaging stations used in the study*--Continued

Map number (fig.1)	Station number	Station name	CDA[1]/ (square miles)	Sl[2]/ (feet per mile)	Sh[3]/ (dimensionless)	Lat[4]/ (degrees)	I2[5]/ (inches)	SP[6]/ (inches per hour)
56	06868900*	Bullfoot Creek tributary near Lincoln	2.64	31.0	11.4	38.974	2.90	0.7
57	06869500	Saline River at Tescott	2,820	5.02	52.5	39.004	2.56	.9
58	06869950	Mulberry Creek near Salina	250	9.67	5.80	38.844	3.00	.7
59	06870300	Gypsum Creek near Gypsum	120	9.54	6.39	38.653	3.30	.6
60	06871000	North Fork Solomon River at Glade	849	7.79	50.4	39.677	2.40	1.3
61	06871500	Bow Creek near Stockton	341	6.73	44.6	39.562	2.45	1.3
62	06871800	North Fork Solomon River at Kirwin	1,367	7.60	36.3	39.660	2.44	1.3
63	06871900	Deer Creek near Phillipsburg	65	16.5	7.04	39.780	2.50	1.3
64	06872100	Middle Cedar Creek at Kensington	58.9	8.61	16.4	39.755	2.60	1.3
65	06872300	Middle Beaver Creek near Smith Center	71	11.1	11.0	39.800	2.60	1.3
66	06872600	Oak Creek at Bellaire	4.75	22.0	8.89	39.798	2.70	.8
67	06873000	South Fork Solomon River above Webster Reservoir	1,035	8.29	32.3	39.373	2.40	1.3
68	06873300	Ash Creek tributary near Stockton	.89	58.9	3.97	39.437	2.50	1.3
69	06873500	South Fork Solomon River at Alton	1,678	8.38	32.4	39.459	2.43	1.2
70	06873700	Kill Creek near Bloomington	52	10.9	11.7	39.379	2.63	.3
71	06873800	Kill Creek tributary near Bloomington	1.45	23.9	30.9	39.399	2.70	.2
72	06874000	South Fork Solomon River at Osborne	2,012	7.93	34.2	39.428	2.40	1.2
73	06874500	East Fork Limestone Creek near Ionia	25.6	11.8	13.2	39.697	2.80	.2
74	06876000	Solomon River at Beloit	5,530	6.30	19.7	39.419	2.51	1.0
75	06876200	Middle Pipe Creek near Miltonvale	10.2	29.6	5.23	39.350	3.00	.7
76	06876700	Salt Creek near Ada	384	4.65	14.1	39.141	2.90	.7
77	06876900	Solomon River at Niles	6,770	5.23	21.4	38.968	2.60	.9
78	06877000	Smoky Hill River at Solomon	18,830	5.70	11.9	38.900	2.70	--
79	06877120	Mud Creek at Abilene	87	6.09	6.53	38.929	3.20	.2
80	06877200	West Fork Turkey Creek near Elmo	26.6	12.2	6.36	38.667	3.30	.7
81	06877400	Turkey Creek tributary near Elmo	2.48	26.3	8.79	38.682	3.30	.1
82	06877500	Turkey Creek near Abilene	143	6.67	8.37	38.806	3.30	.1
83	06877600	Smoky Hill River at Enterprise	19,260	5.68	12.8	38.906	2.50	--
84	06878000	Chapman Creek near Chapman	300	4.25	11.2	39.031	3.20	.4
85	06878500	Lyon Creek near Woodbine	230	5.45	10.5	38.884	3.40	.5
86	06879200	Clark Creek near Junction City	200	6.12	14.0	39.007	3.40	.5
87	06879700	Wildcat Creek at Riley	14	10.2	7.95	39.292	3.30	.2
88	06884100	Mulberry Creek tributary near Haddam	1.64	52.0	2.89	39.813	3.10	.7
89	06884200	Mill Creek at Washington	349	4.58	11.3	39.813	3.00	.7
90	06884300	Mill Creek tributary near Washington	3.2	52.4	2.45	39.813	3.10	.7
91	06884400	Little Blue River near Barnes	3,324	4.33	16.7	39.775	2.80	.9
92	06884500	Little Blue River at Waterville	3,514	4.26	17.4	39.777	2.80	.9
93	06884900	Robidoux Creek at Beattie	40	13.5	7.52	39.863	3.20	.1
94	06885500	Black Vermillion River near Frankfort	410	5.72	3.96	39.684	3.20	.2
95	06886000	Big Blue River at Randolph	9,100	2.69	7.71	39.450	2.90	.5
96	06886500	Fancy Creek at Winkler	174	8.40	8.29	39.472	3.20	.4
97	06887200	Cedar Creek near Manhattan	13.4	37.6	5.67	39.258	3.40	.7
98	06887600*	Kansas River tributary near Wamego	.83	96.4	4.08	39.174	3.40	.7
99	06888000	Vermillion Creek near Wamego	243	5.50	8.03	39.350	3.33	.6
100	06888030	Vermillion Creek near Louisville	297	4.63	10.7	39.278	3.30	.6
101	06888300	Rock Creek near Louisville	128	10.6	8.10	39.264	3.30	.7
102	06888500	Mill Creek near Paxico	316	10.5	5.08	39.062	3.50	.6
103	06888600	Dry Creek near Maple Hill	15.6	16.8	5.78	39.051	3.50	.7
104	06888900*	Blacksmith Creek tributary near Valencia	1.31	65.9	2.33	39.022	3.50	.7
105	06889100	Soldier Creek near Goff	2.06	25.1	4.19	39.624	3.30	.3
106	06889120	Soldier Creek near Bancroft	10.5	18.0	3.70	39.595	3.30	.3
107	06889140	Soldier Creek near Soldier	16.9	14.6	5.10	39.565	3.30	.3
108	06889160	Soldier Creek near Circleville	49.3	10.8	8.27	39.463	3.40	.4
109	06889180	Soldier Creek near St. Clere	80	9.20	12.2	39.375	3.40	.5
110	06889200	Soldier Creek near Delia	159	6.56	19.0	39.202	3.40	.6
111	06889500	Soldier Creek near Topeka	290	5.55	17.4	39.100	3.42	.5
112	06889600	South Branch Shunganunga Creek near Pauline	3.84	18.3	3.74	38.978	3.30	.7
113	06890100	Delaware River near Muscotah	431	5.80	6.37	39.521	3.40	.1
114	06890300	Spring Creek near Wetmore	21	20.2	5.11	39.636	3.30	.3
115	06890500	Delaware River at Valley Falls	922	4.63	5.10	39.350	3.35	.15

Table 5.--*Physical and climatic characteristics used in regression analyses for streamflow-gaging stations used in the study*--Continued

Map number (fig.1)	Station number	Station name	CDA[1/] (square miles)	Sl[2/] (feet per mile)	Sh[3/] (dimensionless)	Lat[4/] (degrees)	I2[5/] (inches)	SP[6/] (inches per hour)
116	D6890560	Rock Creek 6 miles North Fork of Meriden	1.98	51.7	3.04	39.288	3.40	0.3
117	06890600	Rock Creek near Meriden	22	11.9	7.44	39.192	3.50	.3
118	06890700*	Slough Creek tributary near Oskaloosa	.83	59.4	2.46	39.201	3.50	.1
119	06890800	Slough Creek near Oskaloosa	31	13.3	3.91	39.223	3.50	.4
120	06891050	Stone House Creek at Williamstown	12.9	34.7	4.09	39.066	3.50	.7
121	06891500	Wakarusa River near Lawrence	425	3.78	11.6	38.911	3.56	.7
122	06892000	Stranger Creek near Tonganoxie	406	2.86	13.4	39.116	3.43	.3
123	06893080	Blue River near Stanley	46	15.0	3.34	38.812	3.60	.7
124	06910800	Marais Des Cygnes River near Reading	177	6.21	10.8	38.566	3.60	.7
125	06911000	Marais Des Cygnes River at Melvern	351	4.17	16.1	38.515	3.62	.7
126	06911500	Salt Creek near Lyndon	111	5.80	13.0	38.608	3.59	.7
127	06911900	Dragoon Creek near Burlingame	114	6.63	13.5	38.708	3.60	.7
128	06912300*	Dragoon Creek tributary near Lyndon	3.76	36.1	2.20	38.692	3.60	.7
129	06912500	Hundred and Ten Mile Creek near Quenemo	322	6.70	3.59	38.644	3.59	.7
130	06913000	Marais Des Cygnes River near Pomona	1,040	3.41	10.4	38.584	3.60	.7
131	06913500	Marais Des Cygnes River near Ottawa	1,250	2.84	12.3	38.616	3.61	.6
132	06913600*	Rock Creek near Ottawa	10.2	12.0	5.79	38.554	3.60	.7
133	06913700	Middle Creek near Princeton	52	8.74	4.56	38.477	3.70	.7
134	06914000	Pottawatomie Creek near Garnett	334	4.40	7.48	38.333	3.70	.3
135	06914250	South Fork Pottawatomie Creek tributary near Garner	.35	125	2.52	38.233	3.70	.4
136	06914500	Pottawatomie Creek at Lane	513	3.27	10.3	38.443	3.75	.4
137	06915000	Big Bull Creek near Hillsdale	147	8.12	3.98	38.636	3.60	.2
138	06915100	Big Bull Creek at Paola	230	4.26	4.00	38.576	3.60	.6
139	06916000	Marais Des Cygnes River at Trading Post	2,880	2.08	15.0	38.250	3.65	.6
140	06916700*	Middle Creek near Kincaid	2.02	36.2	2.28	38.056	3.80	.1
141	06917000	Little Osage River at Fulton	295	4.97	8.99	38.019	3.80	.7
142	06917100	Marmaton River tributary near Bronson	.88	29.9	3.09	37.905	3.80	.7
143	06917380	Marmaton River near Marmaton	292	5.89	7.37	37.817	3.90	.6
144	06917400	Marmaton River tributary near Fort Scott	2.8	35.6	4.03	37.790	3.80	.7
145	06917500	Marmaton River near Fort Scott	408	4.55	9.24	37.863	3.80	.7
146	07138600	White Woman Creek tributary near Selkirk	7.59	16.3	.99	38.525	2.30	1.1
147	07138650	White Woman Creek near Leoti	750	12.6	8.70	38.481	2.30	1.1
148	07138800	Lion Creek tributary near Modoc	1.19	31.B	.17	38.480	2.40	1.2
149	07139700*	Arkansas River tributary near Dodge City	8.66	14.0	8.64	37.714	2.60	.9
150	07139800	Mulberry Creek near Dodge City	73.8	7.30	9.01	37.598	2.60	11.0
151	07140300	Whitewoman Creek near Bellefont	14	10.7	10.4	37.923	2.70	.3
152	07140600	Pawnee River tributary near Kalvesta	6.89	15.3	4.63	38.061	2.50	.6
153	07140700	Guzzlers Gulch near Ness City	58.2	9.64	20.6	38.294	2.50	.8
154	07141200	Pawnee River near Larned	2,010	4.18	13.8	38.200	2.50	.9
155	07141400	South Fork Walnut Creek tributary near Dighton	.81	15.8	1.49	38.482	2.40	.9
156	07141600	Long Branch Creek near Ness City	28	10.0	22.2	38.450	2.50	.5
157	07141780	Walnut Creek near Rush Center	1,152	5.97	18.4	38.468	2.50	.8
158	07141800	Otter Creek near Rush Center	17	13.0	11.5	38.404	2.70	.9
159	07141900	Walnut Creek at Albert	1,306	5.36	22.7	38.461	2.50	.8
160	07142100	Rattlesnake Creek tributary near Mullinville	10.3	13.1	7.26	37.586	2.80	1.0
161	07142300	Rattlesnake Creek near Macksville	356	4.96	11.5	37.872	2.80	6.6
162	07142500	Spring Creek near Oillwyn	14.3	10.7	2.11	37.956	2.90	1.7
163	07142575	Rattlesnake Creek near Zenith	519	4.10	25.9	38.100	2.95	6.6
164	07142700	Salt Creek near Partridge	72	5.11	6.85	38.039	2.90	1.0
165	07142860	Cow Creek near Claflin	43	6.73	7.20	38.522	2.80	.9
166	07142900	Blood Creek near Boyd	61	9.82	6.04	38.536	2.80	.9
167	07143100	Little Cheyenne Creek tributary near Claflin	1.48	21.7	4.49	38.456	2.90	6.6
168	07143200	Plum Creek near Holyrood	19	9.40	8.38	38.598	2.90	.7
169	07143300	Cow Creek near Lyons	499	3.44	8.21	38.308	2.90	3.1
170	07143500	Little Arkansas River near Geneseo	25	20.8	1.14	38.456	3.10	.7
171	07143600	Little Arkansas River near Little River	71	8.32	4.41	38.413	3.00	.7
172	07143665	Little Arkansas River at Alta Mills	681	3.58	7.40	38.112	3.35	2.9
173	07144000	East Emma Creek near Halstead	58	9.00	5.16	38.027	3.40	.1
174	07144200	Little Arkansas River at Valley Center	1,250	2.30	11.6	37.832	3.30	2.2
175	07144780	North Fork Ninnescah River above Cheney Reservoir	550	5.85	6.62	37.844	3.00	1.8

Table 5.--*Physical and climatic characteristics used in regression analyses for streamflow-gaging stations used in the study*--Continued

Map number (fig.1)	Station number	Station name	CDA1/ (square miles)	Sl2/ (feet per mile)	Sh3/ (dimensionless)	Lat4/ (degrees)	I25/ (inches)	SP6/ (inches per hour)
176	07144800	North Fork Ninnescah River near Cheney	693	5.36	9.80	37.666	3.10	0.9
177	07144850	South Fork South Fork Ninnescah River near Pratt	21	10.6	8.55	37.586	3.00	.9
178	07144900	South Fork Ninnescah River tributary near Pratt	1.48	18.8	4.92	37.675	3.00	.9
179	07145200	South Fork Ninnescah River near Murdock	543	7.13	13.8	37.564	3.10	1.2
180	07145300*	Clear Creek near Garden Plain	5.03	15.3	5.97	37.663	3.40	.7
181	07145500	Ninnescah River near Peck	1,785	4.80	7.69	37.457	3.20	.9
182	07145700	Slate Creek at Wellington	154	6.08	12.1	37.250	3.50	.7
183	07145800	Antelope Creek tributary near Dalton	.41	56.5	5.05	37.276	3.60	.7
184	07146570	Cole Creek near Degraff	30	7.36	10.4	37.947	3.62	.1
185	07146700	West Branch Walnut River tributary near Degraff	11	13.2	8.37	37.955	3.60	.1
186	07147020	Whitewater River tributary near Towanda	.17	66.2	5.30	37.850	3.60	.1
187	07147070	Whitewater River at Towanda	426	4.15	5.68	37.795	3.50	.1
188	07147200	Dry Creek tributary near Augusta	.9	42.9	1.46	37.679	3.60	.7
189	07147800	Walnut River at Winfield	1,872	2.50	8.71	37.224	3.60	.15
190	07147990	Cedar Creek tributary near Cambridge	2.41	53.2	4.46	37.321	3.70	.7
191	07148100	Grouse Creek near Dexter	170	8.16	9.50	37.227	3.70	.6
192	07148700	Dog Creek near Deerhead	5.31	30.9	2.24	37.280	3.00	2.0
193	07148800	Medicine Lodge River tributary near Medicine Lodge	2.04	27.4	4.47	37.311	3.20	2.0
194	07149000	Medicine Lodge River near Kiowa	903	8.27	12.9	37.038	3.00	1.4
195	07151500	Chikaskia River near Corbin	794	7.79	10.4	37.128	3.30	.9
196	07151600	Rush Creek near Harper	12	21.5	9.18	37.253	3.30	.9
197	07155590	Cimarron River near Elkhart	2,416	17.5	10.8	37.125	2.40	6.0
198	07155900	North Fork Cimarron River tributary near Elkhart	10	16.4	9.72	37.190	2.40	.9
199	07156000	North Fork Cimarron River tributary near Richfield	58.9	13.8	5.30	37.310	2.40	.9
200	07156010	North Fork Cimarron River at Richfield	463	16.5	15.8	37.258	2.37	.9
201	07156220	Bear Creek near Johnson	835	13.9	17.8	37.626	2.35	.9
202	07156600	Cimarron River tributary near Moscow	8	27.5	4.65	37.335	2.50	.3
203	07156700	Cimarron River tributary near Satanta	2.41	41.6	4.51	37.270	2.50	.3
204	07157100	Crooked Creek near Copeland	44	11.4	5.96	37.565	2.50	.5
205	07157400	Crooked Creek tributary at Meade	6.57	33.1	4.77	37.296	2.70	.3
206	07157500	Crooked Creek near Nye	813	4.23	13.9	37.033	2.60	.9
207	07157700	Kiger Creek near Ashland	34	29.9	7.06	37.193	2.80	1.3
208	07157900	Cavalry Creek at Coldwater	39	8.61	7.85	37.266	2.90	1.1
209	07165700	Verdigris River near Madison	181	11.2	8.48	38.137	3.60	.7
210	07166000	Verdigris River near Coyville	747	4.98	11.2	37.705	3.70	.7
211	07166200*	Sandy Creek near Yates Center	6.8	19.3	5.56	37.846	3.70	.1
212	07166500	Verdigris River near Altoona	1,138	3.33	15.9	37.490	3.70	.7
213	07166700	Burnt Creek at Reece	8.85	36.0	4.27	37.805	3.70	.7
214	07167000	Fall River near Eureka	307	9.95	4.92	37.785	3.60	.7
215	07167500	Otter Creek at Climax	129	13.2	5.99	37.708	3.70	.7
216	07168500	Fall River near Fall River	585	6.28	6.36	37.642	3.70	.7
217	07169200*	Salt Creek near Severy	7.59	21.9	2.43	37.620	3.80	.7
218	07169500	Fall River at Fredonia	827	5.46	6.94	37.508	3.70	.9
219	07169700*	Snake Creek near Howard	1.84	38.4	3.13	37.541	3.80	.7
220	07169800	Elk River at Elk Falls	220	9.21	7.67	37.375	3.80	.7
221	07170000	Elk River near Elk City	575	5.25	9.67	37.266	3.80	1.2
222	07170500	Verdigris River at Independence	2,892	2.68	9.80	37.223	3.70	.9
223	07170600	Cherry Creek near Cherryvale	15	16.5	2.62	37.296	3.90	.7
224	07170700	Big Hill Creek near Cherryvale	37	9.10	15.8	37.266	3.90	.7
225	07170800	Mud Creek near Mound Valley	4.22	25.7	2.86	37.193	3.90	.7
226	07171700	Spring Branch near Cedar Vale	3.1	50.0	3.40	37.113	3.80	.7
227	07171800	Cedar Creek tributary near Hooser	.56	165	4.18	37.107	3.70	.7
228	07172000	Caney River near Elgin	445	7.39	8.25	37.003	3.80	.7
229	07179500	Neosho River at Council Grove	250	4.88	3.41	38.665	3.51	.3
230	07180000	Cottonwood River near Marion	329	5.54	5.08	38.351	3.38	.2
231	07180300	Spring Creek tributary near Florence	.55	43.2	3.66	38.183	3.50	.7
232	07180500	Cedar Creek near Cedar Point	110	9.42	3.01	38.198	3.57	.2
233	07181000	Cottonwood River at Elmdale	1,045	3.74	6.70	38.370	3.50	.5
234	07181500	Middle Creek near Elmdale	92	3.69	22.3	38.393	3.50	.7
235	07182000	Cottonwood River at Cottonwood Falls	1,327	3.19	7.01	38.385	3.51	.4

Table 5.--*Physical and climatic characteristics used in regression analyses for streamflow-gaging stations used in the study*--Continued

Map number (fig.1)	Station number	Station name	CDA[1] (square miles)	Sl[2] (feet per mile)	Sh[3] (dimensionless)	Lat[4] (degrees)	I2[5] (inches)	SP[6] (inches per hour)
236	07182400	Neosho River at Strawn	2,933	2.75	4.48	38.266	3.60	0.5
237	07182520*	Rock Creek at Burlington	8.27	8.34	7.26	38.196	3.70	.7
238	07182600	North Fork Big Creek near Burlington	46	5.93	16.6	38.110	3.70	.6
239	07183000	Neosho River near Iola	3,818	1.84	9.51	37.890	3.60	--
240	07183100	Owl Creek near Piqua	177	5.87	4.55	37.850	3.80	.2
241	07183500	Neosho River near Parsons	4,905	1.85	18.7	37.310	3.70	.6
242	07183800	Limestone Creek near Beulah	12	16.2	3.18	37.403	3.90	.7
243	07184000	Lightning Creek near McCune	197	3.43	10.6	37.281	3.90	.7
244	07184500	Labette Creek near Oswego	211	4.74	5.54	37.191	3.90	.7
245	07184600	Fly Creek near Faulkner	27	7.80	4.16	37.104	4.00	.7

1 Contributing-drainage area (CDA)-- area upstream from the station location that contributes directly to the streamflow the location, in square miles.

2 Main-channel slope (Sl)-- slope of the main channel, in feet per mile, as measured by dividing the difference in elevation at points on the channel the 10- and 85-percent of the main channel length by the intervening main-channel length, in feet per mile.

3 Shape (Sh) - a dimensionless shape factor, which is the ratio of the square of the main-channel length to the contributing-drainage area (CDA), in square miles.

4 Latitude (Lat) - the latitude at the gage, in degrees.

5 2-year, 24-hour rainfall (I2) - the depth of rainfall, in inches, in a 24-hour period that has an estimated recurrence interval of 2 years as determined from figure 6.

6 Soil permeability (SP) - estimated permeability of the soil located within the watershed, in inches per hour, as determined from figure 7.