Development of a 2D Hydrodynamic Model of the Mississippi River and Application To Long-Term Management Scenarios, Contaminant Transport and Sediment Transport

Basic Information

Title:	Development of a 2D Hydrodynamic Model of the Mississippi River and Application To Long-Term Management Scenarios, Contaminant Transport and Sediment Transport
Project Number:	2011LA79B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	5th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Sediments, Solute Transport
Descriptors:	None
Principal Investigators:	Clinton S. Willson, Clinton S. Willson

Publications

1. Willson, C.S. et al., 2012 Linking Science, Engineering and Design in Envisioning the Future of Coastal Louisiana: A Study of the Lowermost Mississippi River, to be presented at the 2012 State of the Coastal Conference being held in New Orleans, LA
2. Willson, C.S. et al., 2012, Envisioning a Sustainable Future for the Lower Mississippi River: Linking Engineering, Science and Design, to be presented at the CUAHSI 3rd Biennial Colloquium on Hydrologic Science and Engineering Science Sessions: July 16-18, 2012

SYNOPSIS

Title: Development of a 2D Hydrodynamic Model of the Mississippi River and Application To Long-Term Management Scenarios, Contaminant Transport and Sediment Transport

Project Number 2011LA79B

Start Date March 1, 2011

End Date February 28, 2012

Funding Source 104B

Research Category: Climate and Hydrologic Processes

Focus Categories Hydrology (HYDROL), Sediments (SED), Solute Transport (ST),

Descriptors Mississippi River Hydrodynamics, Fate-and-Transport, Sediment Transport

Primary PI Clinton S. Willson

Other PIs None

Problem and Research Objectives

The Mississippi River has an annual average flow rate of 495,000 cfs (ranks seventh worldwide in both annual sediment and water discharge) and drains approximately 1,245,025 mi^2 representing about 41% of the 48 contiguous United States (Knox, 2007) (NAP, 2008). The coastal system that the river created and the ease of passage to/from the Gulf of Mexico for ports up to Baton Rouge make the lower river of vital economic importance to Louisiana and the U.S. The availability of freshwater and ease of navigation has also provided for a large presence on the river of petrochemical plants and related industry. While not a regular occurrence, unintended releases of chemicals within and along the banks of the river occur and can have major consequences for drinking water supplies and ecological systems. Finally, there are a number of proposed projects that intend to utilize Mississippi River water and its resources (e.g., nutrients, sediment) for coastal and wetland restoration projects. Improved understanding of the hydrodynamics of the river and transport of these resources is crucial for optimal planning and utilization.

Here, we are developing two complimentary models of the Mississippi River from Tarbert Landing out into the Gulf of Mexico that can be used for three purposes: (1) simulate the river hydraulics under potential future scenarios associated with climate change or changes in river management; (2) model the fate-and-transport of chemicals downriver from any location within the study domain; and (3) model the sediment transport dynamics to better understand the timing and delivery of sediment to the lowermost reaches of the river. These models will be useful for state and federal agencies, public officials/decision-makers, researchers and consulting firms in making technically-sound decision regarding the river and its resources.

Methodology

We have already developed and calibrated a 1D HEC-RAS model of the river from Tarbert Landing to the Head of Passes. This 1D model was built using the latest bathymetry and topography data along the river and has been calibrated and validated for the 2009. This same bathymetry and topography is currently being used in our development and calibration of the 2D Adaptive Hydraulics (ADH) finite element model covering the same reach of the river.

Principal Findings and Significance

The HEC-RAS model has been used to model a number of scenarios, including: (1) the impact of both eustatic sea level rise and subsidence on the lower river hydraulics; (2) the impact of a major lower river realignment on the lower river hydraulics.

The Louisiana Coastal Protection and Restoration Authority has issued a draft report regarding Mississippi River Delta Plain future subsidence and local eustatic sea level rise rates. The HEC-RAS model was run under various flow rates (low, medium and high) to look at the water surface elevations, velocities, and sediment transport characteristics for: (1) current conditions; (2) a scenario where the relative sea level rise (i.e,. due to both subsidence and eustatic sea level rise) is accounted for by simply raising the Gulf of Mexico +1 and +1.5 m; and (3) a scenario where the bathymetry and topography in the lower river is lowered to account for local subsidence rates and the Gulf of Mexico water level is raised to account for eustatic sea level rise.

Figure 1 shows the river velocity values for the three scenarios at a flow rate of 1,000,000 cfs while Figure 2 shows the bottom shear stress values for the same conditions. In both cases, it is clear that the combined effects of subsidence and sea level rise will cause the lower river to flatten out causing decreases in the velocity and in the sediment carrying capacity. These characteristics may create problems related to navigation and will likely increase the need to dredge more of the river. Figure 3 shows the water surface elevations from the HEC-RAS model for 2009 flow rates: simulated and observed for 2009 conditions; simulated for a river that is realigned to end around RM 55; and simulated for a river that is realigned to end around RM 30. By realigned, we mean that the river has been "shortened" around either River Mile (RM) 55 or 30 so that ~80% of the river is diverted to build land and ~ 20% flows through a relatively slackwater navigation channel. The results in Figure 3 first show the good quantitative match between the simulated and observed 2009 water surface elevations. Second, it is obvious that a shortened river will increase the hydraulic efficiency of the river and reduce water surface elevations in an above the New Orleans area. The bottom shear stress in the river at a flow rate of 1,000,000 cfs for current conditions and one of the river realignment scenarios is shown in Figure 4. While a realigned river may reduce water surface elevations, the changes will also impact water velocities, sediment transport, etc. Figure 4 also highlights how this modeling work is eventually going to integrate with socioeconomic data and information being gathered by the LSU Coastal Sustainability Studio (www.css.lsu.edu); in the figure, the water surface elevation is shown along with population data. Note: These modeling results (particularly, the ones with the shortened/realigned river) are very preliminary and are included mostly to show the type of future management scenarios that we are looking to address with our model(s).

The 2D model is currently being calibrated and validated with initial results expected by the end of Summer 2012.

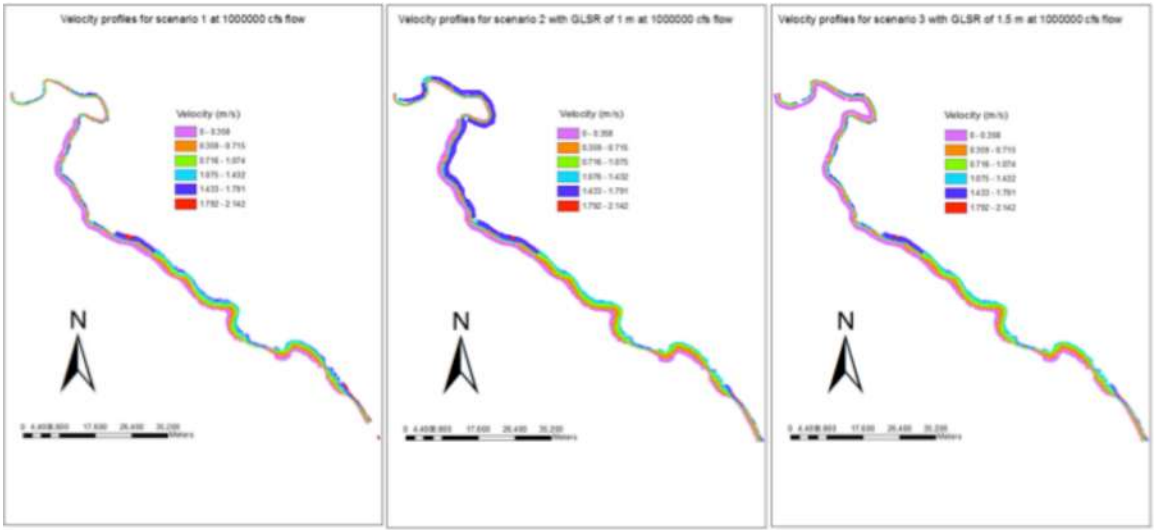

Figure 1: River velocity profiles for the lower ~110 miles of the Mississippi River at a flow rate of 1,000,000 cfs and three conditions (left: current; center: relative sea level rise of 1.5 m all accounted for through Gulf of Mexico; right: subsidence and eustatic sea level rise accounted for independently.

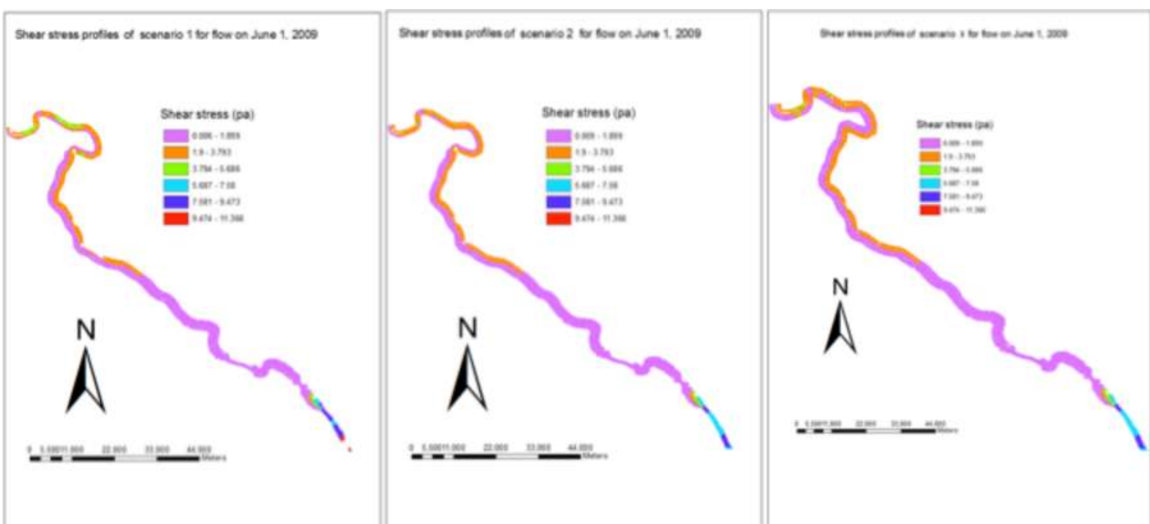

Figure 2: River shear stress profiles for the lower ~110 miles of the Mississippi River at a flow rate of 1,000,000 cfs and three conditions (left: current; center: relative sea level rise of 1.5 m all accounted for through Gulf of Mexico; right: subsidence and eustatic sea level rise accounted for independently.

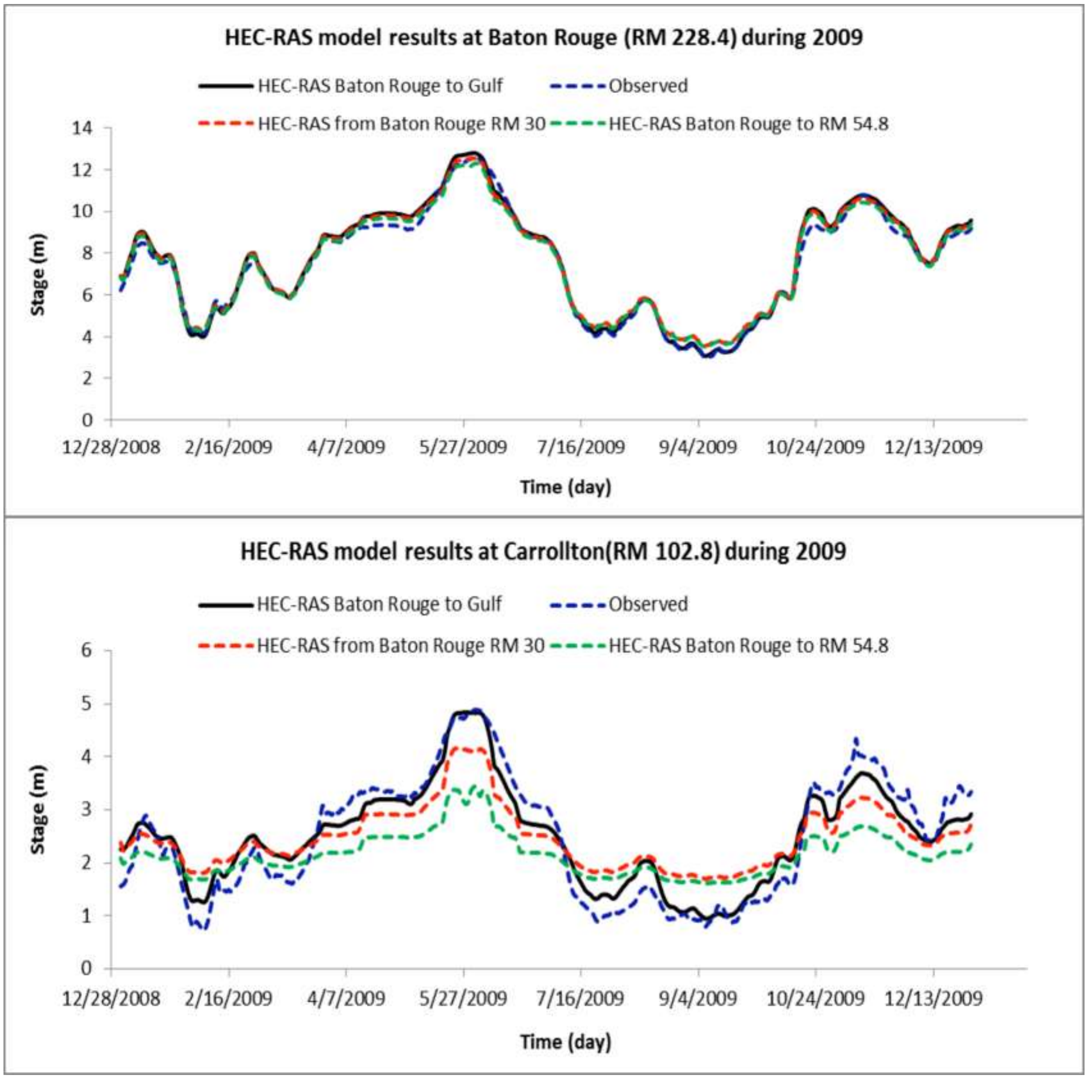

Figure 3: Water Surface Elevations for Baton Rouge (top) and Carrollton (bottom) during 2009 flow rates for simulated and observed 2009 conditions and for two shortened/realigned river scenarios.

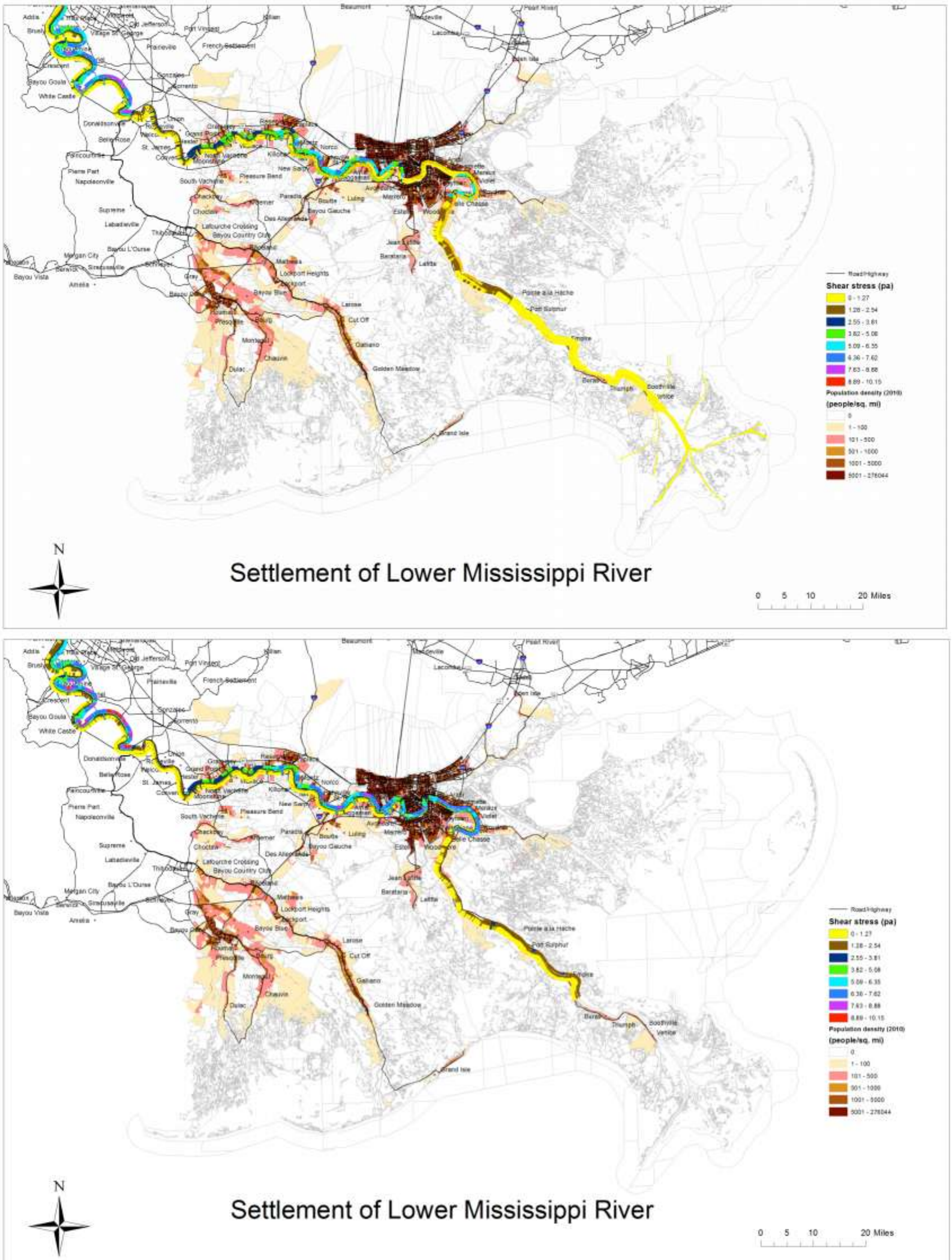

Figure 4: Bottom Shear Stress Values at a flow rate of 1,000,000 cfs for current conditions (top) and for a shortened/realigned river (bottom).