Estimating the Magnitude and Frequency of Floods for Urban and Small, Rural Streams in Georgia, South Carolina, and North Carolina

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ABSTRACT. Reliable estimates of the magnitude and frequency of floods are essential for such things as the design of transportation and water-conveyance structures, Flood Insurance Studies, and flood-plain management. The flood-frequency estimates are particularly important in densely populated urban areas. A multistate approach was used to update methods for determining the magnitude and frequency of floods in urban and small, rural streams that are not substantially affected by regulation or tidal fluctuations in Georgia, South Carolina, and North Carolina. The multistate approach has the advantage over a single state approach of increasing the number of stations available for analysis, expanding the geographical coverage that would allow for application of regional regression equations across state boundaries, and building on a previous flood-frequency investigation of rural streamflow-gaging stations (streamgages) in the Southeastern United States. In addition, streamgages from the inner Coastal Plain of New Jersey were included in the analysis.

Generalized least-squares regression techniques were used to generate predictive equations for estimating the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probability flows for urban and small, rural ungaged basins for three hydrologic regions; the Piedmont-Ridge and Valley, Sand Hills, and Coastal Plain. Incorporation of urban streamgages from New Jersey also allowed for the expansion of the applicability of the predictive equations in the Coastal Plain from 2.1 to 53.5 square miles. Explanatory variables in the regression equations included drainage area (DA) and percent of impervious area (IA) for the Piedmont-Ridge and Valley region; DA and percent of developed land for the Sand Hills; and DA, IA, and 24-hour, 50-year maximum precipitation for the Coastal Plain. An application spreadsheet also was developed that can be used to compute the flood-frequency estimates along with the 95-percent prediction intervals for an ungaged location.

INTRODUCTION

Building on the success of a multistate approach for developing regional flood-frequency equations to estimate the magnitude and frequency of floods at ungaged rural streams in the Southeast, (Feaster and others, 2009; Gotvald and others, 2009; Weaver and others, 2009), a similar approach was applied to urban and small, rural streams (Feaster and others, 2014). For this investigation, “Southeast” refers specifically to Georgia, South Carolina, and North Carolina. The analytical techniques used incorporate both urban and rural streamgages and, therefore, can be applied to urban and small, rural streams. The lower limit of drainage area for basins included in the Southeast rural flood-frequency study was 1 square mile (mi^2). The lower limit of drainage area for rural basins included in the this investigation was 0.1 mi^2. Consequently, in this study, small, rural streams refer to those with drainage areas less than 1 mi^2. Some of the benefits of including both urban and rural streamgages in the regression analysis are (1) smoother transition between urban and rural flood-frequency estimates, (2) larger database than would be available with urban streamgages alone, and (3) larger geographical coverage in the hydrologic regions, which will represent a broader range of hydrologic conditions likely to occur at ungaged locations.

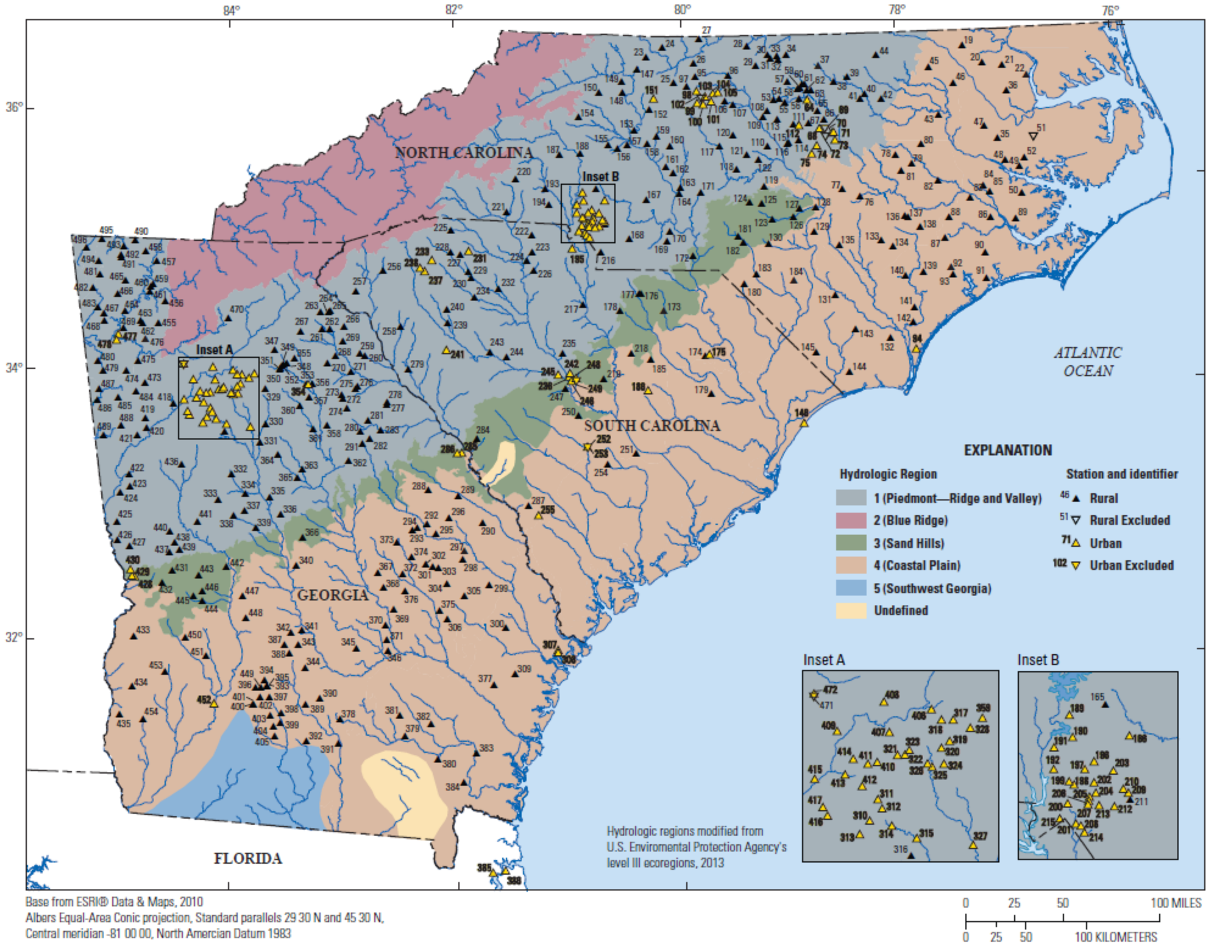

Figure 1. Locations of hydrologic regions and U.S. Geological Survey streamgages with 10 or more years of record that were included in the Southeast regional-regression analysis for urban and small, rural streams.

The focus of the investigation was on three hydrologic regions (HR) in the Southeast (fig. 1): HR1, Piedmont--Ridge and Valley; HR3, Sand Hills; and HR4, Coastal Plain. The Blue Ridge (HR2) was not included due to the lack of urban streamgages having sufficient record lengths to include in a regional regression analysis. Regression equations for HR5, which is contained solely in southwest GA, were previously developed and published by Gotvald and Knaak (2011).

FLOOD-FREQUENCY ANALYSIS

For the rural streamgages in Georgia, South Carolina, and North Carolina, the flood-frequency estimates were obtained from those previously published in the Southeast rural flood-frequency investigation (Feaster and others, 2009; Gotvald and others, 2009; Weaver and others, 2009). In addition, the flood-frequency estimates for the Georgia urban and small, rural streamgages included in Gotvald and Knaak (2011) were updated by including additional data collected through September 2011. Updating the flood-frequency analyses for the Georgia urban and small, rural streamgages allowed for the inclusion of the historic floods that occurred in northern Georgia during September 2009 (McCallum and Gotvald, 2010). For the streamgages included from the New Jersey inner Coastal Plain, the flood-frequency estimates were updated in consultation with USGS New Jersey Water Science Center hydrologists and included peak-flow data through September 2011.

The flood-frequency estimates for urban streamgages were completed using a modified version of the methods described in Bulletin 17B of the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data (1982) by including the expected moments algorithm, which allows for a more generalized approach to representing observed annual peak-flow information by using an interval range as compared to the conventional method of using point data (Cohn and others, 1997), and a generalized Grubbs-Becks test, which allows for the detection of multiple potentially influential low outliers (Cohn and others, 2013).

REGRESSION ANALYSIS

Exploratory regression analysis to determine the best regression models for all combinations of basin characteristics was done using ordinary least squares regression techniques. Generalized least squares (GLS) regression methods, as described by Stedinger and Tasker (1985), were used to determine the final regional regression equations with the use of the weighted-multiple-linear regression (WREG) program version 1.06 (Julie Kiang, U.S. Geological Survey, written commun., May 2013; Eng and others, 2009). The GLS regression analysis included flood-frequency estimates generated for 488 USGS streamgages: 340 rural; 32 small, rural; and 116 urban. The regional-regression analysis resulted in predictive equations that can be used to estimate the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probability (AEP) flows (also referred to as the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flows) at urban and small, rural ungaged locations in the Southeast (table 1). Explanatory variables included in the equations are as follows: HR1, drainage area (DA) and percentage of impervious area (IA); HR3, DA and percentage of developed land; and HR4, DA, IA, and the 24-hour, 50-year maximum precipitation. Incorporation of urban streamgages from the inner Coastal Plain of New Jersey allowed for an increase in DA size from 2.1 to 53.5 mi^2 for which the predictive equations for the Southeast Coastal Plain are applicable (fig. 2). Average standard error of prediction for the predictive equations, which is a measure of the average accuracy of the regression equations when predicting flood estimates for ungaged sites, ranged from 25 percent for the 10-percent AEP regression equation for the Piedmont--Ridge and Valley region to 73 percent for the 0.2-percent AEP regression equation for the Sand Hills region.

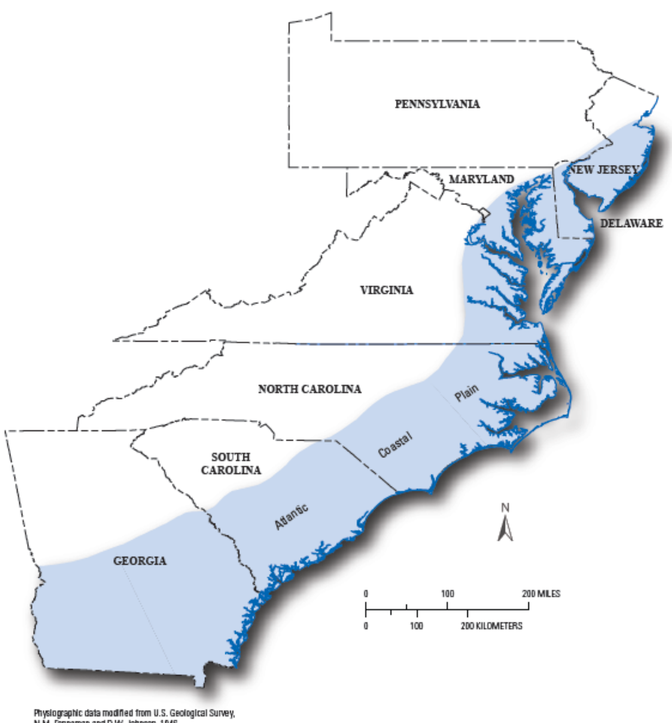

Figure 2. The Atlantic Coastal Plain from Georgia to New Jersey.

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Table 1. Regional flood-frequency equations for ungaged urban and small, rural streams in Georgia, South Carolina, and North Carolina

[mi^2, square miles; DRNAREA, drainage area, mi^2; IMPNLCD06, percentage of impervious area from the 2006 National Land Cover Dataset, in percent; DEVNLCD06, percentage of developed land from the 2006 National Land Cover Dataset; I24H50Y, 24-hour, 50-year maximum precipitation, in inches]

Percent annual exceedance probability	Hydrologic Region (shown in fig. 1)		
	1		3
	$0.10\ mi^2 \leq DRNAREA \leq 3 mi^2$	$3\ mi^2 < DRNAREA \leq 436\ mi^2$	$0.22\ mi^2 \leq DRNAREA \leq 459\ mi^2$
50	$163(DRNAREA)^{0.7089}10^{(0.0133*IMPNLCD06)}$	$198(DRNAREA)^{0.5735}10^{(0.0101*IMPNLCD06)}$	$30.0(DRNAREA)^{0.6605}10^{(0.0122*DEVNLCD06)}$
20	$284(DRNAREA)^{0.7351}10^{(0.0096*IMPNLCD06)}$	$359(DRNAREA)^{0.5605}10^{(0.0074*IMPNLCD06)}$	$51.4(DRNAREA)^{0.6535}10^{(0.0109*DEVNLCD06)}$
10	$381(DRNAREA)^{0.7536}10^{(0.0076*IMPNLCD06)}$	$484(DRNAREA)^{0.5539}10^{(0.0060*IMPNLCD06)}$	$68.4(DRNAREA)^{0.6507}10^{(0.0102*DEVNLCD06)}$
4	$518(DRNAREA)^{0.7752}10^{(0.0053*IMPNLCD06)}$	$657(DRNAREA)^{0.5470}10^{(0.0046*IMPNLCD06)}$	$93.3(DRNAREA)^{0.6472}10^{(0.0095*DEVNLCD06)}$
2	$632(DRNAREA)^{0.7903}10^{(0.0037*IMPNLCD06)}$	$794(DRNAREA)^{0.5428}10^{(0.0037*IMPNLCD06)}$	$114(DRNAREA)^{0.6451}10^{(0.0090*DEVNLCD06)}$
1	$753(DRNAREA)^{0.8038}10^{(0.0024*IMPNLCD06)}$	$941(DRNAREA)^{0.5386}10^{(0.0028*IMPNLCD06)}$	$138(DRNAREA)^{0.6430}10^{(0.0086*DEVNLCD06)}$
0.5	$884(DRNAREA)^{0.8181}10^{(0.0011*IMPNLCD06)}$	$1096(DRNAREA)^{0.5351}10^{(0.0021*IMPNLCD06)}$	$163(DRNAREA)^{0.6413}10^{(0.0082*DEVNLCD06)}$
0.2	$1045(DRNAREA)^{0.8160}$	$1319(DRNAREA)^{0.5305}10^{(0.0011*IMPNLCD06)}$	$201(DRNAREA)^{0.6386}10^{(0.0077*DEVNLCD06)}$

Percent annual exceedance probability	Hydrologic Region (shown in fig. 1)	
	4	*5
	$0.10\ mi^2 \leq DRNAREA \leq 53.5 mi^2$	$0.20\ mi^2 < DRNAREA \leq 10\ mi^2$
50	$26.3(DRNAREA)^{0.5908}10^{(0.0173*IMPNLCD06)}10^{(0.0515*I24H50Y)}$	$165(DRNAREA)^{0.537}$
20	$40.6(DRNAREA)^{0.5958}10^{(0.0125*IMPNLCD06)}10^{(0.0623*I24H50Y)}$	$265(DRNAREA)^{0.583}$
10	$51.8(DRNAREA)^{0.6004}10^{(0.0101*IMPNLCD06)}10^{(0.0666*I24H50Y)}$	$349(DRNAREA)^{0.600}$
4	$67.1(DRNAREA)^{0.6067}10^{(0.0075*IMPNLCD06)}10^{(0.0708*I24H50Y)}$	$473(DRNAREA)^{0.615}$
2	$78.4(DRNAREA)^{0.6111}10^{(0.0058*IMPNLCD06)}10^{(0.0738*I24H50Y)}$	$574(DRNAREA)^{0.624}$
1	$90.5(DRNAREA)^{0.6154}10^{(0.0043*IMPNLCD06)}10^{(0.0762*I24H50Y)}$	$684(DRNAREA)^{0.632}$
0.5	$103(DRNAREA)^{0.6201}10^{(0.0029*IMPNLCD06)}10^{(0.0785*I24H50Y)}$	$804(DRNAREA)^{0.639}$
0.2	$119(DRNAREA)^{0.6261}10^{(0.0012*IMPNLCD06)}10^{(0.0813*I24H50Y)}$	$971(DRNAREA)^{0.649}$

*From Gotvald and Knaak, 2011.