VERIFICATION OF THE REGION 3 URBAN FLOOD-FREQUENCY EQUATIONS FOR TIFTON, GEORGIA

U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the

TIFT COUNTY

and the

CITY OF TIFTON, GEORGIA

Open-File Report 96-596

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Atlanta, Georgia

1996

U.S. DEPARTMENT OF THE INTERIOR

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By Ernest J. Inman

ABSTRACT

A U.S. Geological Survey rainfall-runoff model was calibrated for four urban drainage basins ranging in size from 0.16 to 0.71 square mile in Tifton, Ga. Rainfall-runoff data were collected over a period of about five years at each station, beginning in April 1991 and ending in July 1996. Calibrated models were used to synthesize long-term annual flood-peak discharges from existing long-term rainfall records for these basins. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year flood-frequency estimates were developed for each basin by fitting a Pearson Type III frequency distribution curve to the logarithms of these annual peak discharges.

The 2- through 500-year flood-frequency estimates from the four Tifton stations were compared to the 2- through 500-year flood-frequency estimates computed from the equations presented in a statewide urban flood-frequency report in 1995. All floods, except the 2-year flood at one site, were within the average standard error of prediction; thereby, verifying the urban flood-frequency equations for use in the Tifton area.

INTRODUCTION

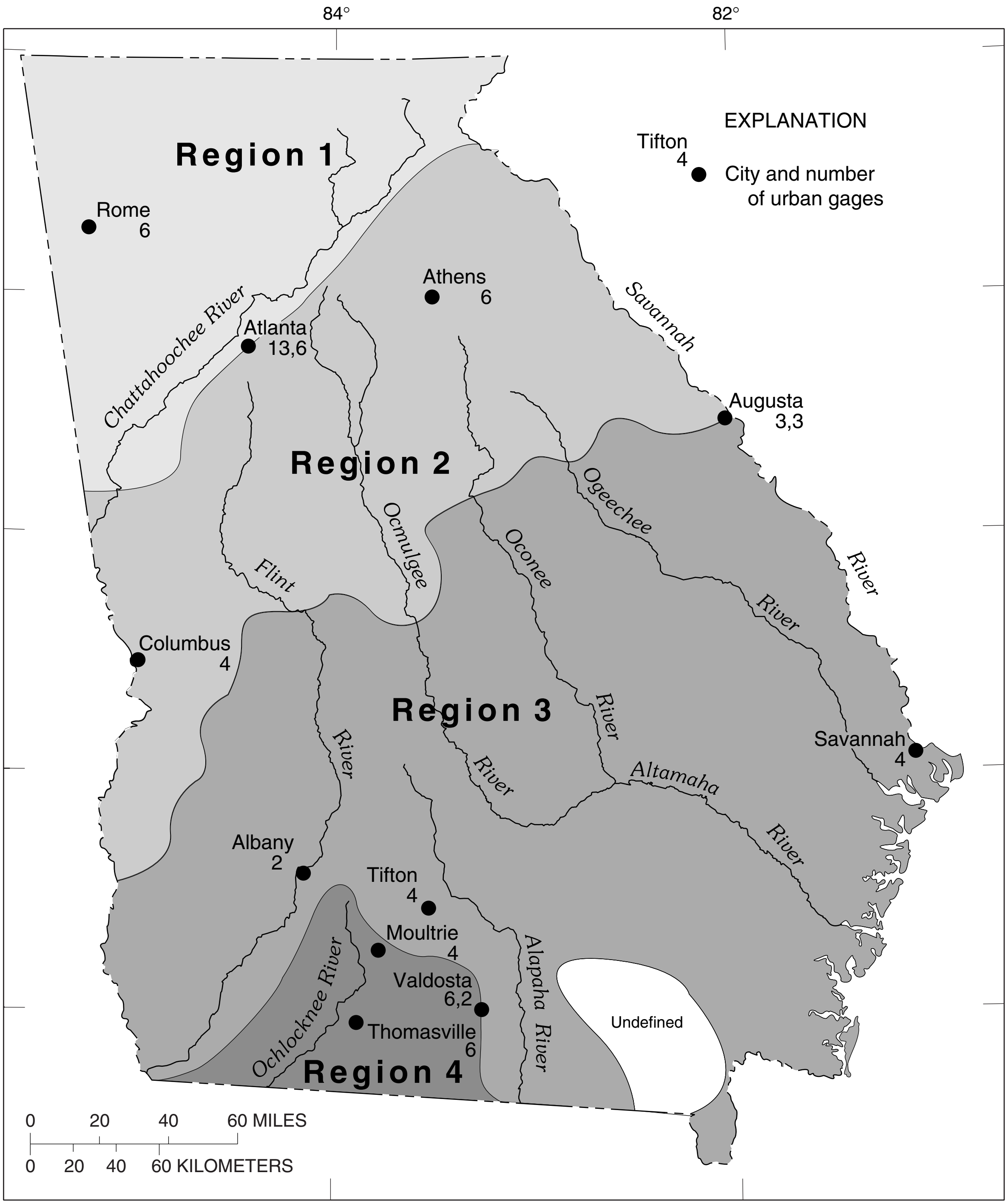
A knowledge of flood characteristics of streams is essential for the design of roadway drainage structures, establishing flood-insurance rates, and for other uses by urban planners and engineers. Urbanization can produce significant changes in the flood-frequency characteristics of streams; therefore, natural (rural) basin flood-frequency relations are not applicable to urban streams.

Recognizing the need for reliable urban peak-flood data and improved equations for estimating floods, the U.S. Geological Survey (USGS) collected data at 65 rainfall-runoff stations—beginning in 1973 in Metropolitan Atlanta (Inman, 1983); continuing in 1978 in Athens, Augusta, Columbus, Rome, and Savannah (Inman, 1988); and ending in 1992 in Albany, Moultrie, Thomasville, and Valdosta, Ga. (Inman, 1995). These data were used to calibrate a USGS rainfall-runoff model and to develop equations for estimating urban flood-frequency relations throughout the State.

Region 3 is the largest of the flood regions in Georgia (fig. 1). Because only 11 of the 65 rainfall-runoff stations were in this region, a verification of the urban flood-frequency equations was warranted for region 3. In November 1990, the USGS, the city of Tifton, Ga., and Tift County, Ga., entered into a cooperative agreement to verify the urban flood-frequency equations for Tifton and the adjacent area in Tift County. Data collection began in April 1991 and concluded in July 1996.

Purpose and Scope

This report describes the results of a study to verify urban flood-frequency equations in Tifton and adjacent area of Tift County (region 3), as reported by Inman (1995). Four drainage basins were selected in Tifton to verify the equations (table 1). Data from at least 40 floods in each basin were used to calibrate a USGS rainfall-runoff model (RRM), as described by J.M. Bergmann, E.J. Inman, and A.M. Lumb (U.S. Geological Survey, written commun., 1990).



Base from U.S. Geological Survey digital files

Figure 1. Rural flood-frequency regions in Georgia, cities where gaging stations were used in this study, and number of gages in each city (modified from Inman, 1995). Some cities have gaging stations in more than one region.

Table 1. Gaging stations used in the verification of urban flood-frequency relations in region 3, Tifton, Georgia

Station number[1/]	Station name	Latitude	Longitude	Location
02317713	New River at Tifton	31° 28'21"	83° 31'09"	Tift County at culvert on U.S. Highway 41, Tifton
02317715	New River tributary at Tifton	31° 27'27"	83° 29'36"	Tift County at culvert on Pineview Avenue, Tifton
02317802	Little River tributary no. 1 at Tifton	31° 27'28"	83° 31'22"	Tift County at culvert on W 2nd Avenue, Tifton
02317816	Little River tributary no. 2 at Tifton	30° 26'06"	83° 31'22"	Tift County at culvert on South Park Avenue, Tifton

[1/]U.S. Geological Survey downstream order number.

After the RRM was successfully calibrated for each drainage basin, long-term rainfall and daily pan-evaporation data from nearby U.S. Department of Commerce, National Weather Service (NWS) stations were used to synthesize 61 years of annual peak flows. These synthesized peaks were used to develop flood-frequency relations for each of the basins. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval floods were compared to the 2- through 500-year recurrence interval floods computed with the regional equations developed by Inman (1995).

Site Selection

Extensive field reconnaissance was conducted at about 20 prospective sites. A range in drainage area, main-channel slope, and main-channel length was considered in the site-selection process. Suitability for rain-gage location, hydraulic characteristics at the gaging site, absence of significant permanent surface storage, and land use (such as residential, commercial, or institutional) also were factors involved in the selection process.

The next step in this study was to conduct a field reconnaissance of prospective basins in areas considered stable. Some basins were excluded because their hydraulic characteristics were not suitable for indirect computations of peak discharge or they contained no suitable location for a rain gage. The remaining basins were delineated on USGS 7 1/2-minute topographic maps; and approximate drainage areas, main-channel slopes, and lengths were determined. Four urban basins were selected for study with the best hydraulic characteristics for indirect computations of peak discharge and the most suitable rain-gage locations. The selected basins also provide suitable distributions of drainage area, main-channel slope, and main-channel length.

DATA COLLECTION AND PROCESSING

Electronic data recorders were used to collect stream stage and rainfall at 5-minute intervals in each basin. The recording stage gage for the four basins was housed on top of an 18-inch vertical corrugated metal-pipe stilling well in the upstream approach section. Each stilling well had two 2-inch intakes near the base and 1/2-inch diameter holes drilled about every 6 inches above ground level to flood stage. The stilling wells were flushed after every flood event and intakes were cleaned during every inspection trip.

Each site had at least one rain gage, generally located near the stage gage. Rain-gage recorders were housed on top of 8-feet collector wells made from 3-inch galvanized pipe. Collector wells of this size will hold about 11 inches of rainfall. A drain plug near the bottom of the collector well was used to drain the pipe during each inspection trip.

Crest-stage gages also were installed at each site, with at least one in the upstream approach section and one at the downstream end of the culvert. The fall in water-surface elevation through the culverts obtained from these crest-stage gage relations and the culvert geometry were used to compute a theoretical stage-discharge relation as described by Bodhaine (1968). Current-meter measurements were made to verify the theoretical stage-discharge relations.

The crest-stage relations also served other purposes. A plot of upstream crest-gage stage and downstream crest-gage stage was established for each site. These relations should remain fairly site-consistent; if not, the reason for the inconsistency must be determined. These plots primarily were used on culverts having backwater control. For example, an accumulation of debris at a culvert entrance which could produce excessive fall, or a blockage downstream that greatly reduces normal fall, could be detected from these crest-stage relations. For culverts with inlet or outlet control, the crest-stage relations are not consistent; however, for large blockages, some indication of the problem might be evident. Sometimes city and county highway maintenance crews would remove debris from culverts between gage servicing trips. When this occurred, outliers from the crest-stage relations were the only evidence of blockage. Records of storm events that were influenced by blockages were not used in model calibration. At all sites, the stage at the recording gage was lower than the stage at the upstream crest-stage gage. This probably was caused by drawdown of the intakes rather than by intake lag, as can be demonstrated by the equation given in Buchanan and Somers (1968, p. 13).

A relation between upstream crest-gage stage and recorder stage was established to enable plotting of the theoretical discharge computations and the recorder stage. Thus, data from the recorders could be processed without having to make a shift correction for each data set. The upstream crest-gage and the recorder-stage relation also would indicate any problem with the stage hydrograph, such as a hanging float, a float tape that jumped the splines, or intakes clogged with sediment.

Current Data

All flood events having complete rain and stage data and without culvert blockages were processed and loaded into USGS computer storage on a near-current basis. Generally, five to eight storm events were processed annually for each site. Unit-rainfall, unit-discharge, and daily rainfall data were then retrieved and the unit data were plotted against time. The unit-data hydrographs were used to:

- visually edit data, allowing an erroneous reading by the recorder or a misread data point by the computers to be easily detected;
- detect partially clogged rain-gage intakes or hanging floats;
- serve as the basis for estimating the rising limb of a storm hydrograph if the stilling well intakes were out of the water at the beginning of a rise;
- estimate the falling limb in the event that the intakes became partially clogged with sediment on the recession; and
- estimate the routing parameters in the RRM.

After editing and estimations were completed, the data were reloaded into USGS computer storage. Daily pan-evaporation data also are needed to calibrate the RRM. Such data were available for Tifton from a nearby NWS station.

Long-Term Rainfall and Daily Pan-Evaporation Data

Long-term rainfall and daily pan-evaporation data are required for flood-peak simulation. The Thomasville-Coolidge NWS station, about 40 miles south of Tifton, is the closest weather station with a period of record long enough to be used to simulate annual peaks. Daily rainfall records were obtained from this station and loaded into USGS computer storage. About four to eight rainfall events per year were selected based on hydrologic judgement and by scanning the daily rainfall totals. The dates of significant rainstorms since 1948 were obtained from hourly data in NWS publications. For periods prior to 1948, the daily charts for all daily rainfall events of 1 inch or more per day were obtained from the NWS. The selected storm-rainfall data were coded at 5-minute intervals and loaded into USGS computer storage.

Daily pan-evaporation data were obtained from the Tifton NWS station. The record from this station (1937-96) was used to synthesize harmonic average evaporation data for the period prior to 1937 by using the USGS computer program H266 (Carrigan and others, 1977).

FLOOD-FREQUENCY RELATIONS

Several phases of data analysis are required to verify equations used to estimate peak discharges for selected recurrence intervals. The first phase is to calibrate the RRM with observed data from the Tifton study area, from which the equations are being verified. The second phase is to analyze the frequency characteristics of peak-discharge simulations from RRM. The final phase is to compare the 2- through 500-year floods computed from the equations with the 2- through 500-year simulated floods.

Description of Rainfall-Runoff Model

Program RRM, a lumped-parameter rainfall-runoff model, was described in detail by J.M. Bergmann, E.J. Inman, and A.M. Lumb (U.S. Geological Survey, written commun., 1990). The original version of the rainfall-runoff model was described in detail by Dawdy and others (1972). Revisions to the original computer code were presented by Carrigan (1973). The model has three basic components—infiltration, soil-moisture accounting, and surface-runoff routing. Provisions for accounting for nonpervious areas were included in the code. Eleven model parameters are used in the three basic components and are listed and defined in table 2.

Table 2. Definitions of infiltration, soil-moisture accounting, and surface-runoff routing parameters for the U.S. Geological Survey rainfall-runoff model (RRM)
[—, dimensionless parameter; RRM from J.M. Bergmann, E.J. Inman, and A.M. Lumb (U.S. Geological Survey, written commun., 1990)]

Parameter code	Units	Definition of parameters
		Infiltration parameters
PSP	inches	combined effects of soil-moisture content and suction at the wetting front for soil moisture at field capacity
RGF	—	ratio of PSP for soil moisture at wilting point to that at field capacity
KSAT	inches per hour	minimum saturated value of hydraulic conductivity used to determine soil-infiltration rates
TIA	—	ratio of total impervious area to total basin area
		Soil-moisture accounting parameters
BMSM	inches	soil-moisture storage volume at field capacity
EVC	—	coefficient to convert pan evaporation to potential evapotranspiration values
DRN	inches per hour	constant drainage rate for redistribution of soil moisture
RR	—	proportion of daily rainfall that infiltrates the soil
		Surface-runoff routing parameters
KSW	hours	time characteristic for linear reservoir storage
TC	minutes	time base of the triangular translation hydrograph
TP/TC	—	ratio of time to peak to base length of the triangular translation hydrograph

The infiltration component of the model uses unit-rainfall data, and the output from the soil-moisture accounting component that indicates the soil moisture content at the beginning of the storm rainfall, to compute infiltration losses. Four parameters (PSP, RGF, KSAT, and TIA) (table 2) are used with the modified Philip (1954) infiltration equation.

The soil-moisture accounting component determines the effect of antecedent conditions on infiltration and is based on daily rainfall and evaporation. Four model parameters (BMSM, EVC, DRN, and RR) (table 2) are used in simulating continuous antecedent soil moisture.

The surface-runoff or routing component (parameters KSW, TC, and TP/TC) (table 2) is based on a modification of the Clark (1945) form of the instantaneous unit-hydrograph procedure. The routing component was modified by Carrigan (1973) to incorporate a triangularly shaped translation hydrograph as an internal feature of the computer program rather than as an externally developed time-area histogram. This modification simplified the calibration procedure and allows separation of compound peaks—a feature that provides the model-user with more events to use in calibration. Mitchell (1972) described the triangular representation of the translation hydrograph as a sufficiently accurate assumption for most drainage areas.

The RRM was calibrated for the four Tifton basins. A detailed description of the RRM calibration procedure was described by Inman (1995). The final optimized parameter values for the models are listed in table 3.

Table 3. Optimized rainfall-runoff model parameter values for each study site in Tifton, Georgia
[RRM, rainfall-runoff model; parameters are defined in table 2; parameters DRN, TP/TC, and EVC are assigned fixed values of 1.00, 0.50, and 0.75, respectively, for all stations and not optimized; SE, standard error of estimate of calibration results, based on the mean-square difference of logs of observed and synthesized peaks]

Station number	RRM infiltration, soil-moisture accounting, and surface-runoff routing parameters								SE (in percent)
	PSP	KSAT	RGF	BMSM	RR	KSW	TC	TIA	
02317713	1.47	0.129	39.6	4.45	0.848	1.27	67.0	14.2	22.2
02317715	2.24	.235	38.9	3.15	.884	.58	25.6	30.6	27.6
02317802	3.00	.248	39.4	2.40	.825	.57	41.4	38.8	28.2
02317816	2.21	.146	30.2	2.25	.720	.55	34.3	37.4	23.7

Flood-Frequency Analysis

The calibrated RRM was run with NWS long-term precipitation and pan-evaporation data to simulate annual peaks for each of the four stations used in the study. The Pearson Type III frequency distribution was fitted to the logarithms of the annual peak discharges at each site in accordance with "Guidelines for Determining Flood Flow Frequency," Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) recommendations. These guidelines include the proper handling of low and high outliers. Frequency curves for flood peaks simulated by the RRM represent an "as is" storage condition that may be present at upstream roadway embankments with culverts of limited capacity or minor flood-plain storage.

Skew coefficients were computed directly from the simulated data. No attempt was made to adjust the skew coefficients of the frequency curves, because the data did not meet the criteria specified in the Interagency Advisory Committee on Water Data (IACWD) (1982). The generalized skew-coefficient map in IACWD (1982), used in the adjustment computations, is for rural watersheds; therefore, it is not applicable to the simulated urban flood peaks. Flood-frequency data from the log-Pearson Type III frequency analyses for selected recurrence intervals are shown in table 4.

Table 4. Flood-frequency discharge data from long-term synthesis for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval floods for Tifton, Georgia, stations

Station number	Drainage area (square miles)	Peak-discharge data, in cubic feet per second, for indicated recurrence interval							
		2-year recurrence interval	5-year recurrence interval	10-year recurrence interval	25-year recurrence interval	50-year recurrence interval	100-year recurrence interval	200-year recurrence interval	500-year recurrence interval
02317713	0.58	108	175	224	291	345	401	460	542
02317715	.71	186	260	314	389	450	516	586	688
02317802	.16	69	95	112	136	155	174	194	222
02317816	.30	103	143	172	213	245	279	316	368

Regional Regression Analysis

So that flood magnitude and frequency could be estimated for ungaged sites, the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval floods obtained from the 65 urban basins in the study by Inman (1995), are related to the basin characteristics of their origin. This was done by the generalized least-squares (GLS) regression method. Further information on the development of these urban regression equations can be obtained from Inman (1995). The number of gages in each city and flood-frequency region are shown in figure 1. The regional flood-frequency equations for urban streams in Georgia are presented in table 5.

Tifton, Ga., is in region 3. The basin characteristics needed to compute the 2- through 500-year recurrence interval floods in region 3 are defined below. The individual station data for the four Tifton stations are shown in table 6.

Drainage area (A)—Area of the basin, in square miles, planimetered from USGS 7 1/2-minute topographic maps. All basin boundaries were field checked.

Total impervious area (TIA)—The percentage of drainage area that is impervious to infiltration of rainfall. This parameter is determined from aerial photography (U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, 1990) by use of a grid-overlay method.

According to Cochran (1963), a minimum of 200 points, or grid intersections, per area or subbasin can provide a confidence level of 0.10. Three counts of at least 200 points per subbasin were obtained and the results averaged for the final value of total impervious area.

Table 5. Regional flood-frequency equations for urban streams in Georgia
[UQT, peak discharge for an urban drainage basin, in cubic feet per second; SE, average standard error of prediction, in percent; A, drainage area, in square miles; TIA, area that is impervious to infiltration of rainfall, in percent; ±, plus-minus; from Inman (1995)]

UQ_T recurrence interval (years)	Region 1		Rome		Region 2		Region 3		Region 4	
	Equation	SE	Equation	SE	Equation	SE	Equation	SE	Equation	SE
2	$167A^{0.73} TIA^{0.31}$	±34	$107A^{0.73} TIA^{0.31}$	±40	$145A^{0.70} TIA^{0.31}$	±35	$54.6A^{0.69} TIA^{0.31}$	±34	$110A^{0.66} TIA^{0.31}$	±34
5	$301A^{0.71} TIA^{0.26}$	±31	$183A^{0.71} TIA^{0.26}$	±36	$258A^{0.69} TIA^{0.26}$	±31	$99.7A^{0.69} TIA^{0.26}$	±31	$237A^{0.66} TIA^{.26}$	±31
10	$405A^{0.70} TIA^{0.21}$	±31	$249A^{0.70} TIA^{0.21}$	±35	$351A^{0.70} TIA^{0.21}$	±31	$164A^{0.71} TIA^{0.21}$	±32	$350A^{0.68} TIA^{0.21}$	±30
25	$527A^{0.70} TIA^{0.20}$	±29	$316A^{0.70} TIA^{0.20}$	±33	$452A^{0.70} TIA^{0.20}$	±29	$226A^{0.71} TIA^{0.20}$	±30	$478A^{0.69} TIA^{0.20}$	±29
50	$643A^{0.69} TIA^{0.18}$	±28	$379A^{0.69} TIA^{0.18}$	±33	$548A^{0.70} TIA^{0.18}$	±29	$288A^{0.72} TIA^{0.18}$	±30	$596A^{0.70} TIA^{0.18}$	±28
100	$762A^{0.69} TIA^{0.17}$	±28	$440A^{0.69} TIA^{0.17}$	±33	$644A^{0.70} TIA^{0.17}$	±29	$355A^{0.72} TIA^{0.17}$	±30	$717A^{0.70} TIA^{0.17}$	±28
200	$892A^{0.68} TIA^{0.16}$	±28	$505A^{0.68} TIA^{0.16}$	±34	$747A^{0.70} TIA^{0.16}$	±28	$428A^{0.72} TIA^{0.16}$	±30	$843A^{0.70} TIA^{0.16}$	±28
500	$1063A^{0.68} TIA^{014}$	±28	$589A^{0.68} TIA^{0.14}$	±34	$888A^{0.70} TIA^{0.14}$	±28	$531A^{0.72} TIA^{0.14}$	±30	$1017A^{0.71} TIA^{0.14}$	±28

Table 6. Basin characteristics of gaging stations used in region 3 urban flood-frequency equations, Tifton, Georgia
[A, drainage area; TIA, area that is impervious to infiltration of rainfall]

Station number	Basin characteristics	
	A (square miles)	TIA (percent)
02317713	0.58	19.3
02317715	.71	35.9
02317802	.16	51.7
02317816	.30	46.8

Standard Error of Prediction

The average standard error of prediction is one measure of how good the flood-frequency equations are for prediction (see table 5). This is the error expected two-thirds of the time when averaged for watersheds similar to those used in the analysis.

The average standard error of prediction for the region 3, 2-year flood-frequency equation is ± 34 percent. One 2-year flood at one of the four Tifton stations (02317715) was not within these limits. All other floods met the objective of being within the average standard error of prediction at all other stations; thereby, verifying the region 3 urban flood-frequency equations for Tifton.

Use of Flood-Frequency Relations

Flood-peak discharges at specific recurrence intervals can be estimated for the Tifton area by using the appropriate equations for region 3 (from table 5). The region 3 flood-frequency equations have been verified for use in Tifton and the results are listed in table 7.

The ranges of basin variables listed below should not be exceeded for the region 3 urban flood-frequency equations. The ranges of basin variables for region 3 (Tifton included) used in the estimating equations presented herein are listed below:

Variable	Minimum	Maximum	Units
A	0.05	4.06	square miles
TIA	11.1	59.50	percent

Table 7. Comparison between computed flood-frequency data using region 3 estimating equations and the long-term synthesized station data for the 2- through 500-year recurrence interval floods, Tifton, Georgia

Station number	Recurrence interval	Flood computations		Difference (percent)
		Region 3 urban equation (cubic feet per second)	Synthesized station data (cubic feet per second)	
02317713	2-year	94	108	+14.9
	5-year	148	175	+18.2
	10-year	207	224	+ 8.2
	25-year	277	291	+ 5.1
	50-year	331	345	+ 4.2
	100-year	397	401	+ 1.0
	200-year	464	460	- 0.9
	500-year	543	542	- 0.2
02317715	2-year	131	186	+42.0
	5-year	200	260	+30.0
	10-year	273	314	+15.0
	25-year	363	389	+ 7.2
	50-year	429	450	+ 4.9
	100-year	510	516	+ 1.2
	200-year	593	586	- 1.2
	500-year	685	688	+ 0.4
02317802	2-year	52	69	+32.7
	5-year	78	95	+21.8
	10-year	102	112	+ 9.8
	25-year	135	136	+ 0.7
	50-year	157	155	- 1.3
	100-year	186	174	- 6.4
	200-year	215	194	- 9.8
	500-year	247	222	-10.1
02317816	2-year	78	103	+32.0
	5-year	118	143	+21.2
	10-year	156	172	+10.3
	25-year	207	213	+ 2.9
	50-year	242	245	+ 1.2
	100-year	287	279	- 2.8
	200-year	333	316	- 5.1
	500-year	382	368	- 3.7

A comparison to the equivalent rural peak discharge also is helpful for small values of total impervious area. If the equivalent rural peak discharge exceeds the peak discharge computed from the urban equations, then the equivalent rural peak discharge should be used. The user also should be cautioned that the equations presented herein are applicable only to basins having insignificant surface storage, and insignificant embankment storage. The equations for computing an equivalent rural discharge (from Stamey and Hess, 1993) are listed in table 8.

Table 8. Regional flood-frequency relations for rural streams in Georgia

Flood discharge Qt, for t-year recurrence interval	Flood-frequency relations for indicated regions (fig.1) in the form $Qt = aA^b$, where A is the drainage area, in square miles, a is the constant, and b is the exponent in the equations below			
	Region 1	Region 2	Region 3	Region 4
RQ_2	$207A^{0.654}$	$182A^{0.622}$	$76A^{0.620}$	$142A^{0.591}$
RQ_5	$357A^{0.632}$	$311A^{0.616}$	$133A^{0.620}$	$288A^{0.589}$
RQ_{10}	$482A^{0.619}$	$411A^{0.613}$	$176A^{0.621}$	$410A^{0.591}$
RQ_{25}	$666A^{0.605}$	$552A^{0.610}$	$237A^{0.623}$	$591A^{0.595}$
RQ_{50}	$827A^{0.595}$	$669A^{0.607}$	$287A^{0.625}$	$748A^{0.599}$
RQ_{100}	$1,010A^{0.584}$	$794A^{0.605}$	$340A^{0.627}$	$926A^{0.602}$
RQ_{200}	$1,220A^{0.575}$	$931A^{0.603}$	$396A^{0.629}$	$1,120A^{0.606}$
RQ_{500}	$1,530A^{0.563}$	$1,130A^{0.601}$	$474A^{0.632}$	$1,420A^{0.611}$

SUMMARY AND CONCLUSION

Because region 3 is the largest of the flood regions in Georgia and only 11 of the 65 stations included in a 1995 statewide urban flood-frequency report were in region 3, a verification of the region 3 equations was warranted.

Rainfall-runoff data were collected at four urban basins, ranging in size from 0.16 to 0.71 square mile and in total impervious area from 19.3 to 51.7 percent in Tifton, Ga., beginning in April 1991 and ending in July 1996. Extensive field reconnaissance was required to select the four basins having a range in drainage area and land-use stability. Each site was equipped with a stage gage and a rain gage with an electronic data recorder set at 5-minute recording intervals. All flood events with complete stage and rainfall data and without culvert blockages were processed and loaded into USGS computer storage.

The U.S. Geological Survey rainfall-runoff model was calibrated for the four basins. After the model was successfully calibrated, long-term rainfall and daily pan-evaporation data from the appropriate U.S. Department of Commerce, National Weather Service station was used to synthesize 61 years of annual peak-flow data. The synthesized peak flows were used to develop flood-frequency relations at each site. The 2- through 500-year recurrence interval floods at each site were compared to the 2- through 500-year recurrence interval floods computed from the region 3 urban statewide flood-frequency equations. All but one 2-year flood at one site was within the standard error of prediction; thereby, verifying the equations for use in the Tifton area.

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