Magnitude and Frequency of Urban Floods in the Southeastern United States

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ABSTRACT. Urbanization can produce significant changes in the flood-frequency characteristics of streams; consequently, rural basin flood-frequency relations are not applicable to urban streams. Updates and improvements of the South Carolina highway infrastructure at stream crossings require an ongoing understanding of flood characteristics, especially for urban watersheds. In addition, urban planners and engineers need current information for establishing flood-insurance rates and other water-resource management decisions. One of the tools necessary for such management are techniques that allow for estimation of the magnitude and frequency of floods at sites on urban streams where gaged data are not available.

In 2009, the U.S. Geological Survey (USGS) South Carolina Water Science Center completed an investigation with the USGS North Carolina and Georgia Water Science Centers to update the rural flood-frequency equations using a multi-state regional approach (Feaster and others, 2009; Gotvald and others, 2009; Weaver and others, 2009). Prior to that investigation, rural flood-frequency analysis in southeastern states had been limited to state boundaries. However, this multi-state regional approach allowed for a significant expansion of the database, in contrast to that used in the previous state rural regression analysis. Additional advantages included: (1) developing equations that are applicable across state boundaries, just as watersheds cross state boundaries, and (2) coordination of explanatory variables used in the regional equations. Because of the benefits gained from the multi-state rural flood-frequency investigation, it was concluded that a multi-state approach for urban flood-frequency analysis would lead to similar benefits. Therefore, in 2011, the USGS began a multi-state urban flood-frequency analysis for the states of Georgia, North Carolina, and South Carolina. This urban flood-frequency investigation includes stations from a recent (2011) Georgia urban flood-frequency investigation and expands the database by including urban stations from South Carolina and North Carolina and other states along the east coast. Geographical Information System (GIS) techniques are being used to generate a number of explanatory variables that will be considered in the regression analysis. The variables being tested include drainage area, main channel length, basin perimeter, main channel slope, mean basin slope, basin shape factor, mean basin elevation, maximum basin elevation, minimum basin elevation, percent of impervious area, percent of developed land, percent of forested land, soil drainage index, hydrologic soil index, drainage density, and population density.

Preliminary Findings. To date, logarithms of annual peak flows have been fit to a Pearson Type III distribution to generate the magnitude and frequency of flood flows at urban stations in South Carolina and North Carolina. These data will be combined with the flood-frequency data from urbans stations in Georgia (Gotvald and Knaak, 2011) along with data from rural stations as published in Feaster and others (2009). Regional regression analysis will be done using generalized least square regression to develop equations for estimating the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probability (AEP) flows, which historically been referred to as the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flows, respectively.

For the rural and urban stations included in the study, the explanatory variables were generated using GIS methods. From the list of potential explanatory variables previously given, the variables related to urbanization are percent of impervious area, percent of developed land, and population density. Gotvald and Knaak (2011) found that for the Georgia Piedmont and Sandhills regions, drainage area and percent of impervious area were the significant explanatory variables. For the Georgia Coastal Plain, drainage area, percent of developed land, and mean basin slope were found to be the significant variables. Preliminary regression analysis for the current study for Georgia, South Carolina, and North Carolina indicates that drainage area and percent of impervious area are significant in the Piedmont region and drainage area and percent developed land are significant in the Sandhills.

For the Georgia Coastal Plain, the upper limit of drainage area size for the urban stations included in the regression analysis was 1.7 square miles (mi^2) (Gotvald and Knaak, 2011). Potential urban stations from the South Carolina Coastal Plain region have a similar upper limit on drainage area size. Therefore, a review of potential urban stations from other states along the Atlantic Coastal Plain was completed. The initial assessment was made by comparing rural flood-frequency data from published reports for various states along the Atlantic Coastal Plain (fig. 1; Austin and others, 2011; Feaster and others, 2009; and Ries and Dillow, 2006). Comparisons of the 1-percent AEP flows for the rural watersheds from the Southeastern study (Feaster and others, 2009) with rural flood-frequency estimates from the other states indicated similar characteristics. Consequently, it is reasonable to assume that the influence of urbanization also would have similar results along the Atlantic Coastal Plain region. Of the states compared, New Jersey has a number of potential urban stations with sufficient data to include in the Coastal Plain analysis. Preliminary assessments indicate that the range of drainage area sizes for the New Jersey urban stations is from 0.3 to 95 mi^2. Therefore, the potential exists for substantially increasing the range of drainage area for which the urban flood-frequency equations would apply.

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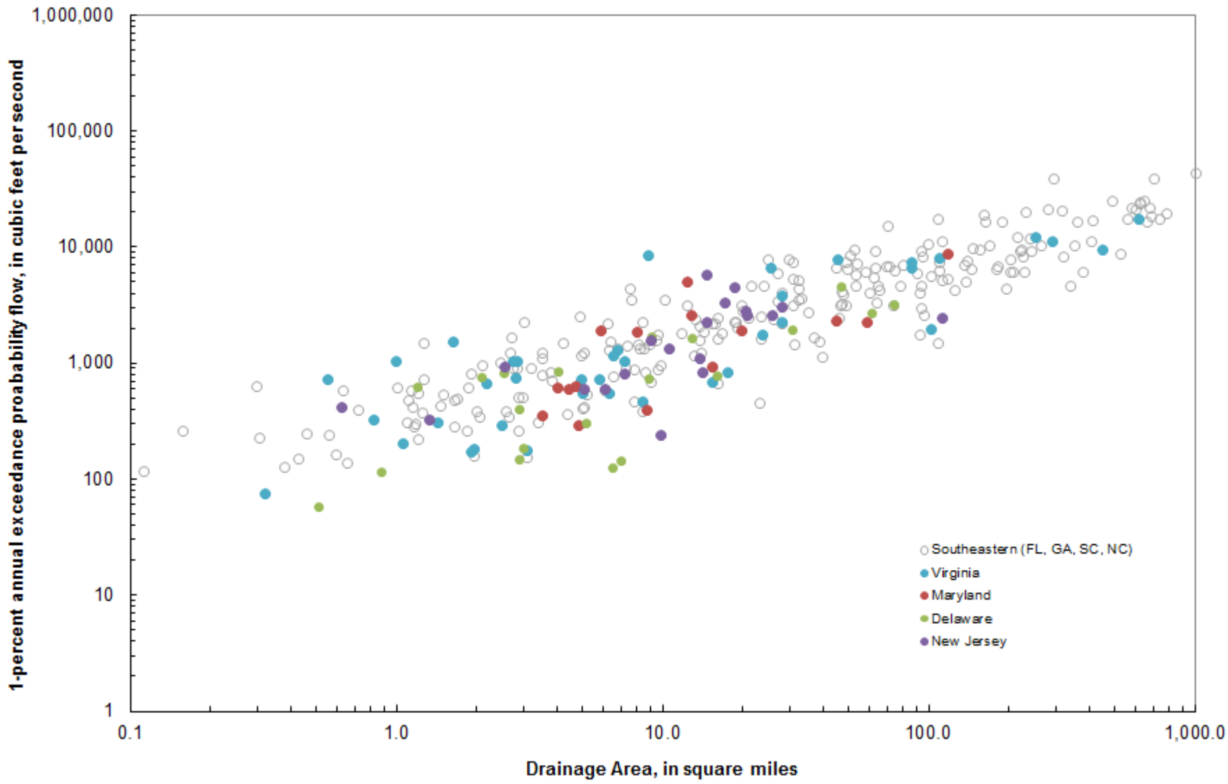

Figure 1. Comparison of 1-percent annual exceedance probability flows from rural stations along the Atlantic Coastal Plain in Florida, Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, and New Jersey.