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Effect of topographic data, geometric configuration and modeling approach on flood inundation mapping

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S U M M A R Y

Technological aspects of producing, delivering and updating of flood hazard maps in the US have has gone through a revolutionary change through Federal Emergency Management Agency's Map Modernization program. In addition, the use of topographic information derived from Light Detection and Ranging (LIDAR) is enabling creation of relatively more accurate flood inundation maps. However, LIDAR is not available for the entire United States. Even for areas, where LIDAR data are available, the effect of other factors such as cross-section configuration in one-dimensional (1D) models, mesh resolution in two-dimensional models (2D), representation of river bathymetry, and modeling approach is not well studied or documented. The objective of this paper is to address some of these issues by comparing newly developed flood inundation maps from LIDAR data to maps that are developed using different topography, geometric description and modeling approach. The methodology involves use of six topographic datasets with different horizontal resolutions, vertical accuracies and bathymetry details. Each topographic dataset is used to create a flood inundation map for twelve different cross-section configurations using 1D HEC-RAS model, and two mesh resolutions using 2D FESWMS model. Comparison of resulting maps for two study areas (Strouds Creek in North Carolina and Brazos River in Texas) show that the flood inundation area reduces with improved horizontal resolution and vertical accuracy in the topographic data. This reduction is further enhanced by incorporating river bathymetry in topography data. Overall, the inundation extent predicted by FESWMS is smaller compared to prediction from HEC-RAS for the study areas, and that the variations in the flood inundation maps arising from different factors are smaller in FESWMS compared to HEC-RAS.

Introduction

Flooding is one of the major natural disasters that affect many parts of the world including developed nations. Besides losing billions of dollars in infrastructure and property damages, hundreds (sometimes thousands) of human lives are lost each year due to flooding. One of the keys in preventing and reducing losses is to provide reliable information to the public about the flood-risk through flood inundation maps. Besides identifying future flood-prone areas, flood inundation maps are also useful in rescue and relief operations related to flooding. Most flood mapping projects in Europe were initiated in late 1990s as a consequence of major floods in that period (Høydal et al., 2000; Menendez, 2000; Pettifer, 2000; TAW, 2004). As a result, many European countries now have flood maps created by governmental organizations and insurance industries (de Moel et al., 2009). In 2007, the European Union also adopted a new flood directive requiring all member states to produce flood inundation and risk maps for their territory by 2015 (EXSCIMAP, 2007).

In the United States, as a part of National Flood Insurance Program (NFIP), the Federal Emergency Management Agency (FEMA) creates and updates flood insurance rate maps (FIRM) that correspond to 100-year return period flow (design flow). FEMA has produced approximately 100,000 flood hazard maps covering 150,000 square miles of floodplain area for 19,200 communities (NFIP, 2002). In 2004, FEMA undertook the ongoing Map Modernization Program (Map Mod) to provide digital FIRMs (DFIRMs) for cost-effective storage, maintenance, distribution, and updating of flood hazard information. Map Mod also includes creation of new maps for newer flood-prone communities, and enhancements of older maps through redelineation of floodplain areas by using recent topographic data. Phase I of Map Mod is nearing completion, and FEMA is now preparing for Map Mod Phase II and beyond (FEMA, 2007).

Although the technological aspect of producing, delivering and updating of flood hazard maps in the US have gone through a revolutionary change through Map Mod, the overall approach

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involved in producing these maps has seen very little changes except the use of detailed LIDAR (Light Detection and Ranging) data in certain studies. For example, the estimation of design flow is still based on methods that were developed more than 20 years ago, and one-dimensional (1D) modeling is still the standard practice in simulating the design flow along a river to delineate a flood inundation map. Recently, (Merwade et al., 2008b) demonstrated the uncertainty arising from different steps in producing a flood inundation map by using simple examples, and made a case for a probabilistic flood inundation map to reflect these uncertainties. Several studies, especially in Europe, have used a two-dimensional (2D) approach for flood inundation mapping, and demonstrated its benefits over 1D modeling in simulating flow dynamics in floodplains (Cobby et al., 2003; Horritt and Bates, 2002; Horritt et al., 2006; Tayefi et al., 2007). However, there still exists ambiguity regarding the selection of appropriate modeling approach (1D/2D) to create an accurate prediction of flood inundation extent when other factors are limiting (e.g., topography). In the absence of detailed topography data in the floodplain, a 1D model can sometimes perform equally well compared to a 2D model in producing the flood inundation extent (Horritt and Bates, 2002). Even with the availability of detailed topographic data from LIDAR in the floodplain, the level at which these data are captured in the geometric description (e.g., spacing of cross-section or mesh size) of a 1D/2D model can have significant impact on the final prediction of flood inundation extent (Bates et al., 2002; Werner, 2001; Yu and Lane, 2006). Considering the interplay of topography, geometric description and modeling approach in the final flood inundation map, it is necessary to investigate how much effect these could have in the FIRMs that are produced by FEMA.

The objective of this paper is to explore and quantify the difference arising from topography, geometry and model type in producing flood inundation maps. This objective is accomplished by using a 100-year FIRM including the input data and model files for a study area as a base map, and comparing it with new flood inundation maps for the same area that are created by changing topographic data, geometric description and modeling approach. The intent of this study is not to validate any specific approach, or to invalidate the FEMA process or the FIRMs, but to highlight the extent of subjectivity involved in producing these maps, and how this subjectivity is reflected in the form of uncertainty associated with flood inundation maps. As mentioned earlier, the effect of topography, geometric configuration and modeling approaches on flood inundation mapping has been conducted separately by several researchers on different study areas.

This study includes a comprehensive assessment of these effects on two focused areas with different physical settings, thus providing an improved understanding of interplay among topography, geometric description and modeling approach in the final inundation mapping. Another unique aspect of this study is the investigation of the effect of including river bathymetry in topography data for flood inundation modeling and mapping.

Study reaches and data

This study includes two reaches: Strouds Creek in Orange County, North Carolina, and Brazos River in Fort Bend County, Texas (Fig. 1 and Table 1). These study reaches are selected primarily because of the availability of data and models. In addition, these two study areas provide distinct physical (topographic and geomorphic) and climatic settings, thus providing good test beds for the study. Strouds Creek is a tributary of the Eno River, and is characterized by a relatively narrow floodplain with a v-shaped valley. Brazos is one of the major rivers in Texas. The Brazos reach included in this study is characterized by meandering bends and a relatively flat floodplain with levees located on both sides of the reach. The available GIS data for Strouds Creek, used in Map Mod and available from North Carolina Floodplain Mapping Program (NCFMP), includes 55 surveyed cross-sections and 6 m horizontal resolution LIDAR digital elevation model (DEM) as shown in Fig. 2a. The average width of these cross-sections is 120 m with an average spacing of 120 m. Similarly, GIS data for the Brazos Reach, used in Map Mod and available from Fort Bend County, includes 53 surveyed cross-sections and 3 m horizontal resolution LIDAR DEM (Fig. 3a).

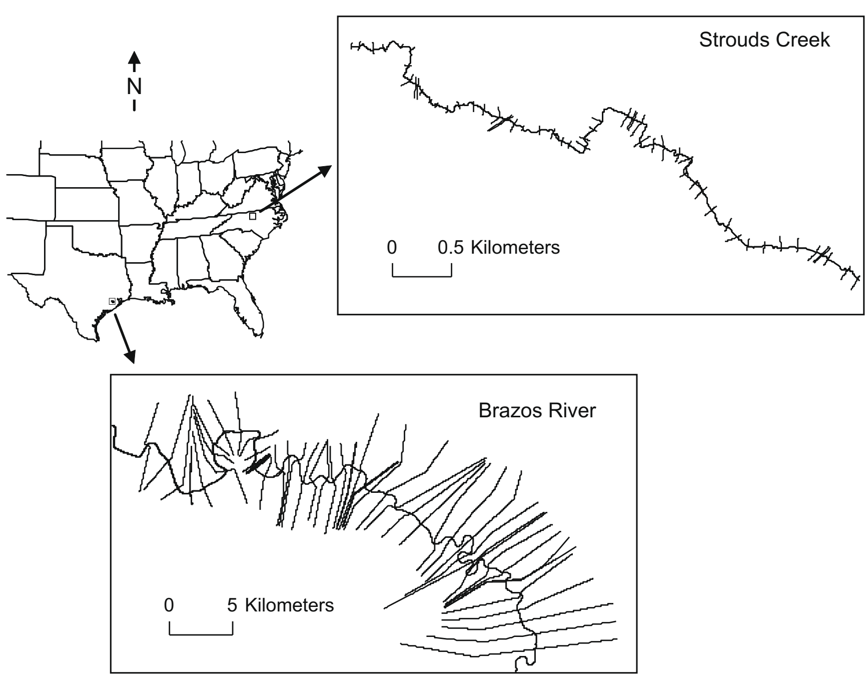

Fig. 1. Layout map of study areas.