ESTIMATING THE MAGNITUDE OF PEAK DISCHARGES FOR SELECTED FLOOD FREQUENCIES ON SMALL STREAMS IN SOUTH CAROLINA [1975]

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U.S. GEOLOGICAL SURVEY

Open-File Report 82-337

Prepared in 1975 in cooperation with the

SOUTH CAROLINA DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION and

U.S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION

Open File
1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

The analyses and compilations of this report were made using inch-pound units of measurements. For convenience, the data may be converted to metric units (SI) with the following conversion factors:

Multiply	By	To obtain
mile (mi)	1.609	kilometer (km)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.59	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.028317	cubic meter per second (m^3/s)
foot per mile (ft/mi)	0.19	meter per kilometer (m/km)

The regression equations must be solved using inch-pound units of measurements.

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ABSTRACT

A program to collect and analyze flood data from small streams in South Carolina was conducted from 1967-75, as a cooperative research project with the South Carolina Department of Highways and Public Transportation and the Federal Highway Administration. As a result of that program, a technique is presented for estimating the magnitude and frequency of floods on small streams in South Carolina with drainage areas from 1 to 500 square miles. Peak-discharge data from 74 stream-gaging stations (25 small streams were synthesized, whereas 49 stations had long-term records) were used in multiple regression procedures to obtain equations for estimating magnitude of floods having recurrence intervals of 10, 25, 50, and 100 years on small natural streams. The significant independent variable was drainage area. Equations were developed for the three physiographic provinces (Coastal Plain, Piedmont, and Blue Ridge) of South Carolina and can be used for estimating floods on small streams.

INTRODUCTION

A knowledge of flood characteristics is an essential tool for designing culverts, bridges, and drainage systems; for planning use of flood-prone lands; and for establishing flood insurance rates. Only through reliable estimates of the magnitude of flooding and the related frequency of occurrence is it possible to obtain economically optimum designs, to prepare realistic zoning ordinances, or to establish equitable flood insurance rates.

This report presents equations for calculating the magnitude and frequency of floods on streams in South Carolina. These equations should be up-dated when deemed necessary upon collection of additional data, new techniques developed, and so forth. The equations were defined by a regression analysis of basin characteristics and flood records for 74 stations with data through 1975. Flood records for 25 small stream stations were synthesized whereas 49 stations had long-term records.

The equations defined in this report apply only to streams (drainage area from 1-500 mi^2 where flood flows are virtually natural and whose watershed characteristics are within the range of values used in the regression analyses.

A previous report by Speer and Gamble (1964) presented flood-estimating techniques. However, no data were available for floods on streams with drainage areas less than 45 mi^2 in South Carolina for that report.

COOPERATION

The report was prepared as a part of the cooperative highway research program with the South Carolina Department of Highways and Public Transportation and the U.S. Department of Transportation, Federal Highway Administration. The opinions, findings, and conclusions expressed in this report do not necessarily reflect the official views or policies of these agencies.

HYDROLOGIC DEFINITIONS

Hydrologic terms and concepts used in this report are:

1. Continuous-record gaging station.--A site on a stream where stage-discharge data are obtained continuously over a period of time.

2. Crest-stage partial-record gaging station.--A site on a stream where only flood peak data are collected systematically over a period of years.

3. Dual-digital gaging station.--A site on a stream equipped with two recorders to measure the stage and the rainfall associated with a flood event.

4. Water year.--The 12-month period from October 1 through September 30, designated by the calendar year in which it ends.

5. Recurrence interval.--The average interval of time, in years, within which the given flood event is expected to be exceeded once. The reciprocal of the recurrence interval is the probability of occurrence during any one year. (A 50-year flood, Q_{50}, has a 2 percent chance of being exceeded in any given year.) Recurrence intervals imply no regularity of occurrence; a 50-year flood event might be exceeded in consecutive years, or it might not be exceeded in a period many times 50 years in length.

6. Flood-frequency curve.--A graphic relationship between recurrence interval and flood magnitude.

7. Multiple regression.--A statistical technique for defining the relationship between a dependent variable and two or more independent variables. In this report the dependent variable is the flow characteristic (flood discharge of a given frequency), and the independent variables are basin characteristics, such as drainage area and slope.

8. Standard error of estimate (Se).--A range of error such that the value estimated by the regression equation is within this range at about two out of three sites and is within twice the range at about 19 out of 20 sites (Thomas and Benson, 1970, p. 27).

9. Skew coefficient.--One of the measures of the distortion of the data from a normal distribution about the mean.

SYNTHESIZED FLOOD RECORDS

A program was initiated in 1967 to gain knowledge about the magnitude and frequency of floods on small streams (drainage area 1-50 mi^2) in order to define estimates of flood peaks to aid in the design of highway drainage structures.

Many techniques have been proposed for estimating the magnitude and frequency of floods and the most reliable are based upon an assessment of long-term records of observed floods. Because there were no long-term records on small streams, an alternative was to synthesize long-term flood records with a rainfall-runoff model using long-term rainfall records.

The rainfall-runoff model used in this study was developed by the Geological Survey (Dawdy, Lichty, and Bergmann, 1972) specifically for the purpose of modeling flood-runoff hydrographs from small watersheds. Primary characteristics of this model are that it employs a deterministic structure-imitating process. Ten parameter values must be evaluated to calibrate the model to any specific drainage site. The model parameters are determined by an optimization technique, which is the best fit of the synthesized peak (or runoff volume) to the observed peak (or runoff volume). The observed rainfall is used as input along with the optimized parameter values to generate the synthesized flood peaks (or runoff).

After calibration, a synthetic flood record for each small stream station was computed by using one or more of the following National Weather Service first-order precipitation stations.

Station name	Period of record
Augusta, Ga.	1902-71
Charlotte, N.C.	1902-66
Columbia, S.C.	1901-54
Greenville, S.C.	1918-71

DEVELOPMENT OF FLOOD-FREQUENCY CURVES

In accordance with recommendations of the U.S. Water Resources Council, Hydrology Committee (1967, 1981), the log-Pearson Type III method was used to develop frequency curves from the flood records.

There were 34 gaging stations in South Carolina in 1975 on nonregulated streams with records longer than 25 years in length. The mean logarithmic skew coefficient for these stations was 0.135 and varied from -1.04 to +1.03. Since there was no recognizable skew pattern across the State, the decision was made to use the generalized skew coefficients of Hardison (1974). The assigned skews varied in South Carolina from 0.1 to 0.5 from west to east generally along the longitudinal axis.

Frequency curves were developed by applying the log-Pearson method with an assigned skew coefficient to the annual peaks for each station with real or synthesized records. The location of the stations with the variations in skew and the physiographic provinces within the State are shown in figure 1.

The reliability of frequency curves is related to the number of years of available record. The minimum years of record used to define floods at the selected recurrence intervals for gaged sites used in this study are:

Recurrence interval	10	25	50	100
Minimum years of record	10	15	20	25

The above criteria applies to data listed in table 1. However, in the regression analysis short-record data was extended to include the 100-year flood.

FLOOD-FREQUENCY EQUATIONS

A multiple-regression analysis was employed using data from stations in each province, which also included nearby stations in Georgia and North Carolina, to define the significant relations in estimating flood characteristics at ungaged sites in that province.

Independent variables used in the analysis were drainage area, slope, length, precipitation intensity, and soils index. Drainage area, slope, and length are listed in tables 1 and 2. Drainage area explained 85 to 90 percent of the variation of the dependent variable, while the other independent variables were not significant (at the 5 percent level of significance).

From multiple regression analysis, flood-frequency equations have been developed for use in estimating magnitude and frequency of floods on

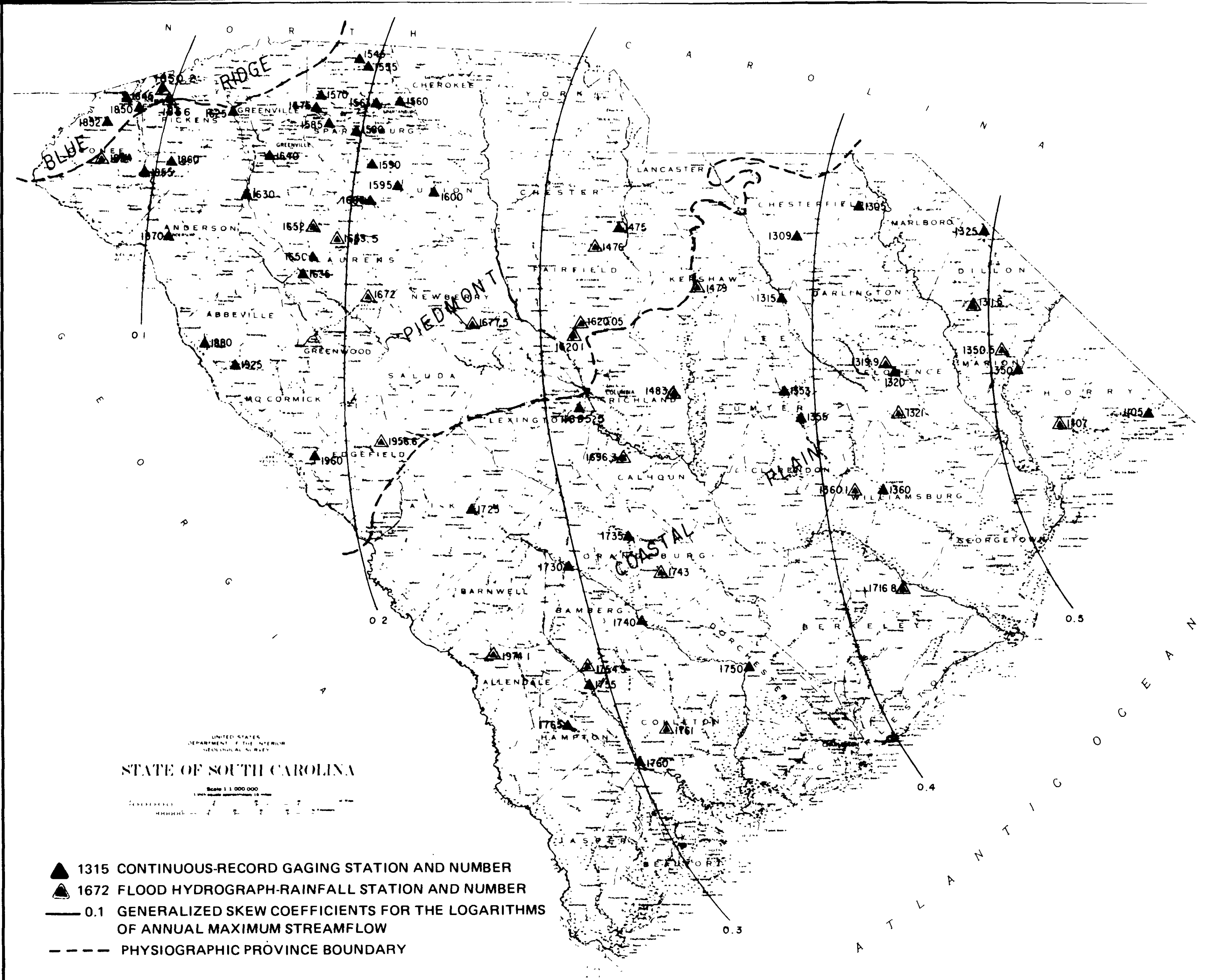

Figure 1.--Map of South Carolina showing gaging stations and physiographic provinces.

Table 1.--Variables used in regression analysis for stations with long-term records

Station	Drainage area (square miles)	Channel slope (foot per mile)	Channel length (miles)	Peak discharge at recurrence interval of 10-year (cubic foot per second)	25-year (cubic foot per second)	50-year (cubic foot per second)	100-year (cubic foot per second)
				Coastal Plain Province			
110500	1110.0	1.1	74.6	11,300	15,400	19,100	23,400
130500	64.0	8.5	17.0	1,060	1,550	2,000	--
130900	108.0	10.2	29.7	1,170	1,390	--	--
131500	675.0	4.7	59.5	14,500	20,000	24,800	30,400
132000	1030.0	3.2	105.6	12,900	18,500	23,600	29,500
132500	524.0	3.2	54.8	5,120	7,020	8,720	10,700
135000	2790.0	2.7	101.4	22,200	28,900	34,600	40,900
135300	70.0	5.2	17.5	1,320	--	--	--
135500	401.0	3.7	27.9	7,580	12,200	--	--
136000	1260.0	2.6	64.3	18,100	29,500	41,100	55,900
169550	136.0	13.4	14.6	1,440	1,740	--	--
172500	198.0	8.2	31.7	3,000	3,900	4,650	5,460
173000	720.0	4.7	62.4	5,820	7,770	9,410	11,200
173500	683.0	3.7	62.0	5,580	7,400	8,940	10,600
174000	1720.0	3.1	99.0	12,900	17,500	21,500	26,100
175000	2730.0	2.4	139.1	21,300	28,700	35,000	42,200
175500	341.0	4.4	43.9	2,290	2,800	3,230	3,670
176000	1100.0	3.2	70.5	11,700	15,500	--	--
176500	203.0	5.3	19.8	3,910	5,370	6,630	8,050

Table 1.--Variables used in regression analysis for stations with long-term records (cont.)

Station	Drainage area (square miles)	Channel slope (foot per mile)	Channel length (miles)	Peak discharge at recurrence interval of			
				10-year (cubic foot per second)	25-year (cubic foot per second)	50-year (cubic foot per second)	100-year (cubic foot per second)
				Piedmont Province			
147500	194.0	9.0	27.4	13,900	18,000	21,500	25,300
154500*	116.0	29.1	31.2	6,620	8,850	10,700	12,800
155500	212.0	26.9	33.2	11,200	15,200	18,500	22,200
156000	320.0	9.0	51.5	16,200	20,300	23,500	27,000
156300	65.2	11.9	21.7	2,930	--	--	--
157000*	44.0	17.8	14.3	2,900	3,810	4,570	5,390
157500*	68.3	11.7	22.8	3,760	4,500	5,060	5,630
158000	162.0	12.4	26.6	7,430	9,890	11,900	14,200
158500	106.0	9.3	32.6	4,580	5,910	6,980	8,120
159000	174.0	9.7	49.6	5,910	7,960	9,690	11,600
159500	351.0	11.8	32.3	16,400	23,200	29,300	36,200
160000	183.0	9.2	39.3	7,120	9,090	10,700	12,400
160500	307.0	9.6	54.8	13,700	18,300	22,100	26,400
163000	405.0	6.0	64.2	11,100	13,700	15,700	17,800
163500	569.0	5.9	94.8	17,900	22,500	26,100	29,900
164000	48.6	12.1	18.6	3,270	3,880	4,340	4,810
165000	228.0	9.9	54.3	8,550	11,000	13,000	15,100
185500	455.0	29.6	46.6	24,100	28,300	31,400	--
186000	106.0	9.9	18.7	4,990	--	--	--
187000	1026.0	9.5	73.3	45,000	57,700	68,000	78,800
188000	267.0	7.3	52.4	9,750	13,300	16,400	--
192500	217.0	8.4	39.4	10,300	13,600	16,400	19,400
196000	545.0	7.4	45.6	23,400	30,100	35,600	41,400

Table 1.--Variables used in regression analysis for stations with long-term records (cont.)

Station	Drainage area (square miles)	Channel slope (foot per mile)	Channel length (miles)	Peak discharge at recurrence interval of			
				10-year (cubic foot per second)	25-year (cubic foot per second)	50-year (cubic foot per second)	100-year (cubic foot per second)
				Blue Ridge Province			
154500*	116.0	29.1	31.2	6,620	8,850	10,700	12,800
157000*	44.0	17.8	14.3	2,900	3,810	4,570	5,390
157500*	68.3	11.7	22.8	3,760	4,500	5,060	5,630
162500	293.0	8.9	46.4	7,980	9,730	11,700	12,500
184500	47.3	237.0	14.8	5,460	6,690	--	--
185000	148.0	121.0	24.5	16,600	20,400	23,300	--
185200	72.0	21.0	14.5	8,270	--	--	--

*Stations used for streams in both the Piedmont and Blue Ridge Provinces.

Table 2.--Variables used in regression analysis for stations with synthesized records

Station	Drainage area (square miles)	Channel slope (foot per mile)	Channel length (miles)	Peak discharge at recurrence interval of			
				10-year (cubic foot per second)	25-year (cubic foot per second)	50-year (cubic foot per second)	100-year (cubic foot per second)
				Coastal Plain Province			
110700	14.0	6.7	5.2	558	865	1,170	1,540
131150	28.0	4.1	13.0	795	1,300	1,830	2,500
131990	8.28	10.3	4.2	579	850	1,100	1,320
132100	19.0	4.3	9.3	477	754	1,030	1,380
135050	36.0	5.8	8.0	704	1,130	1,570	2,120
136010	17.0	4.2	6.0	994	1,520	2,020	2,640
147900	2.79	66.3	2.6	437	635	816	1,030
148300	38.1	11.8	10.6	799	1,180	1,520	1,940
169630	10.0	70.0	2.7	550	945	1,360	1,900
171680	17.4	5.8	3.9	1,050	1,630	2,200	2,910
174300	13.1	5.7	9.6	545	871	1,190	1,590
175450	3.02	10.0	6.2	1,010	1,400	1,800	2,270
176100	7.67	13.9	5.1	636	842	1,020	1,210
197410	7.51	28.4	4.1	802	1,270	1,710	2,260

Table 2.--Variables used in regression analysis for stations with synthesized records (cont.)

Station	Drainage area (square miles)	Channel slope (foot per mile)	Channel length (miles)	Peak discharge at recurrence interval of 10-year (cubic foot per second)	25-year (cubic foot per second)	50-year (cubic foot per second)	100-year (cubic foot per second)
				Piedmont Province			
147600	4.55	63.8	3.4	1,030	1,510	1,960	2,490
147900	2.79	66.3	2.6	437	635	816	1,030
162005	1.13	92.3	1.8	129	191	249	320
162010	48.0	13.1	16.5	4,760	6,090	7,170	8,340
165200	29.5	14.6	17.2	3,510	5,100	6,530	8,190
167200	0.72	76.0	1.0	122	178	229	288
167750	0.52	110.0	1.0	154	225	291	368
195660	1.18	86.7	1.2	150	255	361	496
				Blue Ridge Province			
185020	30.2	104.8	12.8	3,920	5,560	6,980	8,580
185400	1.08	136.0	2.2	465	653	816	1,000
185600	2.77	77.8	2.4	456	690	904	1,160

nonregulated streams in South Carolina. The equations apply only to rural streams whose basin characteristics (the independent variables) fall within the range of values given in tables 1 and 2. Following each equation is the Se (standard error of estimate).

For ungaged streams in the Coastal Plain, peak discharge for recurrence intervals of 10, 25, 50, and 100 years, respectively, can be estimated by the following equations:

	(Se) Percent
$Q_{10} = 200A^{.59}$	44
$Q_{25} = 294A^{.58}$	46
$Q_{50} = 362A^{.58}$	48
$Q_{100} = 496A^{.56}$	50

For ungaged streams in the Piedmont province, peak discharge can be estimated using the following equations:

	(Se) Percent
$Q_{10} = 375A^{.63}$	34
$Q_{25} = 514A^{.62}$	36
$Q_{50} = 620A^{.62}$	38
$Q_{100} = 775A^{.60}$	40

For ungaged streams in the Blue Ridge province, peak discharge can be estimated using the following equations:

	(Se) Percent
$Q_{10} = 330A^{.68}$	32
$Q_{25} = 445A^{.68}$	34
$Q_{50} = 520A^{.68}$	36
$Q_{100} = 654A^{.66}$	38

where:

A is the drainage area of the watershed in square miles, as planimetered from the best topographic map or aerial photograph available; example, U.S. Geological Survey topographic maps at scale of 1:24000.

For streams that cross from one province into another, the user may estimate the flood discharge by weighting results applicable to each province.

Example. Compute the 50-year flood (Q_{50}) for a stream whose drainage area is 25 mi^2 (10 mi^2 in the Coastal Plain and 15 mi^2 in the Piedmont). Then:

1. Assume the basin to lie wholly in each province and compute Q_{50} for the total basin drainage area in each province.

2. Prorate Q_{50} using percentage of drainage area in each province; i.e.,

$$(Q_{50} \text{ Piedmont X } 15/25) + (Q_{50} \text{ Coastal Plain X } 10/25)$$

$$= Q_{50} \text{ Piedmont, Coastal Plain.}$$

SUMMARY AND CONCLUSIONS

The knowledge of floods on small streams and the art of flood predictions on ungaged streams are such that engineering judgment still plays an important role in the determination of a design flood. However, the equations presented in this report provide a method that can be used to compute the discharge for floods of selected recurrence intervals on nonregulated rural streams in South Carolina. The user will be required to exercise judgment when applying the equations, which are applicable only to those streams whose watershed characteristics are within the range of those listed in tables 1 and 2 for each physiographic province. Generally, this range of application is for drainage areas from 1 to 500 mi^2.

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