ANALYZING SHOALING REDUCTION TECHNIQUES ON THE ATCHAFALAYA RIVER AT MORGAN CITY, LA

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Abstract In recent years, shoaling has become a significant problem on the Atchafalaya River at Morgan City, LA. Reducing the amount of dredging volumes in this channel is of vital interest due to the rate at which this shoaling occurs and the ever increasing cost of dredging. This paper focuses on the various proposed design alternatives under consideration to reduce the shoaling at Morgan City, using the Curvilinear Hydrodynamics in 3-dimensions, Sediment (CH3D-SED) code. CH3D-SED is a three-dimensional, hydrodynamic and sedimentation modeling code.

The model domain begins 2 miles above the confluence of the Atchafalaya River and the GIWW above Morgan City and extends to 3 miles below Morgan City, includes 2.5 miles of GIWW to the East of the confluence, and just under 1 mile of Bayou Beouf to the East of Atchafalaya below Morgan City. The model was verified to flow conditions from 2008. This verified condition was used as a base condition and was compared to five separate dike/submerged weir simulations of the model.

A detailed description of the dike/submerged weir scenarios is given in this paper as well as the results and qualitative conclusions for the simulations associated with these scenarios.

INTRODUCTION

Background and Purpose The Atchafalaya River is the largest of all distributaries of the Mississippi River. The U.S. Army Corps of Engineers maintains a 12-foot deep by 125-foot wide Atchafalaya navigation channel that extends from the Mississippi River via Old River Lock downstream to the Gulf Intracoastal Waterway (GIWW) system at Morgan City, LA. The Lower Atchafalaya River is the natural outlet for the Atchafalaya River Basin, draining flows past Morgan City and Berwick, LA to the Atchafalaya Bay and the Gulf of Mexico.

Shoaling has become a significant problem in Atchafalaya River at Morgan City, LA. Historically, the thalweg of the channel ran along the eastern side of the Atchafalaya River at Morgan City, LA; but in recent years the channel has migrated to the Berwick, LA side of the river and the port on the Morgan City side of the river has begun to shoal heavily (see Figure 1). The result of the channel migration is a significant increase in required dredging. Reducing the amount of dredging volumes in this channel reach is of vital interest due to the rate at which this shoaling occurs and the ever increasing cost of dredging. The U.S. Army Engineer District at New Orleans, LA (CEMVN) tasked the

Engineer Research and Development Center (ERDC) at Vicksburg, MS with studying this problem.

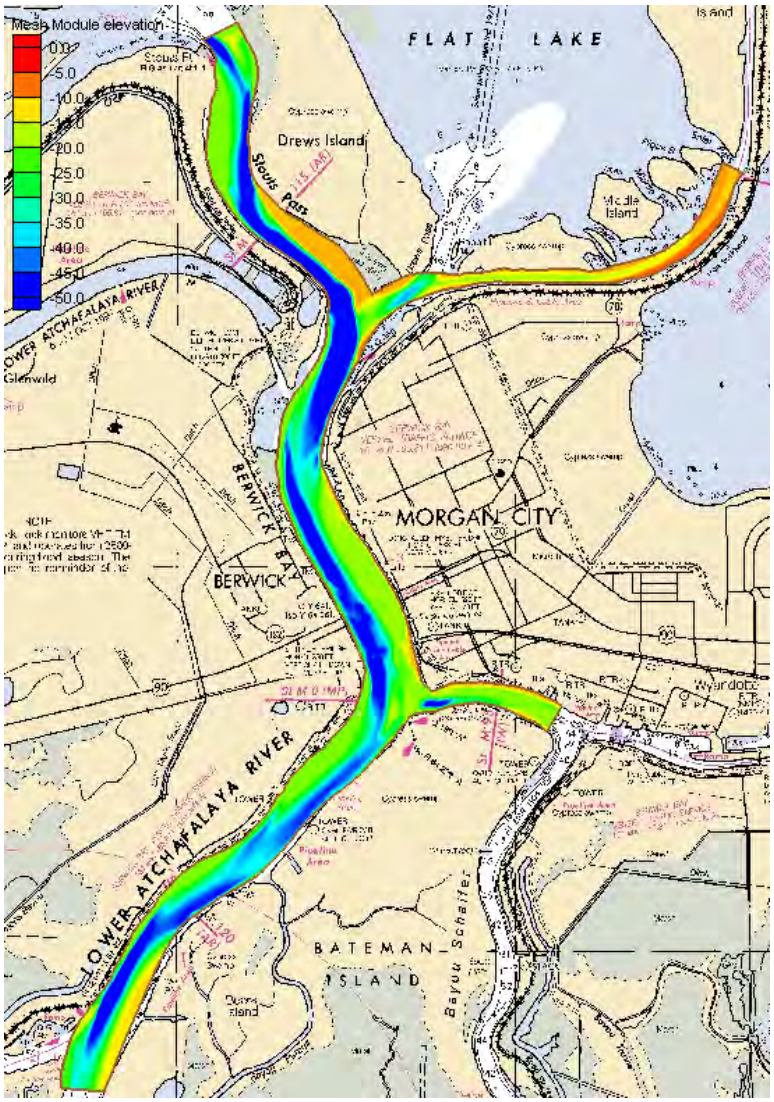

Figure 1 Study area with contours.

The purpose of this study was to develop several proposed solutions to the shoaling problem in consultation with CEMVN and to test those solutions through numerical model simulation and analysis. Using this testing and analysis method, ERDC winnowed the proposed solutions down to the one or two scenarios that provided the most reduction in the shoaling at Morgan City, LA.

Approach A Curvilinear Hydrodynamics in 3-dimensions, sediment (CH3D-SED) model was developed for this study. The model had 31,193 nodes and 30,283 elements of horizontal resolution and ten layers of resolution in the vertical. The model elements are sigma-stretched which means the model has the same number of layers over the entire model domain and those layers vary in thickness with depth.

Conceptual plan alternatives were developed in consultation between ERDC and CEMVN. The validation condition served as the base condition for the model. The plan alternative simulations were then performed and the results analyzed and compared to the base condition. Sediment and velocity analyses were performed on the base conditions and all plan alternatives.

MODEL DEVELOPMENT

Model Description CH3D-SED is a three-dimensional, finite-difference model suitable for simulating hydrodynamics and non-cohesive sediment transport in this study. The hydrodynamics in CH3D are based on work described in Sheng (1986), Johnson et al (1991), Chapman (1993), Chapman (1994), and Chapman et al. (1996). The governing sediment equations are based on a sediment modeling approach introduced by Spasojevic and Holly (1990). The original sediment modeling approach, developed for two dimensional shallow water situations, was extended by Spasojevic and Holly (1993) to fit the three-dimensional, non-orthogonal, curvilinear framework of the CH3D code. The sediment modeling approach includes bed-level changes (deposition and/or erosion), bedload transport, suspended-sediment transport, and interaction between the two. The approach allows for representing a sediment mixture in a natural watercourse through an unlimited number of size classes.

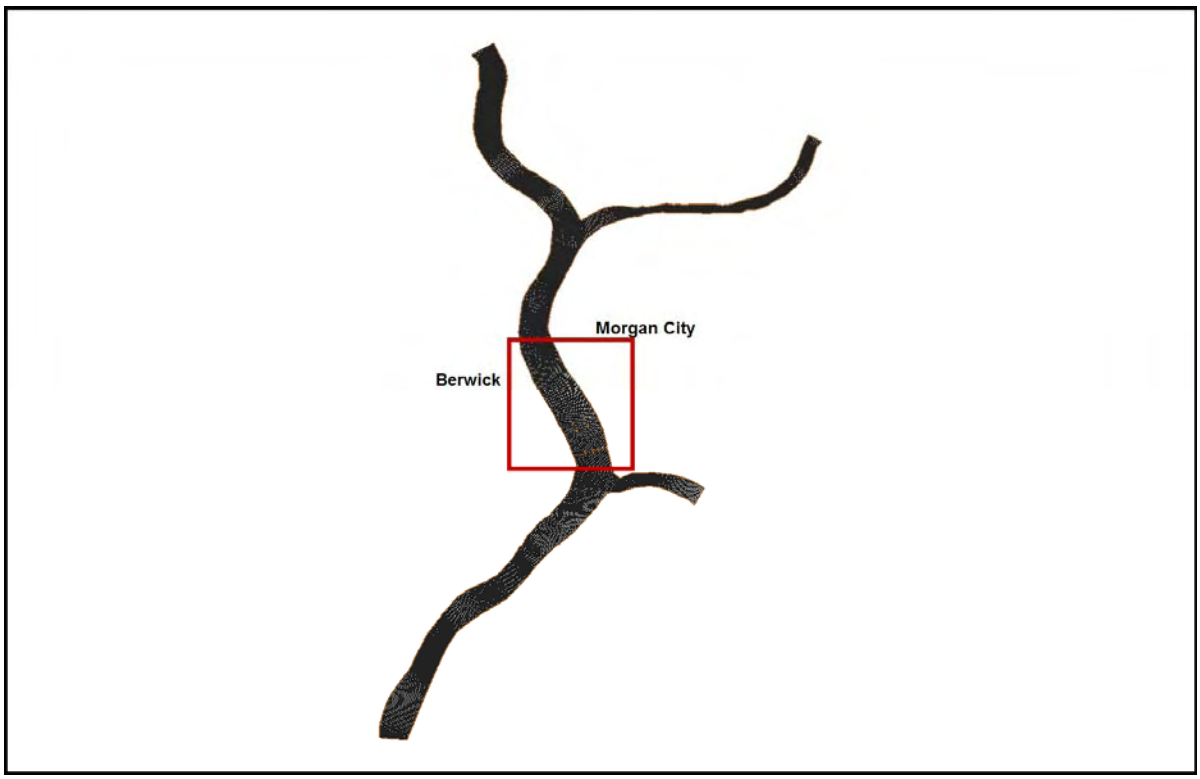

Figure 2 CH3D-SED model grid.

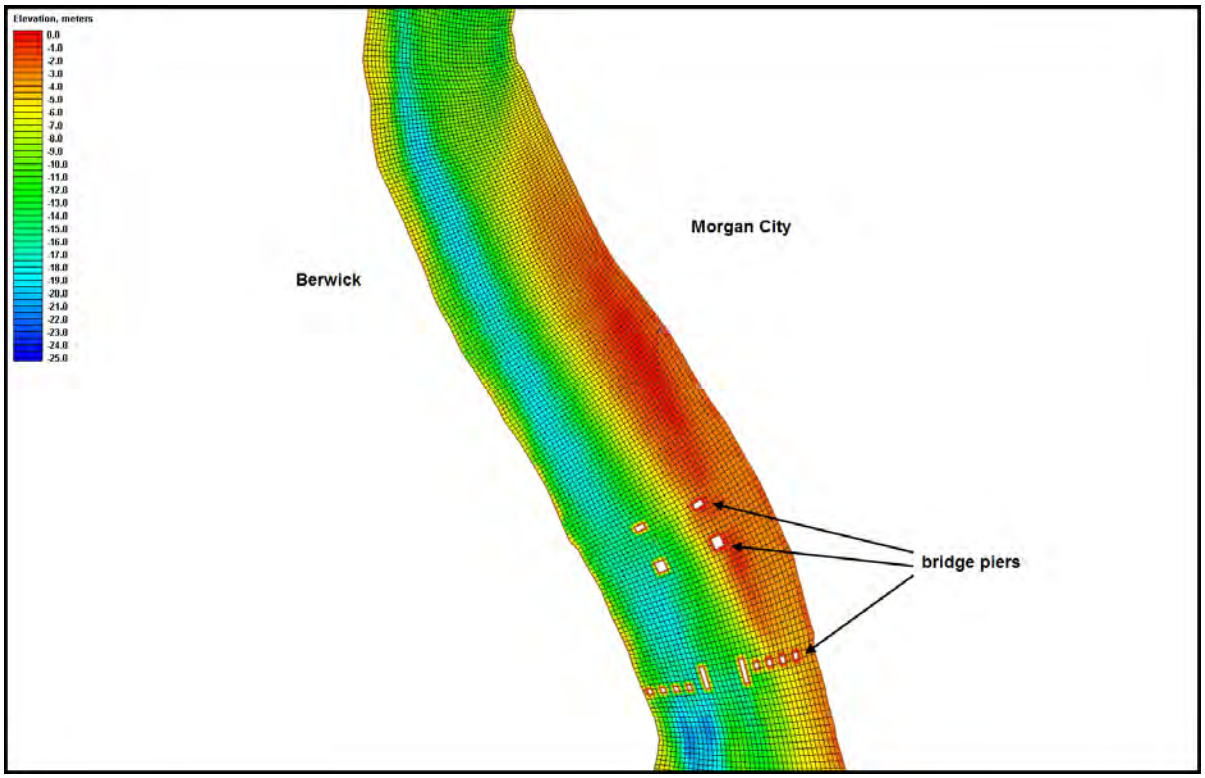

Figure 3 Model inset showing study area.

Model Development The mesh was developed using the Surface-water Modeling System (SMS), a graphical user interface developed by ERDC for increasing the modeling productivity for a variety of Corps numerical models, including CH3D-SED. The entire mesh is shown in Figure 2 and an inset of the model showing the study area is shown in Figure 3. The bathymetry for the grid was developed using multi-beam data provide by CEMVN.

Boundary Conditions One set of boundary conditions was developed for the base condition and all alternatives. These boundary conditions included river inflows and a downstream elevation.

The river inflows were taken from discharge measurements gathered by ERDC personnel on 6 March 2008 for the Atchafalaya River above its confluence with the GIWW above Morgan City, LA and for the GIWW. Discharges of 157,882 cfs and 37,119 cfs were used for the Atchafalaya and GIWW boundaries, respectively. The downstream boundary was set by adjusting the value until the water surface slope measured between the USACE gage at Berwick Lock East, gage #03765, and at Morgan City, gage #03780 on 6 March 2008 was attained. Gage #03780, is a joint USGS and USACE gage.

Model Validation The model was validated to gage #03765 at Berwick Lock East which measured 5.15 ft NGVD29 and gage #03780 at Morgan City which measured 4.72 ft NGVD29. The downstream boundary of the model was adjusted until these values were attained. Slight adjustments were then made to other parameters until the velocity at

gage #03780 of 3.32 ft/sec was achieved without affecting the water surface validation. The velocities in the model also agreed well with velocity data gathered by ERDC personnel. Drogue releases in the Atchafalaya River were also performed to validate flow patterns in the model (see Figure 4).

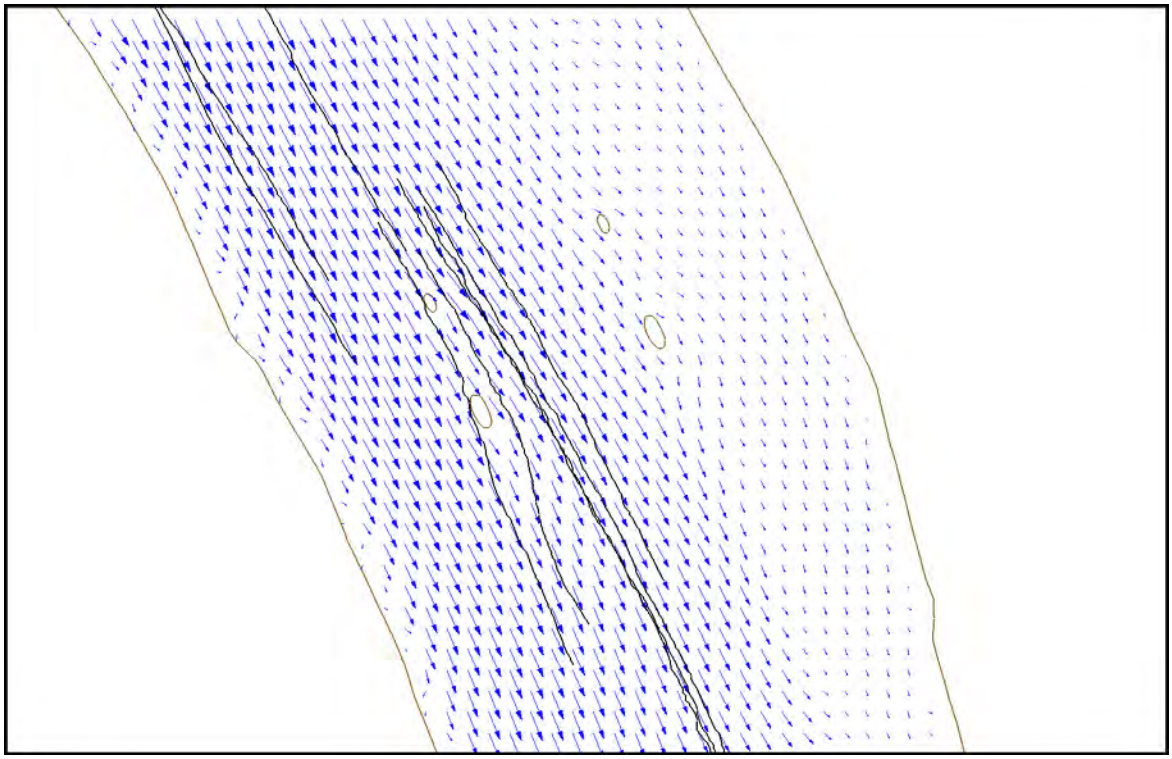

Figure 4 Model Velocity Vectors versus Drogue Tracks.

The currents from the model validation were provided to ERDC navigation personnel for incorporation into ERDC's ship simulator. The ship simulator is used as another level of validation of the numerical model as pilots accustomed to navigating the Atchafalaya were brought to ERDC to navigate the modeled currents and assess the realism of the simulated currents. According to Lynch (2008), the tow pilots' assessment was the model currents were comparable to actual currents experienced during navigation of the Morgan City reach of the river. Overall, the validation of the CH3D-SED model produced favorable agreement with hydrodynamic field measurements.

A sediment validation to dredging records was not performed due to a lack of sufficient dredging records. Due to the rigorous nature of the hydrodynamic validation and the availability of sediment characteristic data in the Atchafalaya River in the vicinity of the study area, ERDC modelers felt that the sediment model would produce results that could be used to sufficiently analyze the impacts of the proposed conceptual designs on shoaling the study area. Therefore, an existing condition sediment simulation was performed for comparison to design alternative sediment simulations.

CONCEPTUAL PLAN ALTERNATIVES

Five alternatives were developed for this study in consultation with CEMVN personnel:

1. Alternative 1 – place ten submerged weirs on in a predetermined configuration (see Figure 5).
2. Alternative 2 – place a protective dike along the Morgan City shoreline that connects to shoreline at the upstream end of the dike (see Figure 6). The top of the dike is to remain above the water surface.
3. Alternative 3 – place seven submerged weirs in a more closely spaced configuration than Alternative 1 (see Figure 7).
4. Alternative 4 – place nine submerged weirs in a more widely spaced configuration than Alternative 1 (see Figure 8).
5. Alternative 5 – place seven submerged weirs in a configuration where three weirs are above the GIWW/Atchafalaya River confluence and four weirs are below the confluence (see Figure 9).

In Alternatives 1, 3, 4, and 5, all weirs are placed on the Berwick side of the Atchafalaya River and the top elevation of all the weirs is to be -10.7 m (-35 ft) NGVD29.

Figure 5 Alternative 1 Configuration.

Figure 6 Alternative 2 Configuration.

Figure 7 Alternative 3 Configuration.

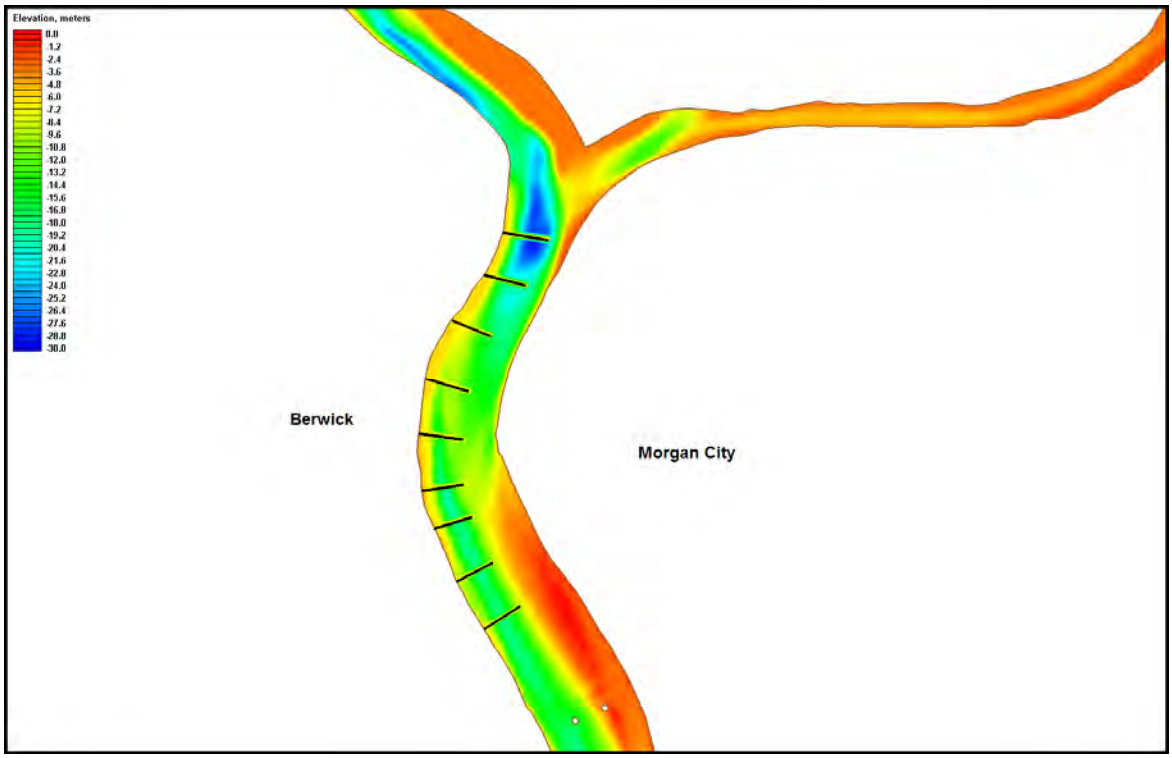

Figure 8 Alternative 4 Configuration.

Figure 9 Alternative 5 Configuration.

RESULTS

Hydrodynamics After the validation, the conceptual plan alternatives were implemented in the model. The analysis area is the portion of the river to the east of the submerged weirs. The analysis area was the area chosen by ERDC to evaluate the impacts of the alternatives on shoaling and is denoted by the box in Figure 10. The ranges of the legends for Figures 11 and 12 were set so as to better show velocity differences. Alternative 1 produced increases in velocity of nearly 0.1 m/sec over a larger portion of the analysis area (Figure 11). Alternative 2 (see Figure 6) was meant to protect the port area from shoaling by sheltering it from sediment-laden flow. A closer examination of the velocity results showed that there was actually a return current circulating back upstream between the dike and the shoreline. From a hydrodynamic standpoint, this situation would appear to be counter-productive to the shoaling problem as any sediment-laden flow entering the area behind the dike would immediately deposit in the semi-quiescent water. The sediment analysis of this alternative illustrated this very point. Alternative 3 produced the least increase in velocities in the analysis area with the increases over the base condition of approximately 0.05 m/sec. Alternative 4 produced the largest increase in velocity of all the proposed alternatives (Figure 12) with increases of approximately 0.15 m/sec. The increases were larger than alternative 1's. Alternative 5's velocity increases were of a similar magnitude as alternative 4, but the effect did not extend as far downstream as alternative 4. These velocity increases are important to sediment transport. As the velocity of the flow increases, the amount sediment that the flow is able to transport will increase. Therefore, if a proposed solution increases the flow velocity in the study area, the probability for deposition/shoaling will decrease.

Sediment Sediment results are reported here as a comparison between the existing conditions and the proposed channel modification scenarios. These comparisons were made for the analysis area in Figure 10. The western portion of the river reach was excluded from the analysis as the submerged weirs in 4 of the proposed scenarios were located in this area. Armoring the weir locations against erosion is very difficult in CH3D, so the tops of the weirs eroded in the weir scenario simulations. To prevent any bias due to this condition, the base to plan shoaling comparisons were only made for the eastern portion of the river reach.

The sediment model simulations had a duration of 40 days with the last 30 days of the simulation used for the analysis. This duration was chosen due to model stability issues beyond the 40 day window. Day 10 bed conditions were differenced with day 40 bed conditions to generate bed change volumes to be used in the base to plan comparisons to determine the effectiveness of each scenario to reduce shoaling in the study area. Experience in modeling of sediment transport in deep-draft channels has shown that the most appropriate use of the model results is as a shoaling index applied to the base condition dredging volumes. If the model shows a 50 percent reduction in shoaling volume, then the absolute volumes from the model are less accurate than taking 50 percent of the historical field dredging at the base condition.

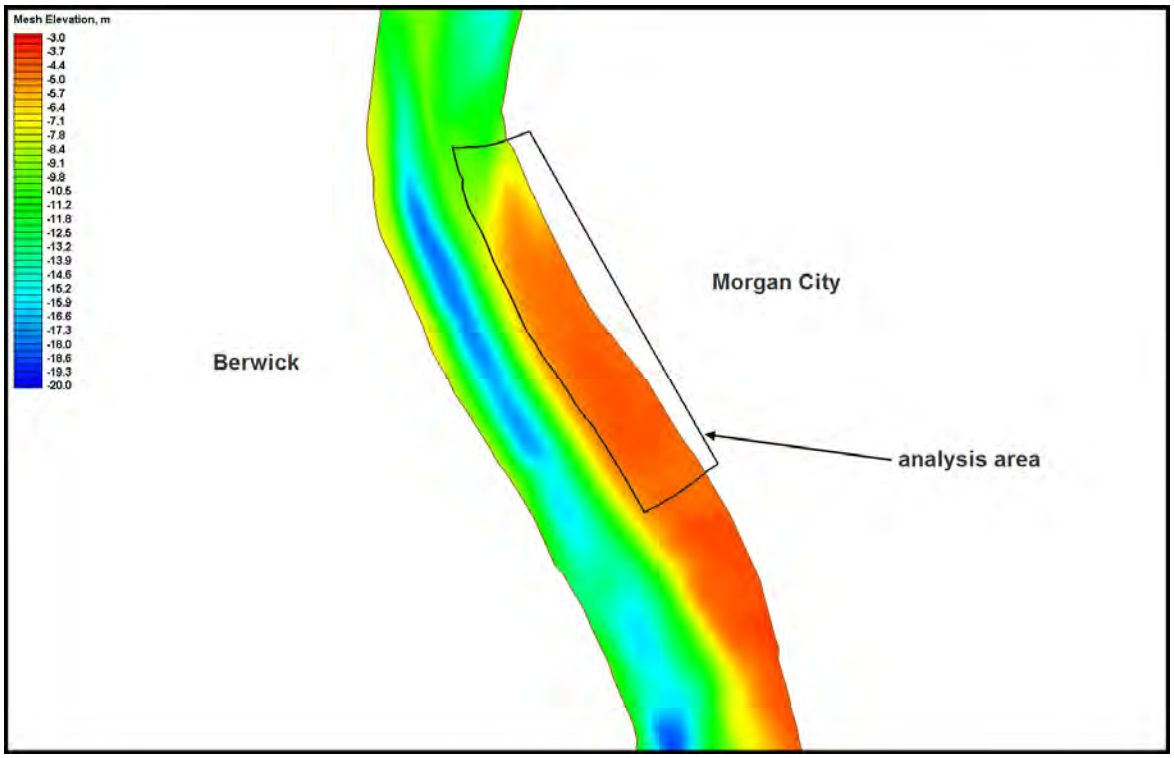

Figure 10 Location of analysis area.

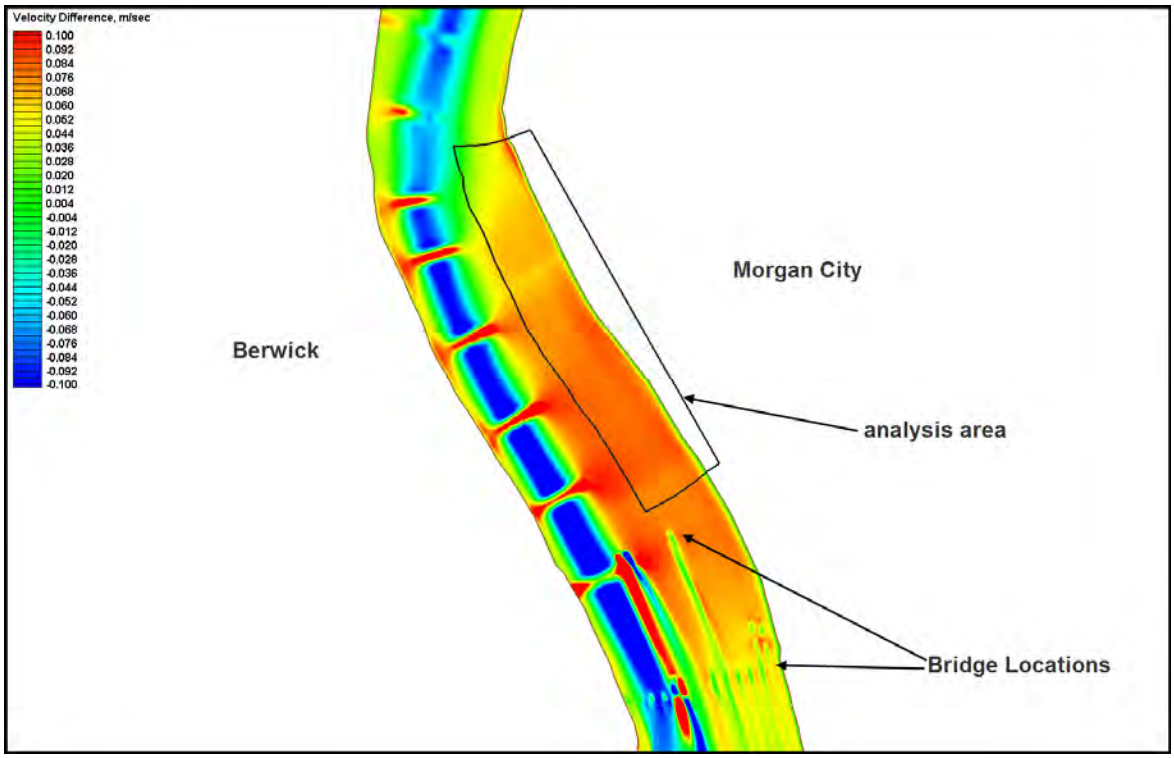

Figure 11 Velocity Differences, Alternative 1 minus Base.

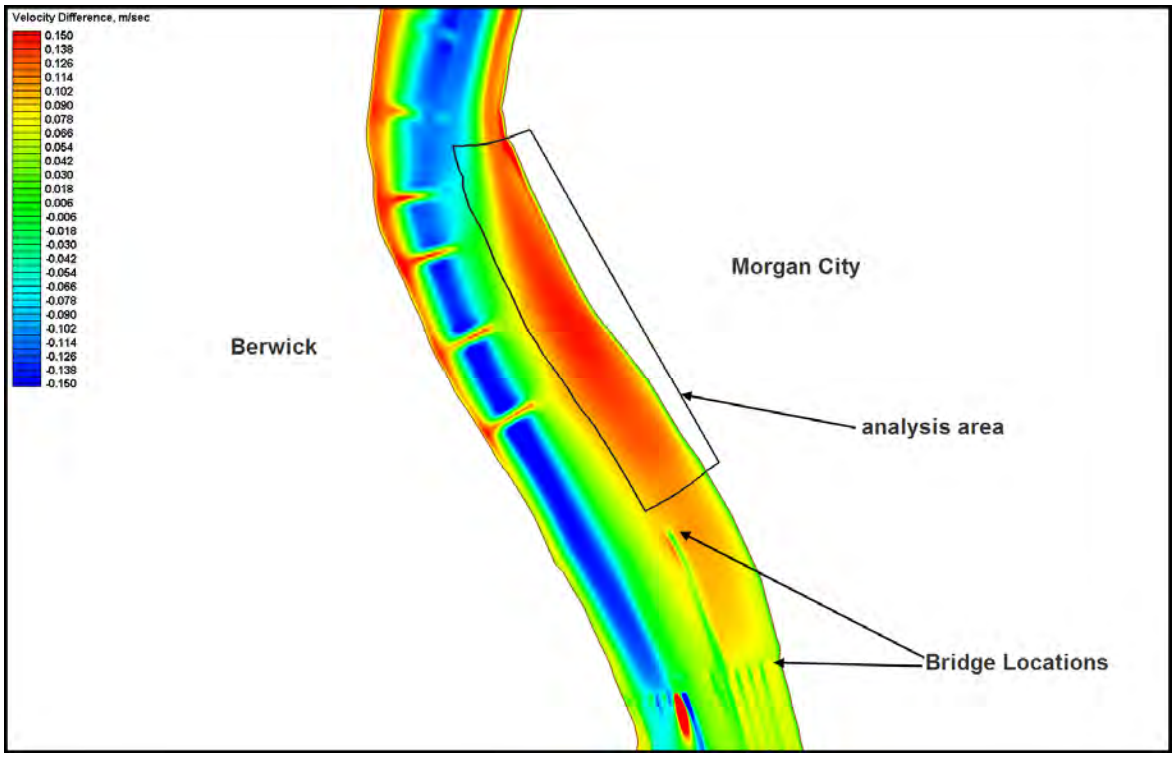

Figure 12 Velocity Differences, Alternative 4 minus Base.

The shoaling indices are presented in Table 4-1. Alternative 2 is not presented in Table 4-1 because the aim of the alternative was to use an emerged dike to shelter the port from sediment laden flow. The hydrodynamic model results showed a current that re-circulated behind the dike. While shoaling appears to drop significantly once the dike of alternative 2 is in place, further analysis showed heavy shoaling at the dike tip

Table 1 Shoaling indices for the Morgan City Reach of the Atchafalaya River.

Scenario	Shoaling Index
Base	N/A
Alternative 1	0.32
Alternative 3	0.83
Alternative 4	0.44
Alternative 5	0.84

A similar analysis of shoaling/scour around the bridge piers of both bridges yield a maximum increase in scour of approximately 3%. This increase in scour was small enough to be considered within the error tolerance of the results and therefore negligible.

CONCLUSIONS

Flow velocities are the primary factor controlling shoaling/erosion in this system. Alternative 5 had significant increases in velocity in the analysis area, but the configuration of alternative 4 maintained velocity increases further downstream than alternative 5, contributing to a better performance in shoaling reduction.

With the exception of alternative 2, the shoaling reductions of the various alternatives were produced by velocity increases in study area. These velocity increases were due to submerged weirs placed on the Berwick side of the river which forced more of the Atchafalaya's flow to the Morgan City side of the river.

Of the original five alternatives tested, alternatives 1 and 4 produced the most favorable results with shoaling reductions of 68% and 56%, respectively.

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