13D.3 MODELING INLAND FLOODING DUE TO TROPICAL CYCLONES

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1. INTRODUCTION

Landfall tropical cyclones often produce heavy precipitation resulting in river and flash floods. Such floods can not only cause lose of human lives and properties, but also lead to ecological disasters in the watershed areas, estuaries and coastal waters. Previous studies (Hilderbrand, 2002 and Croke, 2005) indicated that approximately 40% of damages from land falling tropical cyclones in North Carolina were caused by flooding. The same amount of precipitation can contribute to different response of flooding from different characteristics of watersheds such as land use and soil types, slopes and aspects. Ground water hydrology can also influence base flow in the outlet of watershed. This study investigates the impacts of land falling tropical cyclones on inland flooding in the watersheds of Eastern North Carolina. It also assesses the effects of different distributions of precipitation on the watershed hydrology in order to improve inland-flooding forecasting.

2. STUDY AREA

The Tar-Pamlico River basin (Figure 1) has been selected for this research because it covers a large area reaching to the east coast and it is one of the watersheds entirely located within the state of North Carolina. It covers a 14,089 square kilometers area making it the fourth largest river basin in the state (NCDWQ, 2004). Tar-Pamlico River basin encompasses all or part of 16 counties and 51 municipalities. The latest land cover data generated from satellite imagery indicates that most of the basin is in forested and wetland areas (54%), followed by cultivated cropland (22%), open water area (20%), pasture and other managed herbaceous areas (3%), and urban areas (1%).

3. METHODOLOGY

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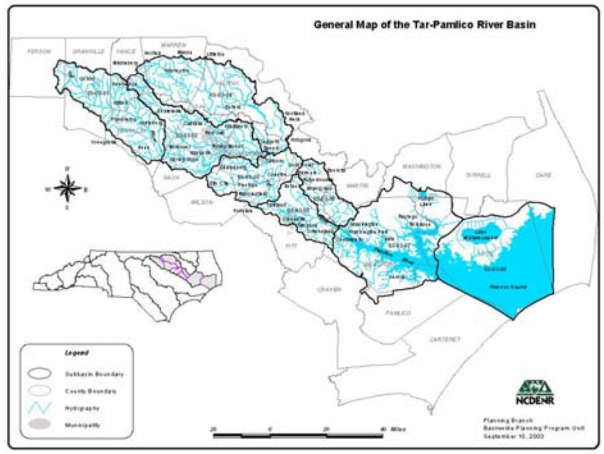

Figure 1. Location of the Tar Pamlico River Basin

In this study, a distributed watershed model – Agricultural Non-Point Source Pollution Model (AGNPS) is applied to the Tar-Pamlico River basin. AGNPS handles watershed topological conditions (elevation, aspect, land use and soil type), overland flow, and channel condition. It is a GIS linked model so that input and output of large amount of watershed data can be easily handled through a automated graphical user interface.

3.1 *Introduction of AGNPS model*

AGNPS Model (Bingner, 2001) is a GIS driven watershed hydrology and water quality model developed by USDA. It is a continuous/single event simulation model and it simulates loading of river discharge and peak runoff and non-point source pollutants (e.g., sediments, nutrients – nitrogen and phosphorus, herbicide).

AGNPS has been widely applied in different areas. Perrone and Madramootoo (1997) determined the predictive capability of the AGNPS model with respect to surface runoff, peak flow, and sediment yield produced by rainfall-runoff events on a 26 km^2 watershed in Quebec, Canada. They concluded that AGNPS was reliable for surface runoff and sediment yield predictions, but generally over-predicted peak flow. Mostaghimi et al. (1997) found better agreement between simulated and observed runoff volumes than between simulated and observed peak rates, sediment or nutrient yields by AGNPS. AGNPS (defined as AnnAGNPS) model was used for Horseshoe Creek watershed, Kansas to estimate the runoff volume, sediment, and nutrient (nitrogen and phosphorus) losses (Mulik, 1999). Bingner (2001) stated that an important consideration in choosing an accurate DEM is the delineation of cell boundaries and the stream network for areas of low relief.

3.2 *Data Acquisition and Automation*

Digital data required to run the watershed model is available in many public sources. However, select the proper scale of the dataset is a difficult work. Small scale dataset may not resolve real world watershed, while large scale dataset with good resolution and representing better realities of real world involves huge amount of works especially in large watershed. Blöschl and Sivapalan (1995) proposed an optimal scale for different types of watershed. According to their study, an optimal scale for Tar Pamlico River basin is 1:250, 000 for DEM, land use and soil data. The projection system of NAD 83 State Plane North Carolina FIPS_3200 has been chosen so that all collected dataset can be projected or transformed into one coordination system.

Collected digital datasets are illustrated in Figure 2. Figure 2a represents digital elevation data in North Carolina watersheds. The highest elevation in the State's watershed is about 600 meters. Land use and soil distribution are depicted in Figure 2b and 2c. Eight weather stations are shown in Figure 2d. Each polygon represents thiessen's polygon that one station covered. There are six parameters in the input data: precipitation, maximum and minimum temperature, monthly dew point, sky cover, wind speed. Figure 2c and 2d, also show the cells and reaches generated by the Flownet generator of the watershed model. Figure 2f shows the locations of ground water stations and hydrogeological aquifers.

3.3 *AGNPS work flow chart*

Figure 3 presents the flow chart of AGNPS. Firstly, digital elevation model (DEM) is imported into Flownet generator to create cells and reaches according to the value of aspects and elevation. There are over one thousand irregular shaped cells in the Tar Pamlico river basin. Flow directions have been created and outlet can be determined. This outlet is met with the gauge station in US Geological Survey. The model output can be compared to gauge measured data. After cells and reaches are created, land use and soil layers are overlaid with cells in the GIS. Each cell captures one identical land use and one soil type. All other information related to land use and soil as well as hydrological characteristic data can then be imported according to their identified types. Each weather station represents certain area defined by thiessen's polygon and overlays with the cells as well. Input Editor is a window-based software to help manage all data that are automated from GIS or input manually as they are not available in digital format. Once all data have been imported, AGNPS can be run to be calibrated and verified and then scenarios can be built up.

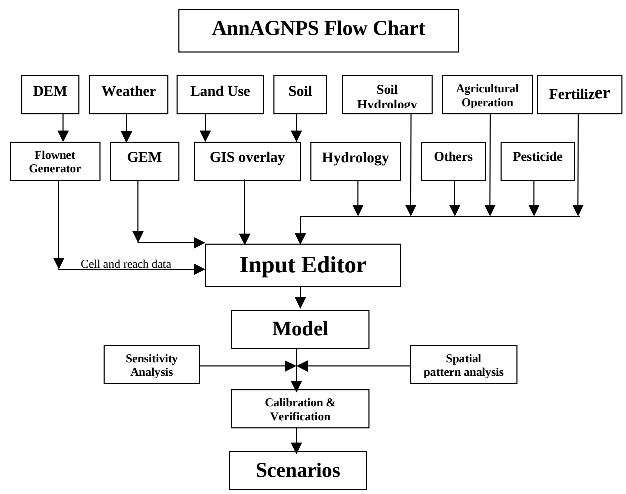

Figure 3. AGNPS flow chart

4. RESULTS

Meteorological data from 1989 to date are used to force the watershed model. The model has been run for three years as a spin-up so that soil moisture content can be initialized.

Annually mean monthly runoff from model output is $95x10^6$ m^3 which is consistent with the basin outlet gage station measured runoff of $96x10^6$ m^3.

Calibration of the model has been done in 2003 from June to September (Figure 4). The estimations by the model generally agree with the observed gage discharges with a R square value of 0.79. However, the model tends to underestimate the data with a slope estimate of 0.8025 from a simple linear regression.

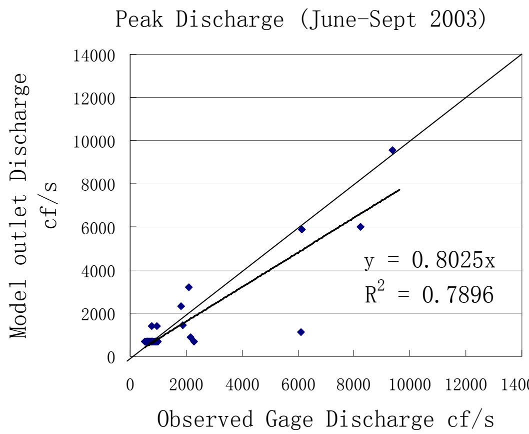

Figure 4. Comparison of model output from USGS gage data

Next, we consider a specific flooding event during the passage of Hurricane Isabel 2003. Figure 5 is the comparison of model result and outlet gage station. It shows that the model is able to capture the peak discharge associated with the precipitation of Hurrricane Isabel.

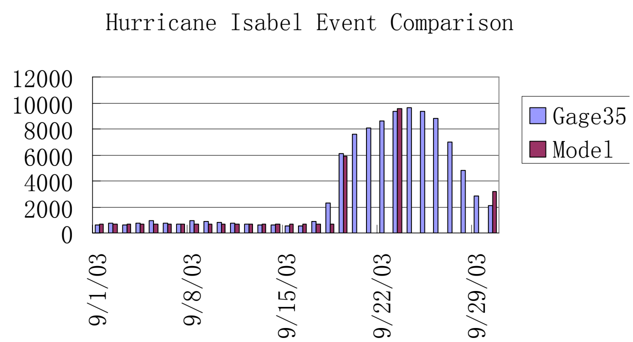

Figure 5. Model result comparison on Hurricane Isabel event in Sept. 2003 (Discharge in cf/s)

5. CONCLUSION AND DISCUSSION

The results shown in this study indicate that the AGNPS model has the capability of simulating the peak flow of the Tar-Pamlico river basin given observed precipitation distributions. Further study is needed to investigate the effects of different precipitation patterns and rates on river flooding and additional cases need to be examined to calibrate the model statistically.

6. ACKNOWLEDGMENT

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7. REFERENCES

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8. ILLUSTRATIONS

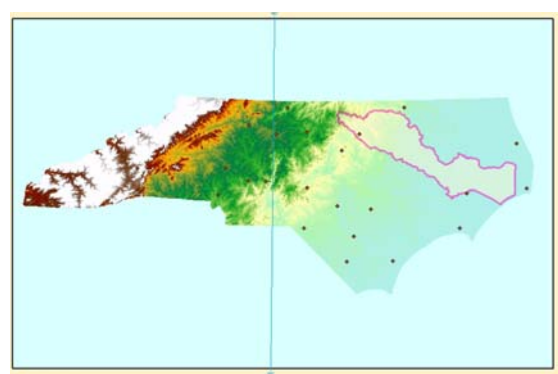

Figure 2a. Digital Elevation Model in the study area

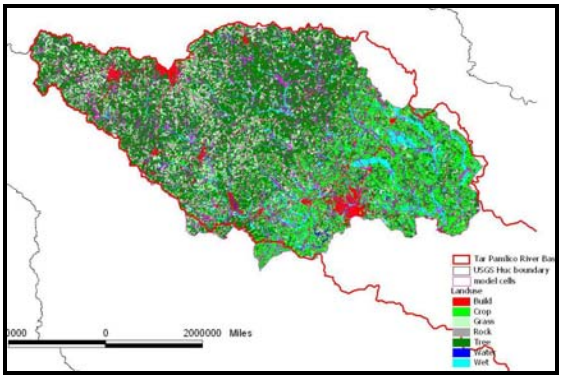

Figure 2b. Land use in the study area

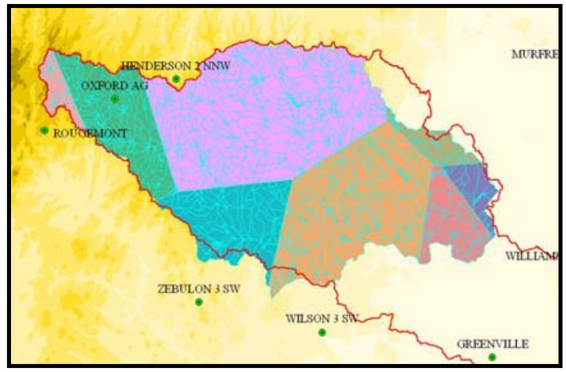

Figure 2d. Distribution of weather stations

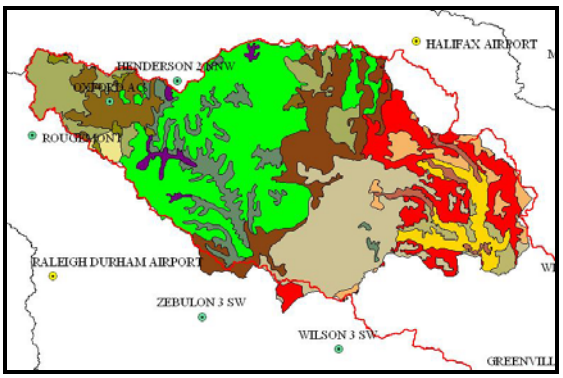

Figure 2c. Soil types in the study area

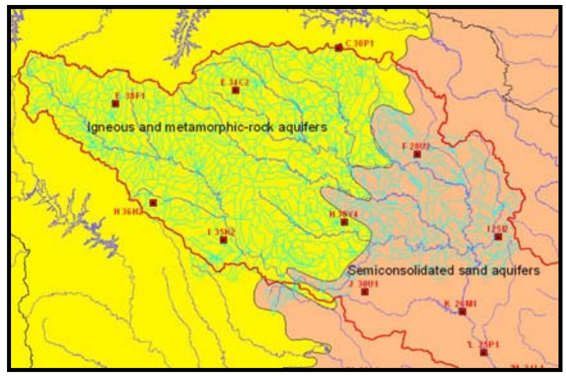

Figure 2f. Ground water stations and its aquifer