Final Report

University: University of Alabama

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NWS Office: National Water Center (NWC)

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Partners or Cooperative Project: Partners

Project Title: Intercomparison of hydraulic models for forecasting flood-inundation extent and depth: An application to the National Flood Interoperability Experiment (NFIE)

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Section 1: Summary of Project Objectives

The major objectives of the project are to:

1. Evaluate DEM-based methods for generating cross-sections and hydraulic parameters suitable for use in hydraulic modeling.

2. Compare water depths simulated by AutoRoute and LISFLOOD-FP to observed water depths.

3. Determine the overall advantages and disadvantages of AutoRoute and LISFLOOD-FP in terms of accuracy, data input requirements, and computational efficiency, with the goal of recommending one or more models for eventual inclusion in the National Water Model framework for forecasting flood inundation at a national scale.

Section 2: Project Accomplishments and Findings

We have simulated flood-inundation extent for the December 2015 flood on selected reaches of the Choctawhatchee-Pea-Yellow rivers in southeastern Alabama using both AutoRoute and LISFLOOD-FP (Table 1). Our analysis of the data input requirements and computational efficiency of the two models concludes that LISFLOOD-FP, while useful for modeling individual river reaches, is too labor-intensive to be used for real-time flood inundation modeling for large spatial domains, in particular because of the time needed to set up boundary conditions for each river segment (Figure 1). AutoRoute, on the other hand, can simulate flood-inundation extent using only a digital elevation model (DEM) as input, and its computational time is quite rapid. A disadvantage of AutoRoute is that it simulates inundation extent only, not depth. AutoRoute was initially designed for high-slope streams in mountainous terrain and its outputs in low-slope, highly sinuous streams of the Gulf Coastal Plain are often suspect (Figure 2). As

AutoRoute employs an automated stream cross-section method to estimate flow, the cross-sections in high-sinuosity stream reaches can interfere with each other, degrading model estimates. Both models have some potential applicability in forecasting flood inundation. AutoRoute can be easily applied to large spatial domains with minimal data input requirements and computational time, which makes it suitable for establishing initial hazard areas based on National Water Model flow forecasts that can then be simulated in higher detail with a two-dimensional model such as LISFLOOD-FP. Because of LISFLOOD-FP's data and computational requirements, however, it is better suited for static scenario analysis of individual river reaches of critical importance, rather than real-time flood forecasting in the National Water Model framework.

Table 1: Summary of data input requirements, computational time, output, and overall advantages and disadvantages of AutoRoute and LISFLOOD-FP.

Model	Data input requirements	Computational time	Output	Overall advantages	Overall disadvantages
AutoRoute	Stream network shapefile, stream geometry (slope), discharge, Digital Elevation Model, and Manning's N surface of the model domain.	1 degree x 1 degree 30 meter resolution DEM simulation requires less than 30 seconds on a consumer class laptop. Multiple DEMs can be run on multiple cores, further increasing the efficiency of the model.	Flood inundation extent.	Processing time and data requirements.	The model tends to become less accurate in low slope stream reaches with high sinuosity. This is likely a function of the automatic cross-section creation function. The model assumes water elevation slope and bed slope are equal which disallows modeling of flood wave propagation.
LISFLOOD-FP	Digital Elevation Model, rasterized stream network, rasterized stream depth and width, and boundary and flow conditions.	Processing time is longer than experienced with AutoRoute, but still measured in minutes.	Flood inundation extent and depth.	Models flood wave propagation, depth, and extent.	Extensive preprocessing and limited documentation.

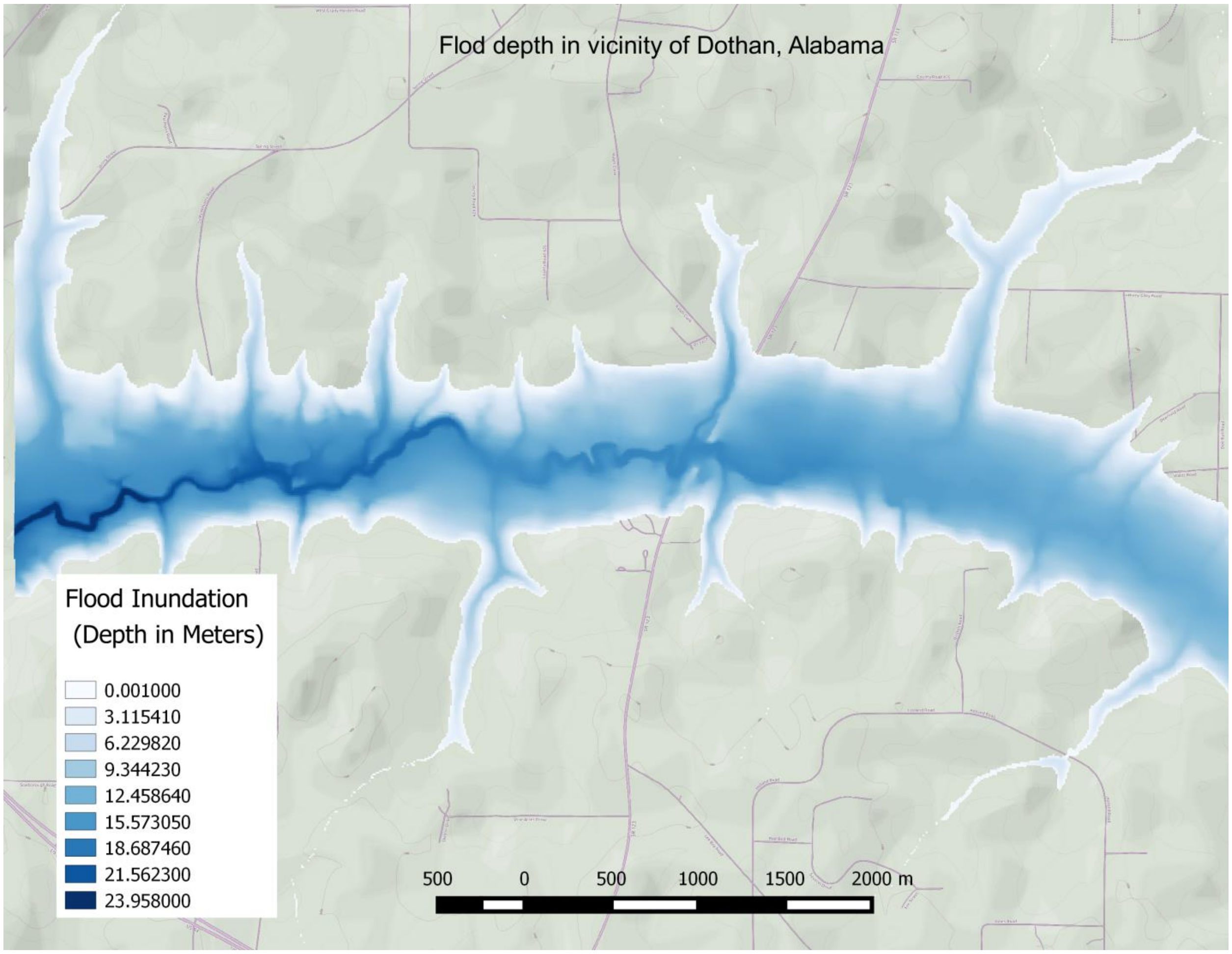

Figure 1: LISFlood-FP simulation of maximum flood depth for the December 2016 flood in southern Alabama, near Dothan.

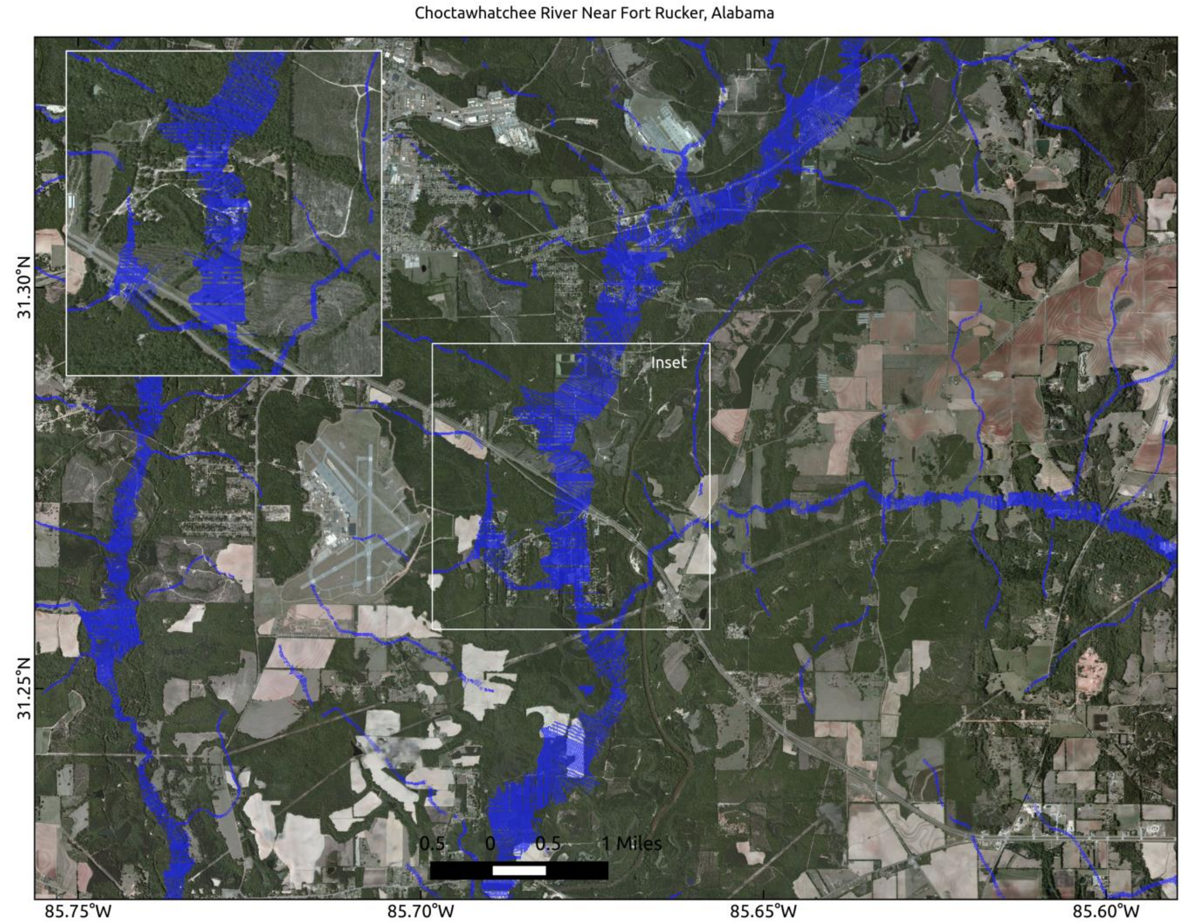

Figure 2: AutoRoute simulation of maximum flood extent for the December 2015 flood on the Choctawhatchee River near Fort Rucker, Alabama.

We were unable to quantitatively assess the accuracy of flood-inundation extent simulations in the Choctawhatchee-Pea-Yellow river basin for the December 2015 flood, because observed data on flood extent were not available and cloud cover during the event precluded the use of remote-sensing data. Compounding the difficulty of using remote sensing to determine flood inundation extents, the Choctawhatchee-Pea-Yellow river basins are under extensive forest canopy. We are, however, in the process of comparing AutoRoute-simulated inundation extent of the May 2016 flood on the Brazos River on Texas to Landsat imagery (Figure 3). Because our initial work in the Choctawhatchee-Pea-Yellow river basin led us to conclude that LISFLOOD-FP is not suitable for real-time flood forecasting in the National Water Model framework, we are not including it in this accuracy assessment. Instead, we are comparing simulations of flood-inundation extent by the terrain-based Height Above Nearest Drainage (HAND) method and the two-dimensional hydraulic model International Rivers Interface Cooperative – Flow and Sediment Transport with Morphological Evolution of Channels (iRIC-FaSTMECH). The resulting analysis will compare flood inundation estimated from a very simple terrain-based approach (HAND), an intermediate-complexity cross-section method (AutoRoute), and a complex hydraulic model (iRIC-FaSTMECH) to remotely-sensed inundation extent, which will provide us with information on the relative accuracy on the models with differing complexity. This analysis will allow us to make a recommendation about which model(s) to consider coupling with the National Water Model in order to make real-time flood-inundation forecasts at the continental scale. We are collaborating with student participants in the 2016 NWC Summer Institute (Jiaqi Zhang of the University of Texas – Arlington, Yu-Fen Huang of the University of Hawaii, and Dinuke Munasinghe of the University of Alabama), who did the Landsat remote-sensing analysis and HAND and iRIC-FaSTMECH modeling for the Brazos flood as part of their Summer Institute project.

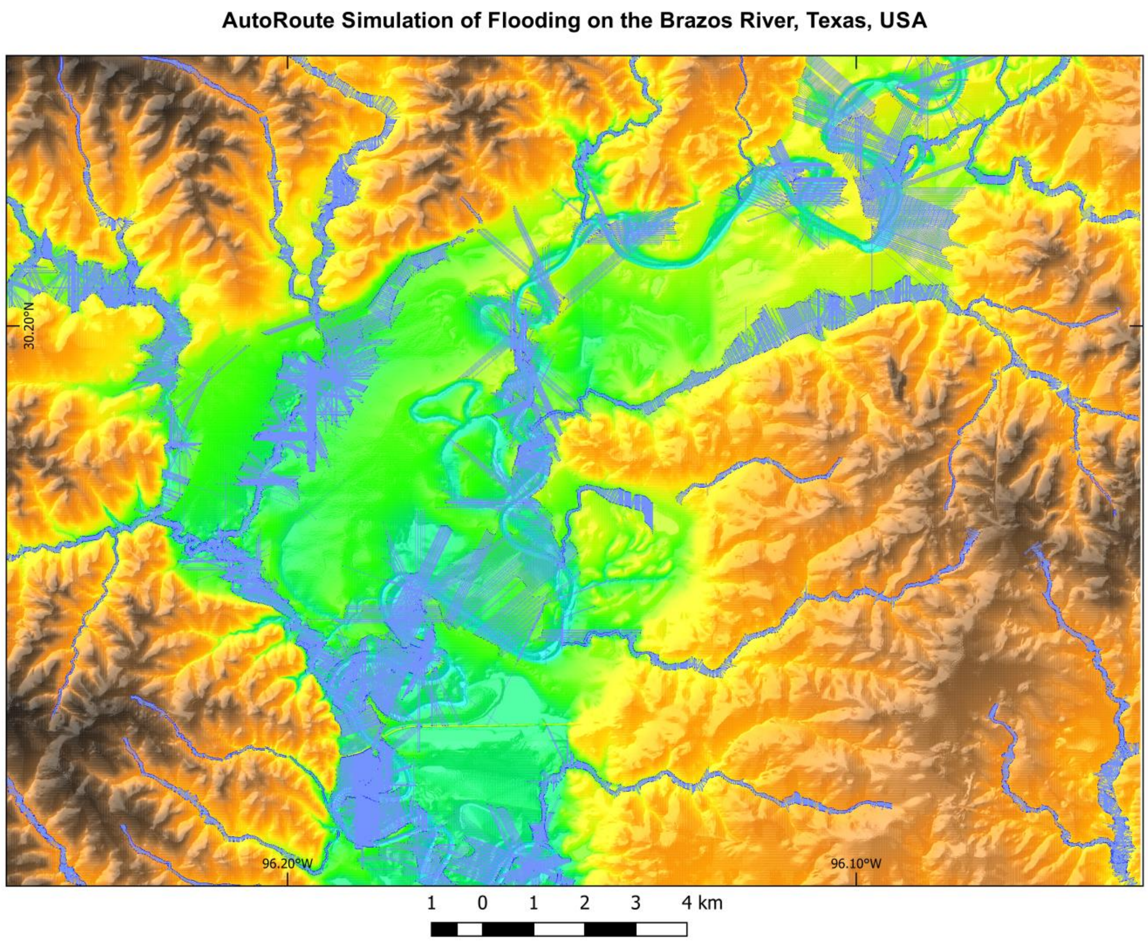

Figure 3: AutoRoute simulation of maximum flood extent for the May 2016 flood on the Brazos River in Texas.

<u>Section 3: Benefits and Lessons Learned: Operational Partner Perspective</u>

The benefits to the NWS included development of a strong research relationship with the University of Alabama, directly and indirectly via the NWC Summer Institute and Mr. Shawn

Carter moving to the NWC. This project provided an insight into the application and use of NWM data in generation of flood-inundation extent and its advantages and disadvantages.

Section 4: Benefits and Lessons Learned: University Partner Perspective

In part because of work on this project, Dr. Praskievicz was selected to be a theme leader in the 2016 NWC Summer Institute. As a theme leader, she advised or co-advised two student groups who worked on projects related to this research, including hydraulic model intercomparison projects that used AutoRoute and other simple DEM-based flood-inundation mapping tools, as well as more complex hydraulic models. These collaborations are continuing and expected to lead to future publications.

Shawn Carter, the graduate research assistant for this project, graduated with his master's degree from the University of Alabama Department of Geography in Summer 2016. He is now working as a University Corporation for Atmospheric Research (UCAR) Associate Scientist at the NWC. His experience with this project helped him develop technical skills and make networking connections that assisted him in securing the NWC position.

Section 5: Presentations and Publications

Dr. Praskievicz is presenting the results of this research in November 2016 at the annual meeting of the Southeastern Division of the American Association of Geographers. The presentation will include the results from this research, as well as an overview of the NWC Summer Institute. The goal will be to encourage more geography students and faculty in the region to participate in the Summer Institute and to build relationships with the NWC.

We are planning to submit a paper based on this research in February 2017 to a special issue of the *Journal of the American Water Resources Association*, which will feature results from the 2016 NWC Summer Institute. Our paper will be co-authored with Summer Institute participants Jiaqi Zhang, Yu-Fen Huang, and Dinuke Munasinghe, and will feature the results of the comparison of AutoRoute, HAND, and iRIC-FaSTMECH inundation extents to Landsat imagery for the May 2016 Brazos River flood. The inclusion of our research within this special collection will ensure its visibility and impact within the scientific community.

Section 6: Summary of University/Operational Partner Interactions and Roles

Dr. Praskievicz supervised graduate research assistant Shawn Carter in setting up, running, and analyzing results from the AutoRoute and LISFLOOD-FP models; organized progress meetings with the NWC; and completed the six-month and final project reports. She will present the results of the project at the Southeastern Division of the American Association of Geographers meeting in November 2016 and help coordinate the submission of a paper to the *Journal of the American Water Resources Association* special issue in February 2017.

Juzer Dhondia coordinated the project from the NWC side; developed metrics for model intercomparison; and participated in regular progress meetings. He will be a co-author on the publication resulting from this research.