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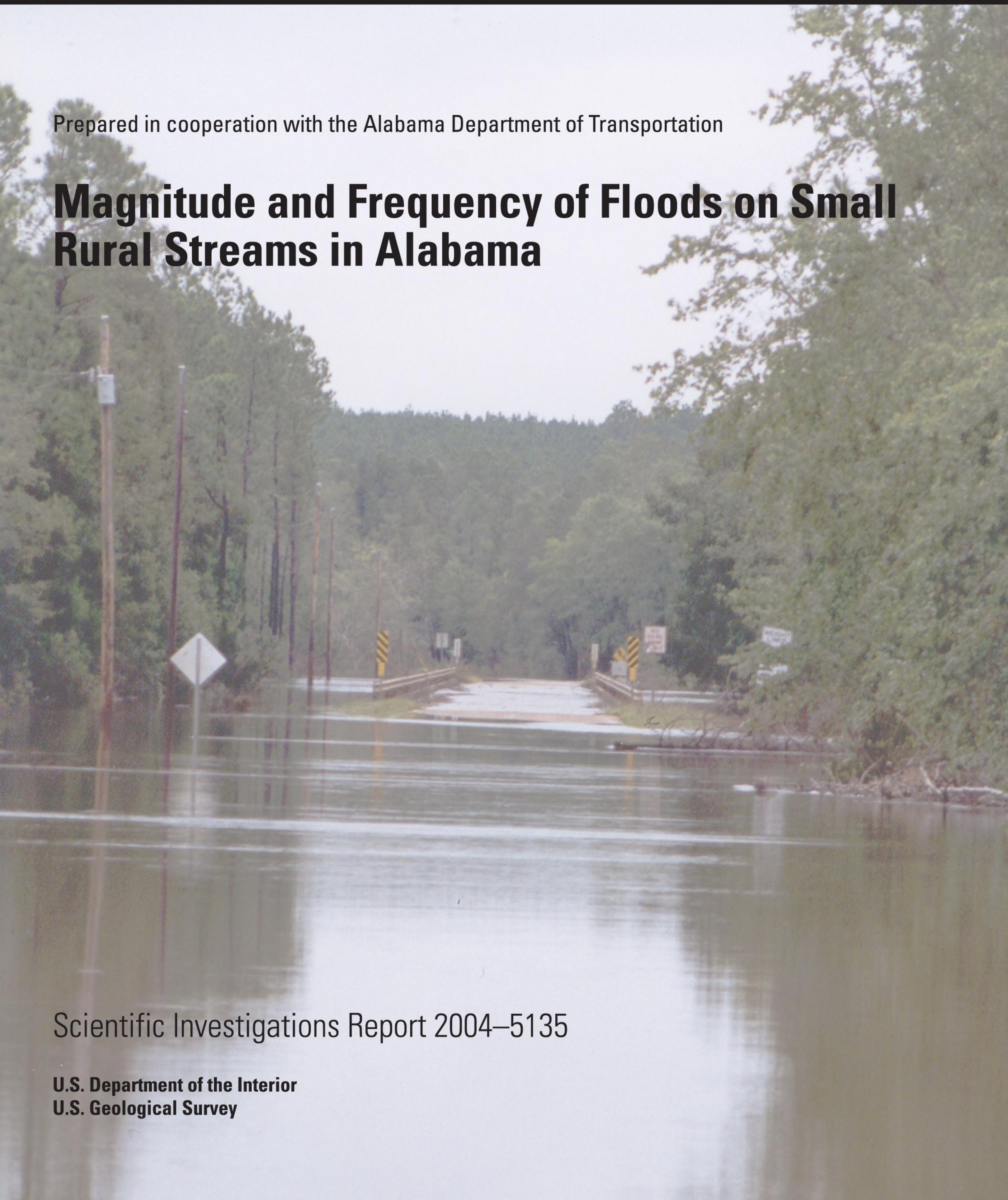
Magnitude and Frequency of Floods on Small Rural Streams in Alabama



Scientific Investigations Report 2004–5135

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph: Styx River near Elsanor, Baldwin County, Alabama *(taken by Will S. Mooty, USGS)*.

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Conversion Factors, Datum, and Acronyms and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).
Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929).

Acronyms and Abbreviations

A	drainage area
ALDOT	Alabama Department of Transportation
F	forest cover
GLS	generalized least squares
L	main channel length
OLS	ordinary least squares
S	main channel slope
SEp	standard error of prediction
T	lag-time factor
USGS	U.S. Geological Survey
W/L	width to length ratio

Magnitude and Frequency of Floods on Small Rural Streams in Alabama

By T.S. Hedgecock

Abstract

Equations for estimating the magnitude and frequency of floods for small rural streams in Alabama are presented for recurrence intervals ranging from 2 to 500 years. Flood-frequency characteristics are documented for 43 streamflow gaging stations included in the analysis. Each station used has a drainage area less than 15 square miles and at least 10 years of record prior to 2003. None of these stations were affected by regulation or urbanization. Regression relations were developed using generalized least-square techniques to estimate flood magnitude and frequency on ungaged streams as a function of the drainage area of a basin.

Introduction

The magnitude and frequency of floods are important factors in the design of bridges, culverts, highway embankments, dams, and other hydraulic structures near streams. Flood magnitude and frequency information also is used in flood-plain management and development, and in establishing flood insurance rates.

The Alabama Department of Transportation (ALDOT) requires accurate flood-frequency information to efficiently design drainage structures for highways in Alabama. To better meet this need, the U.S. Geological Survey (USGS), in cooperation with ALDOT, updated previous flood-frequency estimates on small rural streams by incorporating additional peak flow data collected through the 2003 water year[1] from streamflow gaging stations in Alabama, Mississippi, Georgia, Florida, and Tennessee.

A flood-frequency analysis was conducted on small streams exclusively, to see whether the resulting equations would yield smaller standard errors of prediction than previous analyses. The previous flood-frequency study conducted by Atkins (1996) incorporated a database in which 85 percent of the stations used were larger streams (greater than 15 square miles [mi^2]). The intent of the current study was to remove any bias caused by a database dominated by larger streams.

Purpose and Scope

The purpose of this report is to update previous flood-frequency reports for Alabama by providing an alternative method of estimating the magnitude and frequency of floods for small rural streams, and to provide frequency estimates of water year peak flow data at streamflow gaging stations using peaks collected through September 2003. This report includes regression equations for estimating the magnitude of floods for streams having recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years for ungaged rural streams. These equations are applicable for streams having drainage areas less than 15 mi^2.

Acknowledgments

The assistance of Kathryn Green and Kristin Justice, USGS engineering students, was instrumental in the success and completion of this study. Also, special thanks is given to Brian Atkins, USGS, for his assistance with the statistical analyses used in this study

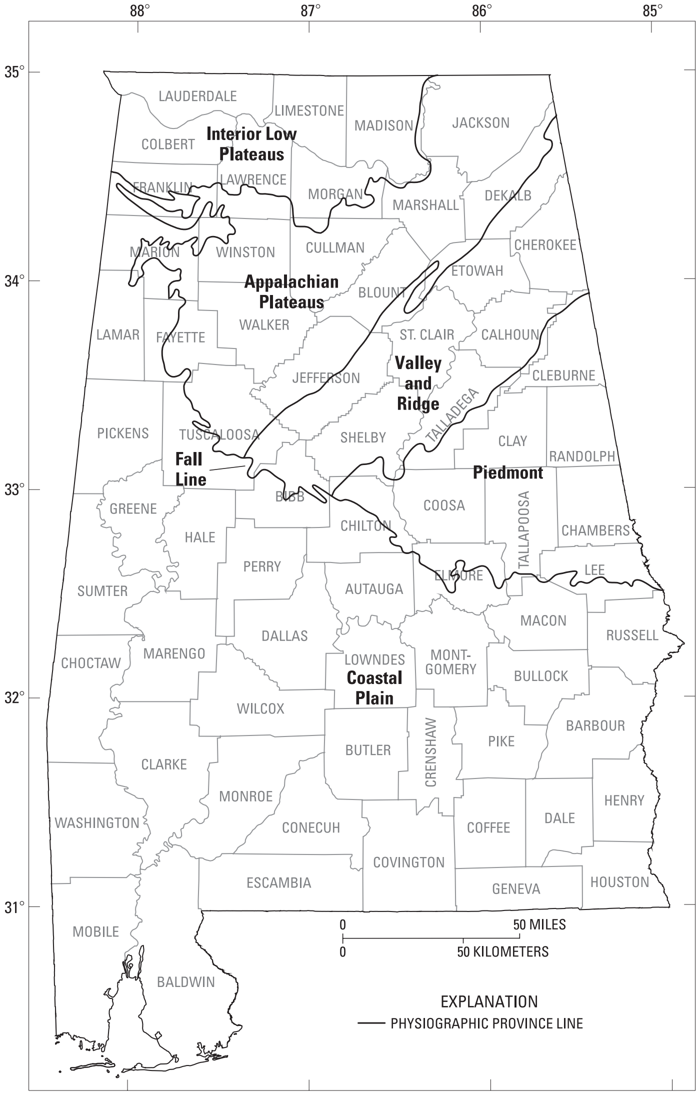
Previous Studies

Magnitude and frequency of floods in Alabama have been described by Pierce (1954), Speer and Gamble (1964), Gamble (1965), Barnes and Golden (1966), Hains (1973), Olin (1984), and Atkins (1996). Magnitude and frequency of floods have been described by Olin and Bingham (1977) for small rural streams, and by Olin and Bingham (1982) for urban streams.

Description of the Study Area

The study area includes all of Alabama, which has an area of about 51,600 mi^2, and is located in five physiographic

[1]Water year refers to the 12-month period from October 1 through September 30 and is designated by the calendar year in which the period ends.



Base from U.S. Geological Survey digital data, 1:100,000, Universal Transverse Mercator Projection, Zone 16.

Figure 1. Locations of physiographic provinces in Alabama (modified from Miller, 1990).

provinces—Coastal Plain, Piedmont, Valley and Ridge, Appalachian Plateaus, and Interior Low Plateaus (fig. 1). The area north of the Fall Line, which delineates the contact of the Coastal Plain with the other provinces, has a diverse topography with land-surface elevations ranging from 200 to 2,400 feet (ft) above NGVD 1929. In the Coastal Plain, elevations range from sea level at the coast to 1,000 ft above NGVD 1929 in the northwestern part of the State. The land surface generally slopes to the south and west.

Average annual precipitation ranges from about 50 inches (in.) in central and west-central Alabama to about 65 in. near the Gulf of Mexico and averages about 55 in. statewide. Rainfall in Alabama generally is associated with the movement of warm and cold fronts across the State during November through April and with isolated summer thunderstorms occurring from May through October. Occasionally, tropical storms or hurricanes entering the State along the Gulf Coast produce unusually heavy amounts of rainfall (U.S. Geological Survey, 1986).

Average annual runoff varies from approximately 18 to 30 in. Runoff typically is greatest from February through April with flooding commonly occurring during March and April. Runoff usually decreases as rainfall decreases from September through November (U.S. Geological Survey, 1986).

Flood Data Used in the Analysis

This study is based on peak flow data collected through water year 2003 at 43 rural streamflow gaging stations (fig. 2), each having a drainage area less than 15 mi^2. All of the stations used have 10 or more years of record. Of these 43 stations, 27 were located within Alabama and 16 were located near the Alabama State boundary in adjacent States of Florida, Georgia, Mississippi, and Tennessee. Eleven of these 43 stations have drainage areas less than 1 mi^2, nine have drainage areas ranging from 1 to 3 mi^2, six have drainage areas ranging from 3 to 6 mi^2, eight have drainage areas ranging from 6 to 10 mi^2, and nine have drainage areas ranging from 10 to 15 mi^2. The peak flow records used in the study were not affected to any great degree by regulation, channelization, or urbanization.

Flood Magnitude and Frequency at Streamflow Gaging Stations

A flood-frequency relation is the relation of peak flow to the probability of exceedance or recurrence interval. Probability of exceedance refers to the chance that a given peak flow will be exceeded in any one year. For example, the probability that a 25-year flood will be exceeded in any given year is 0.04 (or 4-percent chance). Recurrence interval is the reciprocal of the probability of exceedance and is the average number of years between exceedances for a long period of record. A 25-year flood may be expected to be exceeded on the average of once in 25 years, or four times in 100 years. This does not mean that floods occur at uniformly spaced intervals of time; rather, a flood of this magnitude can be exceeded more than once in the same year or can occur in consecutive years.

The flood-frequency relation for a stream where streamflow gaging-station data of 10 or more years of record are available can be defined by fitting a theoretical frequency distribution to the logarithms of water year peak flows (largest instantaneous flow for each water year). The Interagency Advisory Committee on Water Data (1982) has described and recommended a consistent technique for determining flood magnitudes and frequencies by fitting a Pearson Type III distribution to the logarithms of water year peak flows. This

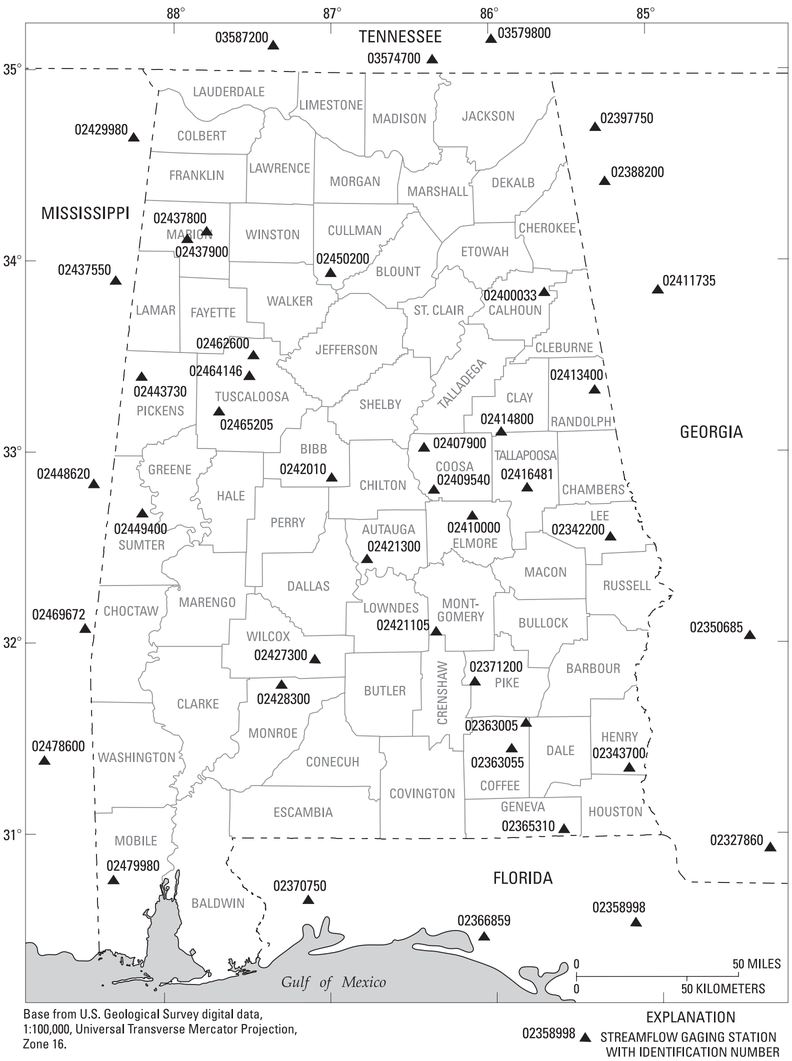


Figure 2. Locations of streamflow gaging stations used in the study.

technique is commonly referred to as the log-Pearson Type III frequency analysis and is generally accepted by most Federal and State agencies. Water year peak flows for each streamflow gaging station used in this study were fitted to the log-Pearson Type III distribution (Interagency Advisory Committee on Water Data, 1982). Flood magnitudes for recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years were computed for each station using the following equation:

$$\log Q_p = M_x + K_p S_x , \qquad (1)$$

where

Q_p is the flood magnitude at a selected exceedance probability, p;

M_x is the mean of the logarithms of the water year peak flows;

K_p is a Pearson Type III factor for a coefficient of skewness (G) computed from the logarithms of the water year peak flows and a selected probability, p; and

S_x is the standard deviation of the logarithms of the water year peak flows.

The flood magnitudes for the above-mentioned recurrence intervals for each of the streamflow gaging stations are listed in table 1. Station frequency estimates are listed for each of the 43 streamflow gaging stations even though two of the stations were not used in the final regression analyses. Flood-frequency estimates from adjacent states were used strictly to supplement the database; these estimates for sites in other states should not be used for design purposes. Persons needing official flood-frequency data in other states should contact the USGS office in that state.

Flood-Frequency Analysis

The flood magnitudes obtained from station frequency curves were related to basin and climatic characteristics, using generalized least squares (GLS) multiple-regression analysis. The equations resulting from these analyses can be used to estimate flood magnitudes for ungaged basins using the respective basin characteristics. The basin characteristics that were tested for significance in the GLS regression analysis were:

- contributing drainage area (A), in square miles, which is the contributing drainage area upstream from the streamflow gaging station;
- main channel slope (S), in feet per mile, which is the average slope between points that are 10 and 85 percent of the distance from the streamflow gaging station to the basin divide;
- main channel length (L), in miles, which is the length of the main channel between the streamflow gaging station and the basin divide;
- lag-time factor (T), which is a basin lag-time factor, defined by the ratio $L/S^{1/2}$ with L and S defined above;
- forest cover (F), in percent, which is the area of forest cover expressed as a percentage of the total contributing drainage area; and
- width to length ratio (W/L), which is the ratio of the average basin width to basin length. The average basin width is the average of the basin widths at points that are 33 and 67 percent of the distance from the streamflow gaging station to the basin divide.

Table 1. Peak flow for selected recurrence intervals at selected streamflow gaging stations in Alabama, Tennessee, Mississippi, Georgia, and Florida.

[mi^2, square miles; ft/mi, feet per mile; Q, peak flow, in cubic feet per second, for indicated recurrence interval in years; top line for each entry is the log-Pearson Type III discharge; bottom line is the weighted-average or best-estimate discharge; *, station not used in regional analysis]

Station number	Station name	Drainage area (mi^2)	Period of record used (years)	Slope (ft/mi)	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
02342200	Phelps Creek near Opelika, Ala.	6.67	16 (1959–74)	31.0	812 808	1,490 1,450	2,020 1,940	2,760 2,650	3,350 3,240	3,980 3,890	4,650 4,600	5,580 5,600
02343700	Stevenson Creek near Headland, Ala.	14.0	15 (1960–70)	30.8	1,060 1,090	1,830 1,930	2,450 2,670	3,370 3,780	4,150 4,700	5,010 5,690	5,980 6,750	7,410 8,330
02363005	Pea River Tributary near Roeton, Ala.	0.76	13 (1990–2002)	78.4	136 138	256 260	355 360	504 508	631 633	772 771	927 924	1,160 1,150
02363055	Moores Branch near Victoria, Ala.	2.17	10 (1973–82)	65.8	276 285	384 441	457 593	552 817	625 988	699 1,160	774 1,320	878 1,540
02365310	Grants Branch Tributary near Fadette, Ala.	1.44	10 (1972–81)	39.6	367 344	650 567	878 725	1,210 969	1,490 1,190	1,800 1,440	2,130 1,730	2,630 2,160
02371200	Indian Creek near Troy, Ala.	8.87	30 (1959–86) (1990, 1994)	27.1	569 588	1,180 1,240	1,780 1,870	2,840 2,910	3,880 3,870	5,200 5,020	6,840 6,430	9,630 8,760
02400033	Nances Creek near White Plains, Ala.	4.62	11 (1971–81)	138	693 675	1,000 1,000	1,210 1,280	1,470 1,700	1,670 2,030	1,870 2,380	2,070 2,730	2,340 3,200
02407900*	Paint Creek near Marble Valley, Ala.	12.7	13 (1960–72)	31.3	1,410 1,390	3,250 2,890	5,140 4,050	8,480 5,840	11,800 7,560	16,000 9,670	21,200 12,400	30,100 16,800
02409540	Proctor Creek near Rockford, Ala.	1.01	10 (1972–81)	80.0	545 457	788 592	956 671	1,180 828	1,350 982	1,520 1,150	1,700 1,350	1,940 1,630
02410000	Patterson Creek near Central, Ala.	4.91	37 (1952–88)	71.4	627 626	1,080 1,080	1,460 1,460	2,050 2,040	2,580 2,560	3,180 3,140	3,870 3,800	4,940 4,820
02413400	Wedowee Creek above Wedowee, Ala.	6.87	14 (1960–72) (1979)	43.6	904 890	1,210 1,250	1,420 1,570	1,680 2,060	1,880 2,450	2,080 2,840	2,290 3,210	2,570 3,730

Table 1. Peak flow for selected recurrence intervals at selected streamflow gaging stations in Alabama, Tennessee, Mississippi, Georgia, and Florida.—Continued

[mi^2, square miles; ft/mi, feet per mile; Q, peak flow, in cubic feet per second, for indicated recurrence interval in years; top line for each entry is the log-Pearson Type III discharge; bottom line is the weighted-average or best-estimate discharge; *, station not used in regional analysis]

Station number	Station name	Drainage area (mi^2)	Period of record used (years)	Slope (ft/mi)	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
02414800	Harbuck Creek near Hackneyville, Ala.	7.97	21 (1951–70) (1979)	68.6	1,240 1,200	2,180 2,030	2,990 2,670	4,240 3,650	5,360 4,550	6,650 5,600	8,130 6,830	10,400 8,720
02416481	Norrell Branch near Dadeville, Ala.	0.50	14 (1999–2003)	123	66.0 70.0	151 162	235 248	397 387	518 492	688 624	894 782	1,230 1,030
02421105	Pintlalla Creek Tributary near Sellars, Ala.	0.45	13 (1991–2003)	56.2	152 145	236 220	304 281	406 376	496 462	597 558	712 668	889 836
02421300	Ivy Creek at Mulberry, Ala.	10.7	13 (1961–73) (1990)	25.9	470 526	1,180 1,340	1,910 2,150	3,210 3,380	4,510 4,460	6,120 5,710	8,100 7,190	11,400 9,570
02424010	Sandy Creek near Centerville, Ala.	0.59	17 (1970–80) (1991–96)	139	180 174	298 280	395 361	541 488	667 600	810 728	972 876	1,220 1,100
02427300	Prairie Creek near Oak Hill, Ala.	10.3	15 (1960–74)	20.5	1,030 1,030	1,390 1,490	1,650 1,920	1,990 2,570	2,260 3,080	2,540 3,590	2,840 4,080	3,250 4,770
02428300	Tallatchee Creek near Vredenburgh, Ala.	13.2	16 (1959–74)	16.0	1,530 1,500	2,930 2,730	4,280 3,750	6,610 5,360	8,910 6,900	11,800 8,760	15,400 11,100	21,500 15,000
02437800	Barn Creek near Hackleburg, Ala.	13.1	15 (1959–73)	23.7	1,300 1,300	2,390 2,330	3,340 3,190	4,850 4,490	6,230 5,660	7,840 7,000	9,720 8,560	12,700 11,000
02437900*	Woods Creek near Hamilton, Ala.	14.3	12 (1960–70) (1972)	31.2	789 853	1,140 1,400	1,400 1,980	1,780 2,850	2,090 3,500	2,430 4,170	2,800 4,800	3,350 5,730
02443730	Kincaide Creek Tributary near Ethelsville, Ala.	0.24	13 (1991–2003)	88.2	68 68	117 117	155 156	210 215	254 263	302 316	353 374	427 458
02449400	Jones Creek near Epes, Ala.	11.8	16 (1959–74)	15.9	2,210 2,060	2,970 2,710	3,500 3,200	4,210 4,030	4,770 4,760	5,360 5,540	5,970 6,350	6,840 7,510

Table 1. Peak flow for selected recurrence intervals at selected streamflow gaging stations in Alabama, Tennessee, Mississippi, Georgia, and Florida.—Continued

[mi^2, square miles; ft/mi, feet per mile; Q, peak flow, in cubic feet per second, for indicated recurrence interval in years; top line for each entry is the log-Pearson Type III discharge; bottom line is the weighted-average or best-estimate discharge; *, station not used in regional analysis]

Station number	Station name	Drainage area (mi^2)	Period of record used (years)	Slope (ft/mi)	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
02450200	Dorsey Creek near Arkadelphia, Ala.	13.0	16 (1959–74)	29.9	1,560 1,520	2,240 2,220	2,700 2,780	3,280 3,620	3,730 4,310	4,180 5,010	4,650 5,710	5,270 6,670
02462600	Blue Creek near Oakman, Ala.	5.32	22 (1960–73) (1977–84)	61.8	1,580 1,470	2,910 2,440	3,940 2,990	5,380 3,810	6,540 4,600	7,760 5,500	9,050 6,570	10,900 8,130
02464146	Turkey Creek near Tuscaloosa, Ala.	6.16	20 (1981–84) (1987–2002)	69.0	626 635	1,190 1,200	1,710 1,710	2,590 2,500	3,430 3,220	4,460 4,070	5,700 5,080	7,760 6,720
02465205	Jay Creek near Coker, Ala.	3.65	13 (1964–74) (1997–98)	52.6	369 383	833 836	1,250 1,210	1,900 1,740	2,470 2,200	3,110 2,720	3,820 3,310	4,880 4,200
02479980	Crooked Creek near Fairview, Ala.	8.08	12 (1991–2002)	19.5	710 733	1,270 1,340	1,740 1,870	2,450 2,670	3,070 3,340	3,780 4,080	4,580 4,890	5,810 6,120
03574700	Big Huckleberry Creek near Belvidere, Tenn.	2.18	20 (1955–74)	18.2	386 381	691 668	938 891	1,300 1,220	1,610 1,510	1,950 1,830	2,320 2,180	2,870 2,720
03579800	Miller Creek near Cowan, Tenn.	4.30	24 (1955–78)	88.9	1,590 1,470	2,390 2,040	2,950 2,360	3,670 2,870	4,220 3,350	4,780 3,890	5,360 4,510	6,140 5,350
03587200	Bluewater Creek Tributary near Leoma, Tenn.	0.49	29 (1955–83)	62.1	148 145	212 210	256 258	314 331	359 389	405 449	452 510	517 594
02429980	Pollard Mill Branch at Paden, Miss.	2.01	34 (1967–2001)	35.2	190 195	359 379	503 547	727 803	924 1,020	1,150 1,260	1,410 1,530	1,800 1,930
02437550	Nicholas Creek Tributary near Quincy, Miss.	0.54	34 (1966–2001)	95.0	168 165	266 258	340 328	446 432	533 521	628 619	730 726	878 882
02448620	Flat Scooba Creek Tributary near Scooba, Miss.	0.44	35 (1967–2001)	48.0	128 126	186 185	232 235	296 308	349 369	407 435	470 506	564 610

Table 1. Peak flow for selected recurrence intervals at selected streamflow gaging stations in Alabama, Tennessee, Mississippi, Georgia, and Florida.—Continued

[mi^2, square miles; ft/mi, feet per mile; Q, peak flow, in cubic feet per second, for indicated recurrence interval in years; top line for each entry is the log-Pearson Type III discharge; bottom line is the weighted-average or best-estimate discharge; *, station not used in regional analysis]

Station number	Station name	Drainage area (mi^2)	Period of record used (years)	Slope (ft/mi)	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
02469672	Little Okatubba Creek near Quitman, Miss.	4.35	19 (1966–84)	43.0	787 762	1,140 1,100	1,380 1,360	1,690 1,750	1,920 2,060	2,150 2,390	2,380 2,720	2,700 3,180
02478600	Granny Branch at Piave, Miss.	0.69	18 (1967–84)	55.6	230 219	326 308	387 371	461 468	515 547	566 628	617 708	682 816
02327860	Popple Branch near Whigham, Ga.	1.71	25 (1977–2001)	37.6	170 176	302 327	413 468	584 684	734 862	906 1,060	1,100 1,270	1,400 1,590
02350685	Choctahatchee Creek Tributary near Plains, Ga.	0.32	24 (1977–2001)	38.1	23.0 25.0	72.0 81.0	136 150	273 273	431 393	655 550	966 760	1,560 1,140
02388200	Storey Mill Creek near Summerville, Ga.	6.02	23 (1966–87) (1990)	112	777 772	1,220 1,220	1,550 1,580	2,020 2,130	2,390 2,570	2,790 3,040	3,220 3,540	3,830 4,250
02397750	Duck Creek above Lafayette, Ga.	6.34	12 (1965–74) (1977, 1990)	71.7	777 772	1,090 1,140	1,320 1,480	1,640 2,010	1,910 2,440	2,190 2,880	2,510 3,340	2,960 4,000
02411735	McClendon Creek Tributary near Dallas, Ga.	0.88	25 (1977–2001)	59.4	238 232	357 347	449 438	582 578	693 698	815 830	949 974	1,150 1,190
02358998	Holliman Branch near Altha, Fla.	2.04	18 (1969–86)	50.5	297 299	539 543	743 747	1,050 1,050	1,320 1,320	1,630 1,610	1,980 1,940	2,500 2,440
02366859	Pate Branch near Freeport, Fla.	1.87	19 (1969–86) (1989)	31.0	172 181	280 319	367 454	494 655	602 814	722 981	855 1,150	1,050 1,400
02370750	Hurricane Branch near Milton, Fla.	2.95	23 (1961–82) (1989)	54.5	119 132	440 482	900 924	1,980 1,740	3,320 2,590	5,360 3,750	8,360 5,400	14,500 8,530

The climatic characteristics that were considered and compiled for each station included mean annual precipitation (P) and the 24-hour 2-year rainfall intensity ($I_{24,2}$). These basin characteristics were computed and checked for each station in the first year of this study.

Multiple regression analyses were performed relating the station frequency curves to basin characteristics using ordinary least squares (OLS) regression techniques. Results of the analysis showed that contributing drainage area, main channel slope, and forest cover were considered to be the explanatory variables of greatest relevance to peak flows predicted at the streamflow gaging stations. Each of these basin characteristics were used in GLS regression analyses.

A plot of the 50-year peak flow and drainage area for all 43 streamflow gaging stations showed that there was no distinct correlation between geographic location and the magnitudes of peak flows at streamflow gaging stations. Neither stations north or south of the Fall Line plotted consistently on one side of a best-fit line through the data points.

Additional analyses were performed using qualitative variables (indicating region) along with cross products of all the variables to determine whether the resulting equations might be improved. Using OLS regression techniques, this exploratory analysis indicated that there was some geographical bias for the smaller recurrence interval floods (2-year to 25-year) for the non-Coastal Plain region of the State (north of Fall Line). This analysis indicated that there should be two sets of regression equations; one for north of the Fall Line for the 2-year to 25-year recurrence intervals, and one equation for south of the Fall Line for the 2-year to 25-year recurrence intervals. The equations for each recurrence interval have the same slope but different intercepts. For each recurrence interval between 50 and 500 years, however, only one equation was needed to estimate flood-frequency values for both regions. When a qualitative variable for a region was incorporated into GLS regression analyses, the resulting equations yielded estimated peak flows that were within 5 percent of the previously developed statewide equations and standard errors that were slightly higher. Consequently, the analyses indicated that using one regression equation for each recurrence interval was not biased and, as such, is applicable statewide.

GLS regression analysis was applied to the study area with contributing drainage area, channel slope, and percent forest cover designated as the explanatory variables used in the analysis. Stedinger and Tasker (1985, 1986) have shown that GLS regression analysis can provide more accurate estimates of regression coefficients and better estimates of the regression model error than OLS regression analysis. OLS regression analysis does not account for the errors associated with estimates of flood magnitude, varying with the length of observed record, nor does it account for the cross correlation of concurrent peak flow data between sites. GLS regression analysis accounts for these errors by using a weighted matrix so that sites are weighted proportionally according to standard errors and the cross correlation of the peak flow estimates. GLS regressions were performed using multiple combinations of the three explanatory variables. These combinations included the following four scenarios: drainage area; drainage area and slope; drainage area and percent forest; and drainage area, slope, and percent forest. The scenario that produced the equations with the lowest standard error included drainage area as the only explanatory variable.

The accuracy of a flood-frequency relation can be expressed in two ways: as the average standard error of prediction (SEp) or as equivalent years of record. The SEp is a measure of how well the regression relation will estimate flood magnitudes when applied to ungaged basins. The SEp can also be expressed as equivalent years of record (Hardison, 1971). The equivalent years of record represents the number of years of peak flow record necessary to provide a flood estimate with accuracy equal to that of the regional regression flood estimate. For example, the 100-year flood estimate from the regression relation could be estimated with the same degree of accuracy as that which could be obtained from 14 years of actual peak flow record (table 2). After conducting initial regression analyses, a second set of analyses was performed using 41 of the 43 initial streamflow gaging stations. Based on the plot of the 50-year flow and drainage area for all of the streamflow gaging stations, two of the stations (Paint Creek near Marble Valley, Alabama, 02407900, and Woods Creek near Hamilton, Alabama, 02437900) were determined to have flood frequencies that were not closely related to the flood frequencies of the other stations. The rating curves (stage and flow relation) for these two sites were poorly defined at the upper end. The larger water year peak flows for both stations were based on extensions of these poorly defined ratings. For this reason, both streamflow gaging stations were excluded in the final regression analysis. Removing these stations lowered the SEp by about 5 percent for floods having a 10-year or greater recurrence interval. The flood-frequency relations developed from this final set of regression analyses are summarized in table 3. The SEp and the equivalent years of record for the regression relations are listed in table 2. A comparison between the SEp for the regional regression equations published by Atkins (1996) and the SEp for the equations presented in this report are provided in table 4.

Table 2. Accuracy of flood-frequency relations for small rural streams in Alabama.

Recurrence interval (years)	Standard error of prediction (percent)	Equivalent years of record
2	53	2
5	35	5
10	30	9
25	29	13
50	31	14
100	35	14
200	40	13
500	47	12

Table 3. Flood-frequency relations for small rural streams in Alabama.

[A, contributing drainage area, in square miles; Q, peak flow, in cubic feet per second]

Recurrence interval (years)	Regression equation
2	$Q = 189A^{0.742}$
5	$Q = 331A^{0.732}$
10	$Q = 449A^{0.731}$
25	$Q = 626A^{0.732}$
50	$Q = 776A^{0.733}$
100	$Q = 941A^{0.733}$
200	$Q = 1{,}126A^{0.732}$
500	$Q = 1{,}401A^{0.731}$

Table 4. Comparison of average standard errors of prediction for the four regional regression equations published by Atkins (1996) and average standard errors from statewide regression equations for small rural streams in Alabama.

Recurrence interval (years)	Standard error of prediction (percent)				
	Region 1	Region 2	Region 3	Region 4	Statewide equations
2	35	40	37	38	53
5	34	36	35	33	35
10	35	35	34	33	30
25	37	35	33	35	29
50	39	36	33	38	31
100	41	37	33	42	35
200	43	39	34	46	40
500	46	43	35	52	47

Use of Flood-Frequency Relations at Gaged Sites

Flood estimates at gaged sites for a selected recurrence interval can be determined best by weighting the regression and station flood estimates for the specified recurrence interval using the number of years of station record and the accuracy of the regression equations expressed as equivalent years of record. This procedure for estimating flood magnitude for a given recurrence interval at gaged sites can be expressed in the following equation (Interagency Advisory Committee on Water Data, 1982):

$$\log Q_w = \frac{N(\log Q_g) + EY(\log Q_r)}{N + EY}, \quad (2)$$

where

Q_w is the weighted flood estimate for the streamflow gaging station for the selected recurrence interval, in cubic feet per second (ft^3/s);

N is the number of years of station record used to compute Q_g from table 1;

Q_g is the flood estimate from the log-Pearson Type III analysis for the selected recurrence interval, in ft^3/s, at the streamflow gaging station;

EY is the equivalent years of record for Q_r from table 2; and

Q_r is the flood estimate from the regional flood-frequency equation from table 3 for the selected recurrence interval, in ft^3/s.

Use of Flood-Frequency Relations at Ungaged Sites

Flood magnitudes at ungaged sites can be estimated by computing the drainage area for the site of interest and then using the appropriate flood-frequency relation from table 3. Flood estimates can be improved if the ungaged site is located on the same stream as a gaged site having 10 or more years of peak flow record and if the drainage area of the ungaged site is equivalent to 0.5 to 1.5 times the drainage area of the gaged site. The weighted flow, Q_w, at the gaged site can be transferred to the ungaged site using the equation

$$Q_u = \left(\frac{A_u}{A_g}\right)^b Q_w, \quad (3)$$

and a weighted flood estimate at the ungaged site can be computed by the equation

$$Q_{u(w)} = \left(\frac{2\Delta A}{A_g}\right)^b Q_r + \left(1 - \frac{2\Delta A}{A_g}\right) Q_u, \quad (4)$$

where

Q_u is the flood estimate at the ungaged site after transferring the weighted peak flow from the gaged site, in ft^3/s;

Q_w is the weighted flood estimate at the gaged site for the selected recurrence interval, from table 1, in ft^3/s;

$Q_{u(w)}$ is the weighted flood estimate at the ungaged site, in ft^3/s;

Q_r is the flood estimate from the statewide flood-frequency equation for the selected recurrence interval, in ft^3/s;

b is the exponent of the drainage area term of the flood-frequency relation for the applicable recurrence interval, from table 3;

A_u is the drainage area of the ungaged site, in mi^2;

A_g is the drainage area of the gaged site, in mi^2; and

ΔA is the absolute difference in drainage areas between the ungaged site and the gaged site, in mi^2.

Flood-Frequency Relations for Streams in Adjacent States

Flood-frequency relations were developed for 16 streamflow gaging stations that are in adjacent states. These relations were used with those developed for the streams in Alabama to determine the regression equations presented earlier. Flood-frequency relations for sites outside of Alabama will differ from those published in their respective states because of differences in the periods of record used for the studies and the differences in the equations used for best-estimate weighting (table 1).

Summary

Flood flows for recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years were determined for 27 streamflow gaging stations on small rural streams in Alabama using the log-Pearson Type III frequency distribution. The data for 25 of these sites in Alabama and for 16 stations in parts of the adjacent States of Florida, Georgia, Mississippi, and Tennessee were used to develop flood-frequency relations, which can be used to estimate flood flows for recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years for ungaged, unregulated, rural streams in Alabama having drainage areas less than 15 square miles. These flood-frequency relations are applicable where urbanization, channelization, and backwater do not significantly affect the site.

Drainage area was determined to be the most important variable used in predicting flood flow in multiple regression analyses using generalized least-squares methods. These regression methods were used to define the final regression coefficients used in the predictive equations and prediction errors.

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