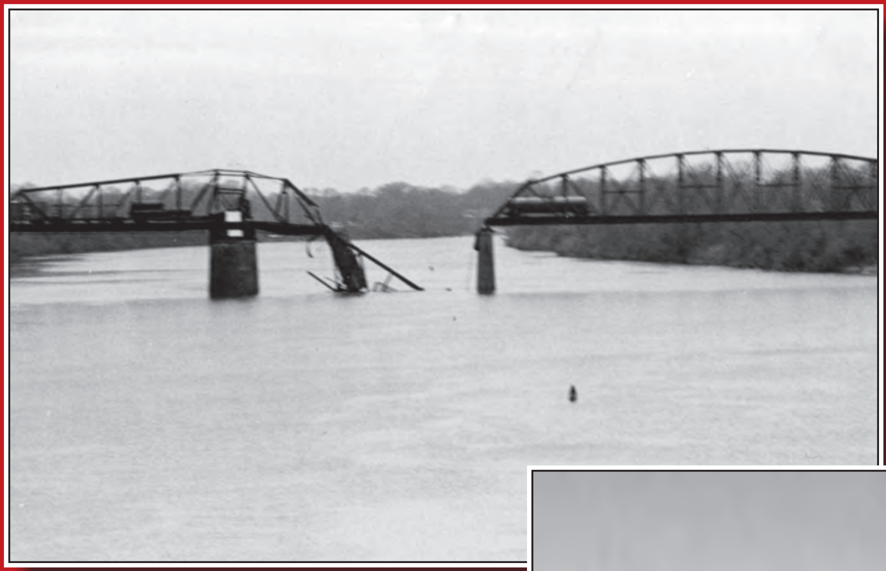
Prepared in cooperation with the Alabama Department of Transportation

Flood-Depth Frequency Relations for Rural Streams in Alabama, 2003



Scientific Investigations Report 2010–5066

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

Cover photographs. ***Front cover:*** *Left:* Alabama River near Montgomery Alabama. *Right:* Selma, Alabama, flooding of 1990. ***Back cover:*** *Clockwise from upper left:* Lake Tuscaloosa, Tuscaloosa, Alabama; Selma, Alabama, flooding of 1979; Choctawhatchee River near Newton, Alabama; Styx River near Elsanor, Alabama. *Center:* Styx River near Elsanor, Alabama.

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By K.G. Lee and T.S. Hedgecock

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.00405	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Flood-Depth Frequency Relations for Rural Streams in Alabama, 2003

By K.G. Lee and T.S. Hedgecock

Abstract

Equations have been defined for estimating the depth of water for floods having a 67-, 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance on rural streams in Alabama. Multiple regression analyses of streamgage data were used to define the equations. Eight basin and climatic characteristics that were computed by using a geographical information system were evaluated as independent variables to determine their statistical significance for the dependent variable, flood depth.

Drainage area was the most statistically significant independent variable tested. Addition of other significant variables did not decrease the standard error of prediction by more than 2 percent. Regression relations, for four different hydrologic regions, were developed to estimate flood depth for rural, ungaged streams as a function of the basin drainage area. These relations are based on computed depths that correspond to the flood magnitude and frequency for 164 streamgages in Alabama and 42 streamgages in adjacent States having at least 10 years of consecutive record. These relations utilize observed flood data collected through 2003. The geologic, physiographic, and climatic variability affecting flood depth is reflected in the constant (intercept) and exponent (slope) for each regional regression equation. Average standard errors of prediction for these regression equations range from 18 to 38 percent.

Introduction

The Alabama Department of Transportation designs bridges, culverts, and highway embankments on the basis of flow magnitude and the associated flood depth. Depending on the capacity and volume of traffic on a highway, the flood depth associated with a flow magnitude having a 10-, 4-, 2-, or 1-percent chance exceedance is used in the design. Additionally, the flood depth and flow magnitude are used by governmental agencies responsible for land-use development, flood-plain zoning, and flood-insurance studies. The U.S. Geological Survey (USGS), in cooperation with the Alabama Department of Transportation defined equations for estimating the depth of water for floods having a 67-, 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance on rural streams in Alabama.

The approach to determine flood depths for hydraulic design of drainage structures and for flood-plain mapping is to determine flood-frequency flows by the best available methods and use an open-channel hydraulic model to obtain flood elevations, flow distributions, and velocities. Although these data are essential for many bridge and culvert design applications, this approach can be expensive and time consuming, because of the demands of collecting geometric surveys of the channel, flood plain, and associated hydraulic structures. Also, the field survey of the necessary calibration data could add substantial time and expense. In cases where flood management and planning require only a flood elevation (as for reconnaissance flood-plain mapping), an alternative approach is to estimate flood depths directly without determining flow or applying a hydraulic model. An example of this approach is Federal Emergency Management Agency's (FEMA) "less-than-detailed methods," which are used to derive flood-hazard maps. A set of regional flood-depth frequency equations will aid engineers in hydraulic design and flood-risk management.

Purpose and Scope

The information in this report updates previously published flood-depth frequency information for Alabama by providing methods of estimating the depth frequency of floods at rural, ungaged streams. The data in this report are based on flood-frequency analyses of annual peak-flow data collected at streamgaging stations through September 2003. The flood-depth values that correspond to the flood-flow frequency were estimated and used to determine a flood-depth frequency for each streamgaging station. The report presents flood-depth frequency statistics at the 67-, 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance levels determined for 206 rural, gaged stations in Alabama and adjacent States with unregulated flow conditions. The report (1) includes regional equations for estimating the magnitude and frequency of flood depths on rural, ungaged streams in Alabama that are not affected by regulation, (2) presents estimates of the magnitude of flood depths at the 67-, 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance levels for 164 streamgaging stations in Alabama, (3) describes techniques used to develop regression equations for use in estimating the depth of floods for rural, ungaged sites in Alabama, (4) describes the accuracy and limitations of the equations, and (5) presents example applications of the methods.

Previous Studies

Flood-depth frequency relations have been described by Hains (1977) and Olin (1985b). When the U.S. Geological Survey began preparing maps of flood-prone areas as directed by the 89th Congress in House Document 465 (1966), a need arose for a method of determining flood depths for use in delineating approximate flood-prone areas. Regional flood-depth-frequency equations for the 10- and 1-percent chance exceedance were developed in Alabama for this purpose (Hains, 1977). These equations are based on 129 rural streamgages with drainage areas ranging from 1.0 to 800 square miles (mi^2). The equations were updated (Olin, 1985b) to include small rural gages, urban gages, and flood records collected through 1983. Olin (1985b) evaluated the relation between basin characteristics and flood depths for the 50-, 20-, 10-, 4-, 2-, 1-, and 0.5-percent chance exceedance at 180 streamgages in Alabama (158 rural and 22 urban).

Description of the Study Area

The study area includes all of Alabama, which covers an area of about 51,600 mi^2 in five physiographic provinces—Coastal Plain, Piedmont, Valley and Ridge, Appalachian Plateaus, and Interior Lowland 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 the North American Vertical Datum of 1988 (NAVD 88). In the Coastal Plain, elevations range from 0 to 1,000 ft above NAVD 88 in the northwestern part of the State. The land surface generally slopes to the south and west.

Average annual precipitation ranges from about 48 inches in central and east-central Alabama to about 68 inches near the Gulf of Mexico and averages about 57 inches statewide (National Oceanic and Atmospheric Administration, 2002). Rainfall in Alabama generally is associated with the movement of warm and cold fronts across the State from November through April and isolated summer thunderstorms from May through October. Occasionally, tropical storms or hurricanes that enter the State along the gulf coast produce unusually heavy amounts of rainfall. Average annual runoff varies from approximately 12 to 40 inches. Runoff typically is greatest during February through April and least when rainfall decreases during September through November.

Definition of Flood Depths

Flood-depth values were computed for the 67-, 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance flows for each streamgage used in the analysis. Flood depths were computed as the difference in the elevation of the flood and the elevation of the gage height of zero flow. The weighted "best estimate" flow was used from "Magnitude and Frequency of Floods in Alabama, 2003" by Hedgecock and Feaster (2007) to develop the relation between flow and depth for each gage. This flow was used with the rating curve (gage height to flow relation) to determine a flood elevation for each exceedance probability.

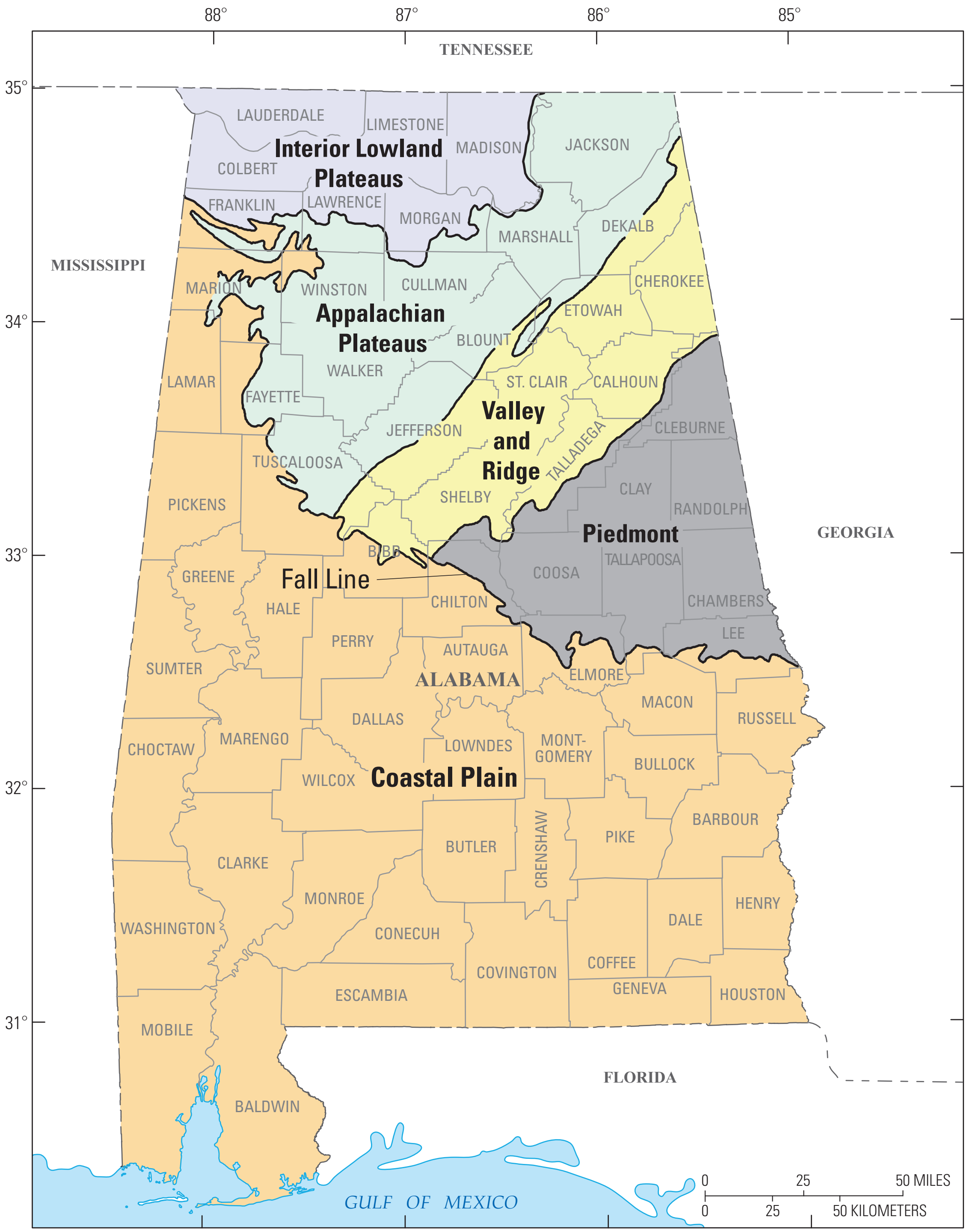
The stage values were converted to depth values by using the gage height of zero flow as a reference point. The gage height of zero flow is the gage height of the lowest point of the control. It represents the thalweg of the measuring section. The gage height of zero flow can change with time because of scouring, filling, and permanent changes. Because the gage height of zero flow is not static for all stations, several methods were used to compute an average value for the entire period of record for each gage. The majority of the stations used in the analysis have direct measurements of the gage height of zero flow. These measurements were inspected for variance throughout the period of record. An average value was computed and used as the reference point. In the instance that the gage has a culvert rating, the culvert invert was used as the point of reference. For stations lacking sufficient documentation of the gage height of zero flow, low-water discharge measurements were used to compute an average reference surface. These values were checked by examining the scale offset of the rating curve when available.

The computed depth values represent a value that corresponds to a flow frequency for each gage rather than a computed frequency of depths for each gage. These depths provide estimates that correspond with percent chance of exceedance flood-flow magnitudes that can be used for design purposes.

Flood Magnitude and Frequency at Streamgages

A flood-frequency estimate is the relation of a flood characteristic to a probability of exceedance. Probability of exceedance refers to the chance that a given flood characteristic will be exceeded in any one year. For example, a 1-percent chance exceedance flood (formerly known as the "100-year flood") corresponds to the flow magnitude that has a probability of 0.01 of being equaled or exceeded in any given year. A frequency analysis of annual peak-flow data at a streamgage provides an estimate of the flood magnitude and frequency at the specific stream site. Flood-frequency flows in previous USGS reports were expressed as T-year floods on the basis of the recurrence interval for that flood quantile (for example, the "100-year flood"). The use of recurrence-interval terminology is now discouraged because it sometimes causes confusion to the general public (Gotvald and others, 2009). The term is sometimes interpreted to imply that there are set time intervals between floods of a particular magnitude, when in fact floods are random processes that are best understood using probabilistic terms.

The terminology associated with flood-frequency estimates is undergoing a shift away from the T-year recurrence



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.

Table 1. T-year recurrence intervals with corresponding annual exceedance probabilities and P-percent chance exceedances for flood-frequency depth estimates.

T-year recurrence interval	Annual exceedance probability	P-percent chance exceedance
1.5	0.67	67
2	0.50	50
5	0.20	20
10	0.10	10
25	0.04	4
50	0.02	2
100	0.01	1
200	0.005	0.5
500	0.002	0.2

interval flood to the P-percent chance exceedance flood (Gotvald and others, 2009). The use of percent chance exceedance flood conveys the probability, or odds, of a flood of a given magnitude being equaled or exceeded in any given year. T-year recurrence intervals with corresponding annual exceedance probabilities and P-percent chance exceedances are given in table 1.

The flood-frequency relations for the streamgages used in the previous flood-depth report (Olin, 1985b) are based on flow values computed using "Magnitude and Frequency of Floods in Alabama" by Olin (1985a). Since the completion of Olin's (1985b) flood-depth report, three subsequent flood-frequency reports (Atkins, 1996; Hedgecock, 2004; Hedgecock and Feaster, 2007) have been published with the inclusion of more data. An additional 20 years of flood-depth data over a wider range of streams are now available.

Methods of estimating flood flow magnitudes for the 67-, 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedance have been developed for rural streams in Alabama that are not affected by regulation or urbanization (Hedgecock and Feaster, 2007). Regression relations were developed using generalized least-squares (GLS) regression techniques to estimate flood magnitude and frequency on ungaged streams as a function of the basin drainage area. These methods are based on flood-frequency characteristics for 169 streamgages in Alabama and 47 streamgages in adjacent States having 10 or more years of record through September 2003.

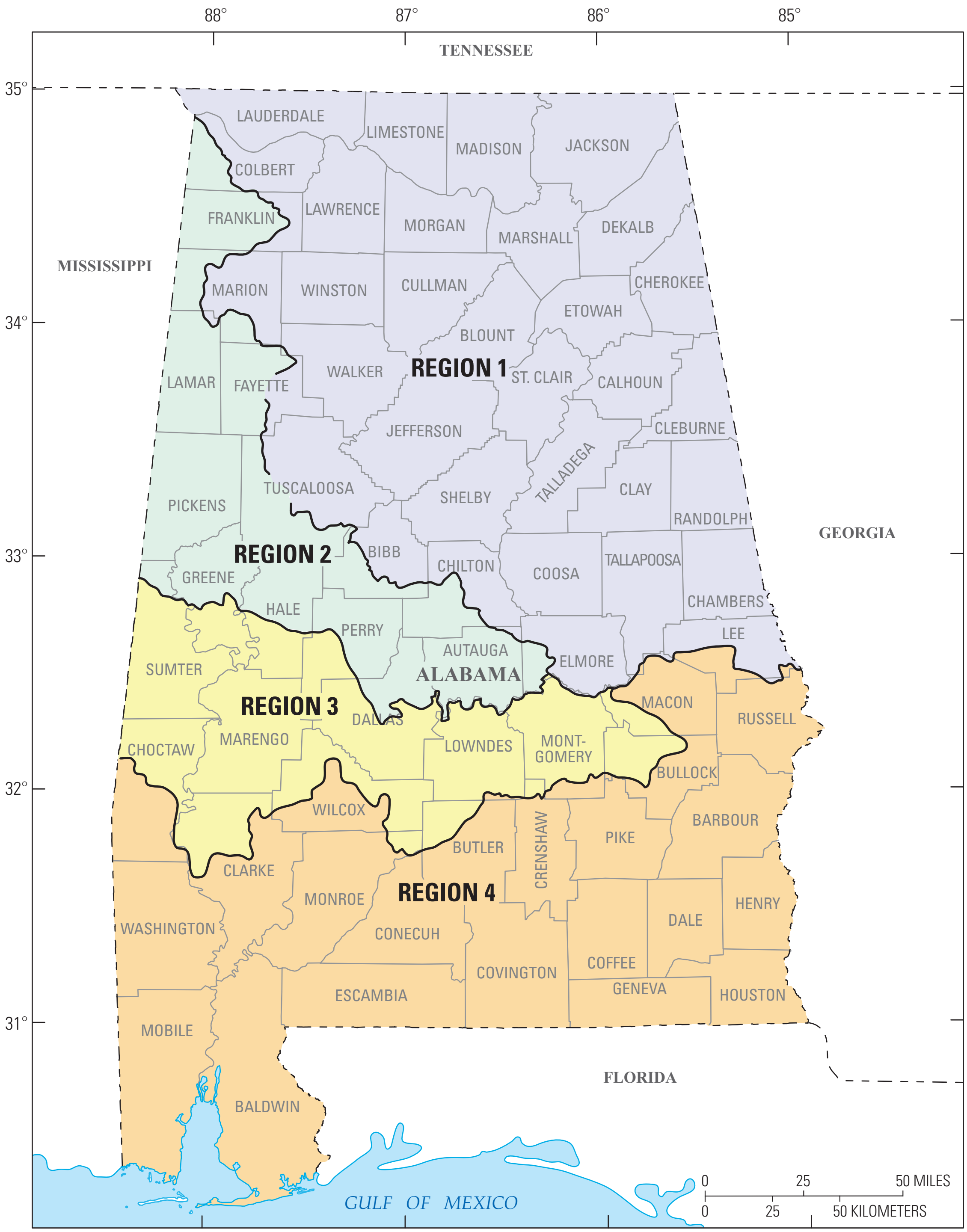
Initial GLS regression analyses were performed for all the streamgages included in the study. The residuals for each streamgage were plotted on a State map and inspected for geographic bias. The residuals plot indicated the presence of geographic biases or clusters, and the four flood regions shown in figure 2 were delineated for Alabama on the basis of the residuals plot, previous flood-frequency studies, drainage area maps, geologic maps, and physiographic maps.

Separate GLS multiple regression analyses were performed for each of the four flood regions, and the standard errors were reduced in comparison to a single statewide GLS regression relation. In each flood region, the contributing drainage area was the most statistically significant variable. Addition of other significant variables did not decrease the standard error of prediction by more than 2 percent. Generalized least-squares regression analysis, using contributing drainage area as the only explanatory variable, was applied to the four flood regions. The flood-frequency relations for the four flood regions are summarized in table 2.

Table 2. Regional flood-frequency relations for rural streams in Alabama.

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

Percent chance exceedance	Rural regression equations for the indicated flood regions (fig. 2)			
	Region 1	Region 2	Region 3	Region 4
67	$Q = 184\ A^{0.666}$	$Q = 126\ A^{0.663}$	$Q = 254\ A^{0.565}$	$Q = 157\ A^{0.586}$
50	$Q = 250\ A^{0.656}$	$Q = 166\ A^{0.660}$	$Q = 322\ A^{0.578}$	$Q = 204\ A^{0.590}$
20	$Q = 466\ A^{0.636}$	$Q = 291\ A^{0.652}$	$Q = 562\ A^{0.593}$	$Q = 367\ A^{0.590}$
10	$Q = 650\ A^{0.623}$	$Q = 393\ A^{0.648}$	$Q = 802\ A^{0.592}$	$Q = 499\ A^{0.588}$
4	$Q = 918\ A^{0.610}$	$Q = 532\ A^{0.645}$	$Q = 1{,}206\ A^{0.586}$	$Q = 692\ A^{0.584}$
2	$Q = 1{,}137\ A^{0.601}$	$Q = 642\ A^{0.643}$	$Q = 1{,}559\ A^{0.583}$	$Q = 857\ A^{0.580}$
1	$Q = 1{,}368\ A^{0.593}$	$Q = 763\ A^{0.641}$	$Q = 1{,}930\ A^{0.584}$	$Q = 1{,}036\ A^{0.578}$
0.5	$Q = 1{,}609\ A^{0.587}$	$Q = 899\ A^{0.638}$	$Q = 2{,}306\ A^{0.588}$	$Q = 1{,}229\ A^{0.577}$
0.2	$Q = 1{,}943\ A^{0.579}$	$Q = 1{,}109A^{0.634}$	$Q = 2{,}798\ A^{0.598}$	$Q = 1{,}502\ A^{0.576}$



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

Figure 2. Locations of the four rural flood regions in Alabama.

Determination of Flood-Depth Frequency Relations

Flood-depth relations can be estimated at ungaged locations by developing regression equations. This was accomplished through the selection of data at streamgages and using regional analysis to extend the records spatially.

Data Selection

Streamflow records for 216 streamgages were used in the development of the statewide rural flood-frequency analysis (Hedgecock and Feaster, 2007). Of these 216 stations, 11 streamgages were not used for flood-depth analysis for one of two reasons: (1) stage-discharge relations were not defined at the upper end of the flow regime or (2) too much variation was determined in the gage height of zero flow. One additional site was included in region 3 (plate 1), Hamilton Branch near DeKalb, Mississippi (USGS gaging station 02467100). This site provided data for the lower range of drainage areas for region 3.

A total of 206 streamgages were used to develop the flood-depth database. Records were analyzed to provide an approximate depth of flow having 67-, 50-, 20-, 10-, 4-, 2- and 1-percent chance exceedance for 164 streamgages on rural streams in Alabama and 42 additional gaging stations in parts of the adjacent States of Florida, Georgia, Mississippi, and Tennessee. Natural forces create stream channels that are in balance with the magnitude and frequency of the flows of the stream. For mature streams that are in a state of quasi-equilibrium, a correlation may exist between some measurable feature or combination of features of the stream channel and basin and the depth and frequency of overflows (Wiitala and others, 1961). Many different correlations were investigated in an attempt to find a significant and hydrologically meaningful relation between flood depth and various basin characteristics. Basin characteristics were computed for each gage by using Geographic Information System (GIS) coverages and included in the rural flood-depth dataset. The names, units of measure, and methods of measurement for the basin characteristics that were considered for use in the study are listed in table 3.

Regression Analysis

Since flood-depth information is collected only at streamgages, mathematical methods are required to transfer the measured information to ungaged sites within the State where flood-depth information is needed. A regional analysis provides a tool for doing this. Regional analysis is concerned with extending records spatially as differentiated from extending records in time. The specific purposes of a regional analysis are to provide estimates of the characteristics of the frequency distributions at ungaged sites and to improve

Table 3. Basin characteristics considered for use in regional regression analysis.

Contributing Drainage Area	Square miles	Area that contributes flow to a point on a stream
Main channel length	Miles	Length along the main channel from the measuring location extended to the basin divide
Main channel slope	Feet per mile	Difference in the elevation at points corresponding to 10% and 85% of the main channel divided by the main channel length between those two points
Lagtime		Main channel length divided by the square root of the main channel slope
Percent Forest	Percent	Percentage of area covered by forest
Percent Storage	Percent	Percentage of area of storage (lakes, ponds, reservoirs, and wetlands)
Slenderness Ratio	Dimensionless	Main channel length squared divided by the contributing drainage area
Weighted 67 percent chance exceedance peak flow	Cubic feet per second	Weighted maximum instantaneous flow that has a 67 percent chance of exceedance

estimates of the frequency distributions of flow characteristics at gaged sites (Riggs, 1973).The regression model (Riggs, 1973) used in regional flood-frequency analyses is:

$$Q_P = aA^bB^cC^d \qquad (1)$$

where

- Q_P is the flood magnitude having a P-percent chance of exceedance (dependent variable);
- A, B, C are the basin and climatic characteristics of the drainage basin (independent variables); and
- a, b, c, d are the constant and coefficients for a given percent chance of exceedance (P).

This regression model was used to develop the flood-depth equations. Multiple regression is directly useful as a regionalization tool because the flood depth for a given frequency level can be related to basin characteristics, leaving residuals that may be considered as due to chance. The regression line averages these residuals. Thus, in one operation, the effects of differing basin characteristics are preserved, and the chance variation is averaged (Riggs, 1973). Multiple regressions were performed using the stepwise procedure maximum R^2 improvement (MAXR) used by the Statistical Analysis System (SAS) (SAS Institute Inc, 1982). R^2 is the coefficient of determination (square of the multiple correlation coefficient); it measures how much variation in the dependent variable can be accounted for by the model (independent variables). The MAXR method begins by finding the one-variable model producing the largest R^2 and adds another variable that will produce the largest increase in R^2. Each variable in the two-variable model is compared to each variable not in the model. The MAXR method determines if removing one variable and replacing it with another would improve R^2. Comparison or replacement of variables continues until the "best" two-variable model, three-variable model, and so forth is derived.

The initial results of the multiple regression analyses for 206 rural, gaged stations showed that contributing drainage area, 67-percent chance exceedance flow, main channel slope, and storage were the four explanatory variables having the greatest statistical significance in relation to estimated flood depths at the gaging stations. Selection of suitable independent variables is often made on a statistical basis; that is, many variables are used in preliminary regressions and those that lack statistical significance are discarded. This practice occasionally results in the retention of a variable in the regression the effect of which does not conform to known hydrologic principles. Usually the effect of such a variable on the result is trivial (a few percentages of reduction in standard error). The multiple regression analysis indicated that the most significant basin characteristic tested was drainage area. The addition of other explanatory variables decreased the standard error of prediction by a maximum amount of 1 percent.

Initially, analyses were preformed for the entire State and included data for 206 rural stations. The residuals from the regression analysis were plotted on a map to check for possible geographical bias. The map of residuals indicated the presence of geographic biases or clusters, and development of separate regression equations for smaller regions representing the clustered values was considered necessary to improve the flood-depth estimates. Regions previously developed in "Magnitude and Frequency of Floods in Alabama, 2003" by Hedgecock and Feaster (2007) were used because the flood-depth dataset is based on depths that correspond to flow magnitude and frequency for each gage as opposed to computing a flood-depth frequency for each gage (see previous section Definition of Flood Depths).

Separate multiple regression analyses were performed for each of the four flood regions (fig. 2), and the standard error of prediction was reduced in comparison to a single statewide regression relation. In each flood region, the contributing drainage area was the most statistically significant variable. Addition of other significant variables did not decrease the standard error of prediction by more than 2 percent. Therefore, contributing drainage area was the only variable retained in the regression analyses. The locations of the rural gaging stations and regional divides can be viewed in plate 1. The resulting regression equations (table 4) for rural streams are in the form:

$$D_P = a\,(A)^b \qquad (2)$$

where

- D_P is the flood depth having a P-percent chance of exceedance (dependent variable);
- A is the basin and climatic characteristics of drainage basin (independent variable); and
- a, b are the constant and coefficients for a given percent chance of exceedance (P).

The regression results and the depth computed from the stage-discharge relation for each gaging station are listed in appendix 1.

Accuracy and Limitations

The accuracy of a flood-frequency relation has been expressed in two ways—as mean standard error of estimate (SE_E) or as mean standard error of prediction (SE_P). The SE_E is a measure of how well the regression equation fits the data used to derive the relation and often is referred to as the model error. The SE_E is the standard deviation of the differences between station data and the corresponding values computed from the regression equation. The SE_E for this investigation ranged from a minimum of 17 percent (region 3) to a maximum of 36 percent (region 2). The SE_P is a measure of how well the regression relation estimates flood depths when applied to ungaged basins. The SE_P is the square root

Table 4. Regional flood-depth frequency relations for rural streams in Alabama.

[d, flood depth, in feet; A, contributing drainage area, in square miles]

Percent chance exceedance	Rural regression equations for the indicated flood regions (fig. 2)			
	Region 1	**Region 2**	**Region 3**	**Region 4**
67	$d = 2.7\,A^{0.283}$	$d = 2.6\,A^{0.284}$	$d = 4.8\,A^{0.215}$	$d = 3.4\,A^{0.225}$
50	$d = 3.3\,A^{0.275}$	$d = 3.0\,A^{0.275}$	$d = 5.3\,A^{0.220}$	$d = 3.9\,A^{0.226}$
20	$d = 4.4\,A^{0.257}$	$d = 4.1\,A^{0.244}$	$d = 6.2\,A^{0.219}$	$d = 4.9\,A^{0.220}$
10	$d = 5.1\,A^{0.247}$	$d = 4.8\,A^{0.230}$	$d = 7.1\,A^{0.205}$	$d = 5.6\,A^{0.214}$
4	$d = 6.0\,A^{0.237}$	$d = 5.9\,A^{0.206}$	$d = 8.6\,A^{0.180}$	$d = 6.7\,A^{0.200}$
2	$d = 6.7\,A^{0.226}$	$d = 6.5\,A^{0.196}$	$d = 9.9\,A^{0.160}$	$d = 7.0\,A^{0.203}$
1	$d = 7.3\,A^{0.221}$	$d = 7.2\,A^{0.182}$	$d = 11.2\,A^{0.142}$	$d = 7.5\,A^{0.201}$

of the mean square error of prediction, MSE_P. The MSE_P is the sum of two components—the mean square error resulting from the model and the sampling mean square error, which results from estimating the model parameters from samples of the population. The SE_P for this investigation ranged from a minimum of 18 percent (region 3) to a maximum of 38 percent (region 2). Table 5 gives the standard error of estimate and standard error of prediction by hydrologic region for the selected recurrence intervals.

The regression relations are valid for ungaged basins where the drainage area is within the minimum and maximum drainage areas used in the regression analysis. Drainage area for the streamgages used in the regression analyses ranged from 0.24 to 1,370 mi^2. However, the distribution of drainage areas varies by hydrologic regions. The user is cautioned that if the equations are used outside the limits shown, errors may be greater than those defined by the data. Reliability of the regression relations for drainage areas outside of the flood region limits is unknown. The range of applicable drainage areas for each flood region is as follows:

Flood region 1 0.50 to 1,027 mi^2
Flood region 2 0.24 to 1,370 mi^2
Flood region 3 0.97 to 607 mi^2
Flood region 4 0.76 to 1,344 mi^2

When computing flood depths for a minor tributary near the confluence of a major tributary, the drainage area below the confluence should be used in the areas of backwater because the major tributary could cause backwater for some distance upstream in the minor tributary. The regression relations should not be used where dams, flood-detention structures, tides, and channelization have a significant effect on peak discharges nor should they be used for streams in urban areas unless the effects of urbanization are insignificant.

Application of Flood-Depth Frequency Equations

Flood depths can be estimated for the 67-, 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance for most ungaged rural streams within the drainage area limits by solving the equations in table 4. The hydrologic areas used for selecting the applicable equations are shown on plate 1. Flood depth estimated from these equations is the depth in feet from the gage height of zero flow to the water-surface elevation. The boundaries of the hydrologic regions shown on plate 1 were drawn to avoid crossing most streams except for large streams (streams with drainage areas greater than those used to define the equations). Flood-depth relations should not be used to obtain flood discharges; the methods for flood-discharge estimation are presented in reports by Hedgecock and Feaster (2007). Average flood depths may be estimated by the following procedure: (1) locate the drainage basin on plate 1 to determine in which hydrologic region it is located, (2) determine the drainage area upstream from the site of interest by using a topographic map or aerial photograph, and (3) use the equations (table 4) for the appropriate hydrologic region to compute average flood-depth values for the probability of exceedance of interest.

An example of the application of the procedure described above is the following computation of the 50-percent chance exceedance depth for the streamgage on Wehadkee Creek below Rock Mills, Alabama (USGS gaging station 02339225).

Locate the drainage basin on plate 1 to find which hydrologic region it is in. For example, Wehadkee Creek below Rock Mills, Alabama, is in hydrologic region 1.

Determine the contributing drainage area upstream from the site at the road crossing. The published drainage area as determined from a U.S. Geological Survey quadrangle map is 60.2 mi^2.

Table 5. Accuracy of regional flood-depth frequency relations for rural streams in Alabama.

[n= number of streamgages (pl. 1) used in regional regressions]

Percent chance exceedance	Region 1 (n=96)		Region 2 (n=29)		Region 3 (n=19)		Region 4 (n=62)	
	Mean Standard error of prediction (percent)	Mean Standard error of estimate (percent)	Mean Standard error of prediction (percent)	Mean Standard error of estimate (percent)	Mean Standard error of prediction (percent)	Mean Standard error of estimate (percent)	Mean Standard error of prediction (percent)	Mean Standard error of estimate (percent)
67	32	32	38	36	26	22	30	29
50	31	31	37	35	25	20	30	29
20	30	29	33	32	24	19	30	30
10	30	29	33	32	23	19	32	32
4	30	30	36	35	22	19	33	33
2	30	30	35	34	18	17	32	31
1	32	32	36	35	20	19	33	32

Using the equations for hydrologic region 1 from table 4, the 50-percent chance exceedance depth is estimated as 10.2 ft above the gage height of zero flow.

The estimates of flood depth produced by these regression equations correspond to flood-flow frequency at particular exceedance probability levels. The equations provide estimated values and are not technically equivalent to a calibrated hydraulic model.

Summary

Flood depths for selected exceedance probabilities were determined for 164 gaging stations on rural streams in Alabama and 42 additional stations in parts of the adjacent States of Florida, Georgia, Mississippi, and Tennessee. Data for these sites were used to develop regional flood-depth frequency relations that can be used to estimate flood depths for 67- , 50-, 20-, 10-, 4-, 2-, and 1-percent chance exceedance flows for ungaged, unregulated rural streams in Alabama.

The depth of floods at streamgages was computed by taking the difference between the elevation of flood with the exceedance probability of 67, 50, 20, 10, 4, 2, and 1 percent and the gage height of zero flow. Multiple regression analyses were made using the “MAXR” maximum R^2 improvement procedures. Eight basin and climatic characteristics that were computed by using a GIS were evaluated as predictors of flood depth in the multiple regression analyses.

Multiple regression analyses were performed on the rural flood-depth dataset for each of the four flood regions. In each flood region, the contributing drainage area was the most statistically significant variable. Addition of other significant variables did not decrease the standard error of prediction by more than 2 percent. Therefore, contributing drainage area was the only variable retained in the final regression equations.

The regional flood-depth frequency equations can be applied to streams in Alabama that are not affected by backwater, regulation, urbanization, tides, or channelization. Methods are presented in the report for determining flood depths for selected exceedance probabilities on ungaged and gaged streams. The equations can be used for streams with drainage areas within the limits shown in this report (0.24 to 1,370 mi^2). When computing flood depths for a minor tributary near the confluence of two streams, the drainage area below the confluence in the area of backwater should be used in the computation because the major tributary could cause backwater for some distance upstream in the minor tributary. The flood-depth relations should not be used to compute flood flows; methods for computing flood flows are given in reports by Hedgecock and Feaster (2007).

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Appendix 1

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02339225	1	Wehadkee Creek below Rock Mills	60.2	9.5	10.4	12.3	13.4	14.8	15.7	16.5
				8.6	10.2	12.6	14.0	15.8	16.9	18.1
02340750	1	Osanippa Creek near Fairfax	99.7	7.0	8.0	10.3	11.8	13.3	14.2	15.1
				9.9	11.7	14.4	15.9	17.9	19.0	20.2
02342150	4	Uchee Creek near Seale	162	9.0	9.8	11.1	11.9	12.7	13.3	13.9
				10.7	12.3	15.0	16.6	18.5	19.7	20.9
02342200	1	Phelps Creek near Opelika	6.67	7.4	7.8	8.5	8.8	9.2	9.4	9.6
				4.6	5.6	7.2	8.1	9.4	10.3	11.1
02342500	4	Uchee Creek near Fort Mitchell	322	9.2	11.5	17.0	20.4	23.1	24.2	24.9
				12.5	14.4	17.5	19.3	21.3	22.6	23.9
02342933	4	South Fork Cowikee Creek near Bates-ville	112	14.4	16.8	21.9	25.3	29.9	33.3	36.7
				9.8	11.3	13.8	15.4	17.2	18.2	19.4
02343275	4	Abbie Creek near Abbeville	48.7	5.9	6.3	7.4	8.1	8.9	9.6	10.0
				8.2	9.4	11.5	12.9	14.6	15.4	16.4
02343300	4	Abbie Creek near Haleburg	146	9.7	11.9	19.2	25.0	29.0	31.2	33.0
				10.4	12.0	14.7	16.3	18.2	19.3	20.4
02343700	4	Stevenson Creek near Headland	14	5.3	6.2	8.0	9.1	10.1	11.2	12.1
				6.2	7.1	8.8	9.9	11.4	12.0	12.7
02358785	4	Cowarts Creek near Cottonwood	103	6.9	7.7	9.4	10.2	11.2	12.2	13.1
				9.6	11.1	13.6	15.1	16.9	17.9	19.0
02360000	4	West Fork Choc-tawhatchee River at Blue Springs	86.8	5.5	6.2	7.9	6.0	10.7	11.9	13.1
				9.3	10.7	13.1	14.6	16.4	17.3	18.4
02360275	4	Judy Creek near Ozark	102	11.3	13.1	15.9	17.0	18.4	19.5	20.4
				9.6	11.1	13.6	15.1	16.9	17.9	19.0
02360500	4	East Fork Choctawhatchee River near Midland City	291	13.8	16.1	19.6	21.9	24.4	26.2	28.0
				12.2	14.1	17.1	18.9	20.8	22.1	23.5

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02361000	4	Choctawhatchee River near Newton	686	16.1	20.3	27.8	31.2	34.5	36.3	38.1
				14.8	17.1	20.6	22.7	24.7	26.4	27.9
02362610	4	Pea River near Midway	18.7	9.4	9.8	10.4	11.1	11.8	12.5	13.0
				6.6	7.6	9.3	10.5	12.0	12.7	13.5
02363000	4	Pea River near Ariton	498	12.4	15.2	17.8	19.3	21.0	22.1	23.2
				13.8	15.9	19.2	21.2	23.2	24.7	26.1
02363005	4	Pea River tributary near Roeton	0.76	2.4	3.1	4.7	5.8	7.2	8.3	9.5
				3.2	3.7	4.6	5.3	6.3	6.6	7.1
02364000	4	Pea River at Elba	959	19.8	22.8	30.0	34.4	40.2	43.6	45.8
				15.9	18.4	22.2	24.3	26.5	28.2	29.8
02364500	4	Pea River near Samson	1182	24.4	27.9	34.3	37.8	41.3	43.5	45.3
				16.7	19.3	23.2	25.5	27.6	29.4	31.1
02365310	4	Grants Branch tributary near Fadette	1.44	4.7	5.5	7.5	8.9	9.5	9.6	9.7
				3.7	4.2	5.3	6.1	7.2	7.5	8.1
02367500	4	Lightwood Knot Creek at Babbie	114	7.7	8.1	9.7	10.9	12.4	13.8	15.1
				9.9	11.4	13.9	15.4	17.3	18.3	19.4
02367800	4	Yellow River near Wing	461	12.5	13.7	16.4	17.7	19.2	20.1	20.8
				13.5	15.6	18.9	20.8	22.8	24.3	25.7
02369800	4	Blackwater River near Bradley	87.7	11.2	13.6	17.3	19.5	22.0	23.5	24.4
				9.3	10.7	13.1	14.6	16.4	17.4	18.4
02371000	4	Conecuh River near Troy	257	11.1	12.3	14.4	15.5	16.7	17.6	18.7
				11.8	13.7	16.6	18.4	20.3	21.6	22.9
02371200	4	Indian Creek near Troy	8.87	3.9	4.2	4.9	5.3	5.7	6.0	6.1
				5.6	6.4	7.9	8.9	10.4	10.9	11.6
02371500	4	Conecuh River at Brantley	500	16.2	18.4	21.2	22.5	23.9	24.7	25.6
				13.8	15.9	19.2	21.2	23.2	24.7	26.2

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi^2, square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi^2)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02372000	4	Patsaliga Creek at Luverne	254	12.3	13.2	14.7	15.6	16.5	17.3	17.9
				11.8	13.6	16.6	18.3	20.3	21.5	22.8
02372250	4	Patsaliga Creek near Brantley	442	18.0	19.3	21.0	21.9	23.1	24.0	23.7
				13.4	15.5	18.7	20.6	22.7	24.1	25.5
02372500	4	Conecuh River near Andalusia	1344	23.5	29.1	34.5	37.4	40.1	42.1	43.8
				17.2	19.9	23.9	26.2	28.3	30.2	31.9
02372800	4	Stallings Creek near Greenville	37.8	8.4	9.0	10.0	10.4	11.1	11.7	12.2
				7.7	8.9	10.9	12.2	13.9	14.6	15.6
02373000	4	Sepulga River near Mckenzie	470	9.7	13.0	19.1	21.9	24.0	25.3	27.0
				13.6	15.7	19.0	20.9	22.9	24.4	25.8
02373500	4	Pigeon Creek near Thad	307	15.9	18.4	22.9	24.9	26.9	28.6	30.0
				12.3	14.2	17.3	19.1	21.1	22.4	23.7
02374500	4	Murder Creek near Evergreen	176	10.7	11.6	13.4	14.6	15.9	16.9	17.9
				10.9	12.5	15.3	16.9	18.8	20.0	21.2
02374970	4	Sizemore Creek near Robinsonville	79.4	7.6	8.2	9.4	10.0	11.0	11.6	12.3
				9.1	10.5	12.8	14.3	16.1	17.0	18.1
02375000	4	Big Escambia Creek at Flomaton	330	11.2	12.1	16.1	17.6	18.7	19.2	19.7
				12.5	14.5	17.5	19.4	21.4	22.7	24.1
02377500	4	Styx River near Loxley	92.2	8.8	12.2	16.9	18.3	19.5	20.5	21.3
				9.4	10.8	13.3	14.7	16.6	17.5	18.6
02378500	4	Fish River near Silver Hill	55.3	9.6	11.0	14.1	15.8	17.8	19.3	20.8
				8.4	9.7	11.8	13.2	14.9	15.8	16.8
02398300	1	Chattooga River above Gaylesville	366	13.7	15.6	18.2	19.8	21.5	22.7	23.9
				14.3	16.7	20.1	21.9	24.3	25.4	26.9
02398500	1	Chattooga River at Gaylesville	379	15.9	16.8	18.5	19.5	20.7	21.7	22.5
				14.5	16.9	20.2	22.1	24.5	25.6	27.1

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02399000	1	Little River near Jamestown	125	7.2	8.2	10.1	11.3	12.6	13.5	14.3
				10.6	12.4	15.2	16.8	18.8	20.0	21.2
02399200	1	Little River near Blue Pond	199	7.6	8.2	9.8	10.7	11.9	12.7	13.6
				12.1	14.1	17.1	18.9	21.0	22.2	23.5
02400000	1	Terrapin Creek near Piedmont	116	9.1	9.9	11.2	11.9	12.6	13.2	13.6
				10.4	12.2	14.9	16.5	18.5	19.6	20.9
02400033	1	Nances Creek near White Plains	4.62	3.1	3.6	5.1	6.1	7.3	8.3	9.2
				4.2	5.0	6.5	7.4	8.6	9.5	10.2
02400100	1	Terrapin Creek at Ellisville	252	9.8	10.9	13.1	14.2	15.4	16.3	17.1
				12.9	15.1	18.2	20.0	22.2	23.4	24.8
02401000	1	Big Wills Creek near Reece City	182	9.8	10.6	12.1	13.1	14.2	15.0	15.6
				11.8	13.8	16.8	18.4	20.6	21.7	23.1
02401370	1	Big Canoe Creek near Springville	45	9.2	9.8	11.0	11.9	12.9	13.7	14.3
				7.9	9.4	11.7	13.1	14.8	15.8	16.9
02401390	1	Big Canoe Creek at Ashville	141	14.5	15.1	16.2	16.8	17.6	18.1	18.6
				11.0	12.9	15.7	17.3	19.4	20.5	21.8
02401470	1	Little Canoe Creek near Steele	22.3	5.7	6.1	6.8	7.2	7.6	8.0	8.2
				6.5	7.7	9.8	11.0	12.5	13.5	14.5
02401500	1	Big Canoe Creek near Gadsden	253	13.9	15.4	18.3	22.1	24.0	26.1	28.2
				12.9	15.1	18.2	20.0	22.3	23.4	24.8
02404000	1	Choccolocco Creek near Jenifer	277	8.4	10.2	14.2	16.4	19.0	20.7	22.5
				13.3	15.5	18.7	20.5	22.8	23.9	25.3
02404400	1	Choccolocco Creek at Jackson Shoals near Lincoln	481	10.2	12.2	17.0	20.2	23.8	26.3	28.9
				15.5	18.0	21.5	23.4	25.9	27.1	28.6

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02404500	1	Choccolocco Creek near Lincoln	496	13.4	16.9	21.6	23.1	25.1	26.0	27.1
				15.6	18.2	21.7	23.6	26.1	27.2	28.8
02405500	1	Kelly Creek near Vincent	193	15.2	17.7	21.9	24.0	25.3	26.0	26.7
				12.0	14.0	17.0	18.7	20.9	22.0	23.4
02406500	1	Talladega Creek at Alpine	150	10.2	11.0	12.1	12.8	13.4	13.9	14.1
				11.1	13.1	15.9	17.6	19.7	20.8	22.1
02407500	1	Yellowleaf Creek near Wilsonville	96.5	13.2	15.5	17.9	19.1	20.4	21.5	22.6
				9.8	11.6	14.2	15.8	17.7	18.8	20.0
02407680	1	Waxahatchee Creek near Columbiana	32.9	9.4	10.8	13.4	14.9	16.9	18.4	19.8
				7.3	8.6	10.8	12.1	13.7	14.8	15.8
02408500	1	Hatchet Creek near Rockford	233	14.5	17.1	20.4	22.5	24.9	26.4	27.9
				12.6	14.8	17.9	19.6	21.8	23.0	24.4
02408540	1	Hatchet Creek below Rockford	263	12.3	15.1	21.0	24.8	29.4	32.9	36.0
				13.1	15.3	18.4	20.2	22.5	23.6	25.0
02409000	1	Weogufka Creek near Weogufka	73.4	8.1	9.1	10.9	11.9	12.9	13.8	14.5
				9.1	10.8	13.3	14.7	16.6	17.7	18.9
02409540	1	Proctor Creek near Rockford	1.01	3.3	4.0	5.8	6.8	8.1	9.3	10.3
				2.7	3.3	4.4	5.1	6.0	6.7	7.3
02410000	1	Paterson Creek near Central	4.91	3.9	5.3	8.0	8.8	9.4	9.6	9.8
				4.2	5.1	6.6	7.6	8.7	9.6	10.4
02412000	1	Tallapoosa River near Heflin	448	15.7	18.5	22.4	24.3	26.7	28.6	30.4
				15.2	17.7	21.1	23.0	25.5	26.6	28.1
02412065	1	Cane Creek at U.S. Hwy. 78 near Heflin	52.8	10.4	10.9	11.6	12.1	12.7	13.0	13.6
				8.3	9.8	12.2	13.6	15.4	16.4	17.5

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02412500	1	Tallapoosa River near Ofelia	792	9.5	11.6	15.4	17.8	20.3	22.1	23.6
				17.9	20.7	24.5	26.5	29.2	30.3	31.9
02413300	1	Little Tallapoosa River near Newell	406	11.5	13.4	16.5	17.7	18.6	19.3	19.8
				14.8	17.2	20.6	22.5	24.9	26.0	27.5
02413400	1	Wedowee Creek above Wedowee	6.87	5.0	5.6	6.8	7.7	8.8	9.6	10.3
				4.7	5.6	7.2	8.2	9.5	10.4	11.2
02413475	1	Wedowee Creek near Wedowee	46.6	8.6	10.0	12.3	13.8	15.4	16.7	17.5
				8.0	9.5	11.8	13.2	14.9	16.0	17.1
02413500	1	Little Tallapoosa River near Wedowee	591	13.3	15.4	18.7	20.5	22.5	23.8	24.6
				16.4	19.1	22.7	24.7	27.2	28.3	29.9
02414800	1	Harbuck Creek near Hackneyville	7.97	3.8	4.8	6.9	8.1	9.4	10.3	11.4
				4.9	5.8	7.5	8.5	9.8	10.7	11.5
02415000	1	Hillabee Creek near Hackneyville	190	12.2	14.7	19.1	21.3	23.7	25.4	26.7
				11.9	14.0	16.9	18.6	20.8	21.9	23.3
02416481	1	Norrell Branch near Dadeville	0.5	1.3	2.0	3.3	4.6	6.4	7.7	9.1
				2.2	2.7	3.7	4.3	5.1	5.7	6.3
02419000	4	Uphapee Creek near Tuskegee	333	11.6	14.6	20.0	22.4	25.3	27.4	29.3
				12.6	14.5	17.6	19.4	21.4	22.8	24.1
02421000	3	Catoma Creek near Montgomery	290	19.5	21.5	23.9	25.7	27.6	28.6	29.4
				16.2	18.5	21.5	22.7	23.9	24.5	25.1
02421300	2	Ivy Creek at Mulberry	10.7	2.9	3.7	6.5	9.5	14.3	17.6	20.9
				5.1	5.8	7.3	8.3	9.6	10.3	11.1
02422000	3	Big Swamp Creek near Lowndesboro	244	16.0	16.7	17.7	18.5	19.4	20.0	20.7
				15.7	17.8	20.7	21.9	23.1	23.9	24.4
02422500	2	Mulberry Creek at Jones	203	8.6	10.7	15.7	19.0	22.4	25.2	28.1
				11.8	12.9	15.0	16.3	17.6	18.4	18.9

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02423500	1	Cahaba River near Acton	230	19.3	23.5	31.8	35.8	39.1	41.2	43.2
				12.6	14.7	17.8	19.5	21.8	22.9	24.3
02423555	1	Cahaba River near Helena	335	14.2	17.4	25.4	31.7	38.2	41.7	45.5
				14.0	16.3	19.6	21.4	23.8	24.9	26.4
02423800	1	Little Cahaba River near Brierfield	147	11.0	13.3	18.2	20.9	23.9	26.0	27.7
				11.1	13.0	15.9	17.5	19.6	20.7	22.0
02424000	1	Cahaba River at Centreville	1027	25.0	28.0	32.0	33.9	35.6	36.7	38.1
				19.2	22.2	26.1	28.3	31.0	32.1	33.8
02424010	2	Sandy Creek near Centreville	0.59	3.0	3.6	4.9	5.7	6.7	7.5	8.5
				2.2	2.6	3.6	4.3	5.3	5.9	6.5
02424500	2	Cahaba River at Sprott	1370	15.0	17.2	20.2	21.9	23.7	25.3	27.0
				20.2	21.9	23.9	25.3	26.1	26.8	26.8
02424940	2	Oakmulgee Creek near Augustin	220	9.8	12.5	16.4	18.1	19.9	21.2	22.3
				12.0	13.2	15.3	16.6	17.9	18.7	19.2
02425500	3	Cedar Creek at Minter	211	14.0	17.1	19.7	20.4	21.2	21.6	22.0
				15.2	17.2	20.0	21.3	22.5	23.3	23.9
02425655	3	Mush Creek near Selma	44.4	7.2	8.4	10.6	11.8	13.3	14.4	15.5
				10.8	12.2	14.2	15.5	17.0	18.2	19.2
02426000	3	Boguechitto Creek near Browns	95.4	14.6	14.9	16.2	17.3	18.8	19.9	21.1
				12.8	14.4	16.8	18.1	19.5	20.5	21.4
02427250	3	Pine Barren Creek near Snow Hill	261	17.5	18.7	21.2	22.8	24.5	26.2	27.4
				15.9	18.0	21.0	22.2	23.4	24.1	24.7
02427300	4	Prairie Creek near Oak Hill	10.3	8.3	9.6	12.3	14.5	16.9	18.7	20.3
				5.7	6.6	8.2	9.2	10.7	11.2	12.0
02427700	3	Turkey Creek at Kimbrough	97.5	12.7	15.1	20.1	21.7	22.8	23.5	24.0
				12.8	14.5	16.9	18.2	19.6	20.6	21.5

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02427875	4	Pursley Creek near Camden	64.3	10.8	12.3	15.6	17.6	20.6	24.1	25.3
				8.7	10.0	12.2	13.7	15.4	16.3	17.3
02428500	4	Big Flat Creek near Fountain	247	12.4	14.6	18.2	19.6	21.1	21.9	23.6
				11.7	13.5	16.5	18.2	20.2	21.4	22.7
02429000	4	Limestone Creek near Monroeville	121	8.6	9.4	10.8	11.8	12.9	13.7	14.5
				10.0	11.5	14.1	15.6	17.5	18.5	19.7
02429595	4	Little River near Uriah	99.2	8.1	9.5	12.3	13.7	15.4	16.6	17.8
				9.6	11.0	13.5	15.0	16.8	17.8	18.9
02429650	4	Majors Creek near Tensaw	44.4	10.9	12.2	14.7	16.3	18.1	19.4	20.5
				8.0	9.2	11.3	12.6	14.3	15.1	16.1
02437800	1	Barn Creek near Hackleburg	13.1	5.7	7.5	10.7	12.0	13.8	14.9	16.0
				5.6	6.7	8.5	9.6	11.0	12.0	12.9
02438000	1	Buttahatchee River below Hamilton	277	18.9	21.9	25.7	27.4	29.4	30.8	32.0
				13.3	15.5	18.7	20.5	22.8	23.9	25.3
02442000	2	Luxapallila Creek near Fayette	130	11.2	11.6	12.3	12.7	13.1	13.5	13.7
				10.4	11.4	13.4	14.7	16.1	16.9	17.5
02442500	2	Luxapallila Creek at Millport	247	11.3	11.7	12.3	12.6	13.0	13.3	13.5
				12.4	13.6	15.7	17.0	18.4	19.1	19.6
02443230	2	Mud Creek near Fernbank	35.8	6.9	7.3	7.7	8.0	8.5	8.8	9.1
				7.2	8.0	9.8	10.9	12.3	13.1	13.8
02443730	2	Kincaide Creek tributary near Ethelsville	0.24	1.2	1.4	2.3	2.5	3.3	3.8	4.3
				1.7	2.0	2.9	3.5	4.4	4.9	5.6
02444000	2	Coal Fire Creek near Pickensville	126	8.2	8.8	9.9	10.5	11.1	11.7	12.3
				10.3	11.3	13.3	14.6	16.0	16.8	17.4
02445000	2	Lubbub Creek near Carrollton	112	8.7	9.0	10.4	11.5	12.8	13.6	14.4
				9.9	11.0	13.0	14.2	15.6	16.4	17.0

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02445245	1	New River near Winfield	59.3	14.0	15.6	18.6	20.4	22.3	23.6	24.9
				8.6	10.1	12.6	14.0	15.8	16.9	18.0
02445500	2	Sipsey River at Fayette	282	13.0	13.7	14.8	15.3	16.1	16.6	17.2
				12.9	14.2	16.2	17.6	18.9	19.6	20.1
02446000	2	Sipsey River at Moores Bridge	413	14.0	14.5	15.6	16.3	17.3	17.8	18.3
				14.4	15.7	17.8	19.2	20.4	21.2	21.5
02446500	2	Sipsey River near Elrod	528	13.2	13.8	14.8	15.6	16.9	17.1	17.5
				15.4	16.8	18.9	20.3	21.5	22.2	22.5
02447000	2	Sipsey River near Pleasant Ridge	769	15.7	17.2	20.3	22.8	25.1	26.4	27.3
				17.2	18.7	20.7	22.1	23.2	23.9	24.1
02448500	2	Noxubee River near Geiger	1097	31.3	34.5	38.5	39.8	41.4	42.5	43.5
				19.0	20.6	22.6	24.0	25.0	25.6	25.7
02448900	3	Bodka Creek near Geiger	158	16.8	17.9	19.6	20.3	22.0	22.7	23.7
				14.3	16.1	18.8	20.0	21.4	22.3	23.0
02449245	2	Brush Creek near Eutaw	43.2	13.4	15.1	16.9	18.0	19.3	20.1	21.0
				7.6	8.5	10.3	11.4	12.8	13.6	14.3
02449400	3	Jones Creek near Epes	11.8	13.4	14.9	17.1	18.6	20.1	21.1	22.1
				8.2	9.1	10.6	11.8	13.4	14.7	15.9
02450000	1	Mulberry Fork near Garden City	365	12.9	14.9	18.1	19.8	21.6	22.8	23.8
				14.3	16.7	20.0	21.9	24.3	25.4	26.9
02450180	1	Mulberry Fork near Arkadelphia	487	25.7	28.6	33.7	36.4	39.7	41.9	43.9
				15.6	18.1	21.6	23.5	26.0	27.1	28.7
02450200	1	Dorsey Creek near Arkadelphia	13	6.1	6.8	8.7	9.8	11.3	12.4	13.3
				5.6	6.7	8.5	9.6	11.0	12.0	12.9
02450250	1	Sipsey Fork near Grayson	92.1	20.6	24.3	30.8	34.0	37.6	39.8	41.6
				9.7	11.4	14.1	15.6	17.5	18.6	19.8

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02450825	1	Clear Creek at New Hope Church nr Poplar Springs	101	9.0	10.9	14.4	16.6	19.4	21.3	23.1
				10.0	11.7	14.4	15.9	17.9	19.0	20.2
02451000	1	Clear Creek at Falls City	149	5.0	6.0	8.1	9.6	11.4	12.7	13.8
				11.1	13.1	15.9	17.6	19.6	20.8	22.1
02453000	1	Blackwater Creek near Manchester	181	6.2	7.2	9.1	10.3	11.7	12.8	13.8
				11.8	13.8	16.7	18.4	20.6	21.7	23.0
02453950	1	Lost Creek near Jasper	115	19.3	20.4	22.7	24.2	25.6	26.8	27.8
				10.3	12.2	14.9	16.5	18.5	19.6	20.8
02454000	1	Lost Creek near Oakman	134	17.5	21.2	25.4	28.7	29.7	30.4	30.9
				10.8	12.7	15.5	17.1	19.2	20.3	21.5
02454200	1	Wolf Creek near Oakman	85	14.6	16.7	20.1	22.5	25.3	27.8	29.0
				9.5	11.2	13.8	15.3	17.2	18.3	19.5
02454500	1	Locust Fork below Snead	147	17.0	19.4	24.4	28.4	31.0	32.5	34.0
				11.1	13.0	15.9	17.5	19.6	20.7	22.0
02455000	1	Locust Fork near Cleveland	303	10.1	11.0	13.1	14.5	16.2	17.5	18.7
				13.6	15.9	19.1	20.9	23.2	24.4	25.8
02455500	1	Locust Fork at Trafford	624	27.8	32.1	40.1	45.6	52.4	57.1	62.3
				16.7	19.4	23.0	25.0	27.6	28.7	30.3
02456000	1	Turkey Creek at Morris	80.9	13.0	15.1	19.2	21.6	24.3	25.6	27.4
				9.4	11.0	13.6	15.1	17.0	18.1	19.3
02456500	1	Locust Fork at Sayre	885	23.8	27.7	34.6	38.8	43.8	47.2	50.2
				18.4	21.3	25.2	27.3	30.0	31.1	32.7
02462000	1	Valley Creek near Oak Grove	148	13.4	16.8	21.7	23.9	26.4	28.0	29.7
				11.1	13.0	15.9	17.5	19.6	20.7	22.0
02462600	1	Blue Creek near Oakman	5.32	4.4	5.0	6.1	6.7	7.4	7.9	8.3
				4.3	5.2	6.8	7.7	8.9	9.8	10.6

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02462800	1	Davis Creek below Abernant	45.3	8.6	9.6	13.0	15.2	18.3	21.0	23.2
				7.9	9.4	11.7	13.1	14.8	15.9	17.0
02463500	1	Hurricane Creek near Holt	108	7.9	9.4	14.4	17.4	20.2	22.1	23.9
				10.2	12.0	14.7	16.2	18.2	19.3	20.5
02464000	1	North River near Samantha	223	12.6	15.0	20.2	24.0	28.4	31.3	34.3
				12.5	14.6	17.7	19.4	21.6	22.7	24.1
02465205	2	Jay Creek near Coker	3.65	3.9	4.5	5.2	5.5	5.8	6.0	6.2
				3.8	4.3	5.6	6.5	7.7	8.4	9.1
02465493	2	Elliotts Creek at Moundville	32.3	5.2	5.5	6.3	6.7	7.3	7.6	7.8
				7.0	7.8	9.6	10.7	12.1	12.8	13.6
02465500	2	Fivemile Creek near Greensboro	73.6	6.7	7.0	8.0	8.6	9.4	9.9	10.4
				8.8	9.8	11.7	12.9	14.3	15.1	15.7
02466500	3	Big Prairie Creek near Gallion	171	16.6	17.3	18.1	18.6	19.3	20.1	20.7
				14.5	16.4	19.1	20.4	21.7	22.5	23.2
02467500	3	Sucarnoochee River at Livingston	607	18.3	21.3	24.6	26.5	28.9	30.7	32.2
				19.0	21.7	25.2	26.4	27.3	27.6	27.8
02468000	3	Alamuchee Creek near Cuba	62.3	11.1	13.9	15.7	16.8	17.9	18.7	19.3
				11.7	13.2	15.3	16.6	18.1	19.2	20.1
02468500	3	Chickasaw Bogue near Linden	257	20.1	21.8	24.6	25.8	27.6	29.5	31.4
				15.8	18.0	20.9	22.1	23.3	24.1	24.6
02469000	3	Kinterbish Creek near York	90.9	12.1	15.3	20.1	21.4	22.4	23.4	23.6
				12.7	14.3	16.6	17.9	19.4	20.4	21.2
02469500	3	Tuckabum Creek near Butler	115	12.9	16.1	18.9	20.1	21.4	22.1	22.8
				13.3	15.1	17.5	18.8	20.2	21.2	22.0
02469550	3	Horse Creek near Sweet Water	60.4	13.7	14.3	15.7	16.1	16.6	17.2	17.3
				11.6	13.1	15.2	16.5	18.0	19.1	20.1

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi², square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi²)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
02469700	4	Okatuppa Creek at Gilbertown	148	9.8	11.1	14.1	15.3	16.3	16.7	17.2
				10.5	12.1	14.7	16.3	18.2	19.3	20.5
02469800	3	Satilpa Creek near Coffeeville	164	11.9	12.6	13.9	14.6	15.6	16.2	16.8
				14.4	16.3	18.9	20.2	21.5	22.4	23.1
02470100	4	Bassett Creek at Walker Springs	195	8.2	8.8	10.1	10.7	11.6	12.3	12.6
				11.1	12.8	15.6	17.3	19.2	20.4	21.6
02471001	4	Chickasaw Creek near Kushla	125	13.5	15.0	17.4	18.7	20.3	21.4	22.1
				10.1	11.6	14.2	15.7	17.6	18.7	19.8
02479431	4	Pond Creek near Deer Park	20.4	10.5	12.2	15.6	17.9	20.8	23.0	25.0
				6.7	7.7	9.5	10.7	12.2	12.9	13.7
02479560	4	Escatawpa River near Agricola, Miss.	562	15.6	16.5	18.6	20.0	21.9	23.1	23.9
				14.1	16.3	19.7	21.7	23.8	25.3	26.8
02479980	4	Crooked Creek near Fairview	8.08	6.4	6.9	8.1	8.8	9.7	10.3	10.9
				5.4	6.3	7.8	8.8	10.2	10.7	11.4
03572110	1	Crow Creek at Bass	131	14.5	15.1	16.1	16.6	17.2	17.6	17.9
				10.7	12.6	15.4	17.0	19.1	20.2	21.4
03572900	1	Town Creek near Geraldine	141	11.8	13.7	17.7	20.0	23.1	25.2	27.4
				11.0	12.9	15.7	17.3	19.4	20.5	21.8
03573000	1	Short Creek near Albertville	91.6	9.6	11.1	13.2	15.1	16.9	19.0	20.2
				9.7	11.4	14.0	15.6	17.5	18.6	19.8
03574500	1	Paint Rock River near Woodville	320	17.6	18.5	19.9	20.7	21.6	22.2	22.7
				13.8	16.1	19.4	21.2	23.5	24.7	26.1
03575000	1	Flint River near Chase	342	10.4	12.9	17.4	19.9	22.8	25.0	27.2
				14.1	16.4	19.7	21.6	23.9	25.0	26.5
03575830	1	Indian Creek near Madison	49	6.5	7.2	8.5	9.2	10.2	10.8	11.4
				8.1	9.6	12.0	13.3	15.1	16.1	17.3

Appendix 1. Flood depths for selected exceedance probabilities at rural streamgages used in Alabama rural depth regression analyses.—Continued

[mi^2, square miles; top line is the average computed depth; bottom line is the result of the regional regression equations]

Station number	Flood region (fig.2)	Station name	Drainage area (mi^2)	Flood depth, in feet, for indicated exceedance probability in percent						
				67	50	20	10	4	2	1
03576250	1	Limestone Creek near Athens	119	9.6	10.6	12.4	13.4	14.6	15.3	15.9
				10.4	12.3	15.0	16.6	18.6	19.7	21.0
03576400	1	Piney Creek near Athens	55.8	5.9	6.7	8.1	9.1	10.1	10.9	11.6
				8.4	10.0	12.4	13.8	15.6	16.6	17.8
03576500	1	Flint Creek near Falkville	86.3	12.0	12.6	13.6	14.1	14.7	15.0	15.4
				9.5	11.2	13.8	15.3	17.3	18.3	19.6
03585300	1	Sugar Creek near Good Springs	152	9.9	10.7	11.4	11.9	12.7	13.1	13.6
				11.2	13.1	16.0	17.6	19.7	20.9	22.2
03586500	1	Big Nance Creek at Courtland	166	16.3	18.3	20.5	21.3	22.0	22.6	23.0
				11.5	13.5	16.4	18.0	20.2	21.3	22.6
03590000	1	Cypress Creek near Florence	209	9.1	11.3	15.3	17.7	20.4	22.4	24.2
				12.2	14.3	17.4	19.1	21.3	22.4	23.8
03591800	1	Bear Creek near Hackleburg	143	16.3	20.6	25.7	29.4	34.2	37.7	40.9
				11.0	12.9	15.8	17.4	19.5	20.6	21.9
03592200	2	Cedar Creek near Pleasant Site	189	16.0	17.8	20.5	22.3	24.0	25.3	27.2
				11.5	12.7	14.7	16.0	17.4	18.2	18.7
03592300	2	Little Bear Creek near Halltown	78.2	10.0	11.1	13.0	13.6	14.4	15.3	16.1
				9.0	9.9	11.9	13.1	14.5	15.3	15.9
03592500	2	Bear Creek at Bishop	667	15.3	17.3	19.2	20.4	21.6	22.6	23.2
				16.5	17.9	20.0	21.4	22.5	23.3	23.5

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