APPENDIX H

Hydrology and Hydraulic Reports

Mississippi River Ship Channel
Gulf to Baton Rouge, LA
Integrated General Reevaluation Report
And Supplemental Environmental Impact Statement

Appendix H

Annex 1

Mississippi River Ship Channel Deepening Study, One-Dimensional, Numerical Sedimentation Model Investigation

April 2018

Mississippi River Ship Channel Deepening Study, One-Dimensional, Numerical Sedimentation Model Investigation

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PURPOSE: This Coastal & Hydraulics Laboratory Letter Report describes a sedimentation analysis of proposed options for deepening the Mississippi River Ship Channel. A one-dimensional (1D) numerical model was applied to estimate the potential impacts of deepening on long-term maintenance dredging requirements in the navigation channel.

INTRODUCTION: The 255 mile long Mississippi River Ship Channel extends from Baton Rouge, Louisiana, to the Gulf of Mexico. The Ship Channel provides deep-draft access to the largest port complex in the United States of America. Annually, the port complex serves an average of 11,000 deep-draft vessels and handles 450 million tons of cargo. The authorized navigation depth of the Ship Channel is 55 feet (ft). The navigation depth is currently maintained to 45 ft. The US Army Engineer District, New Orleans is evaluating the feasibility of increasing the maintained depth to 48 or 50 ft.

Since typical channel depths in much of this reach of the Mississippi River exceed the maintained channel depth, maintenance dredging is required only in relatively short and distinct locations. The Southwest Pass dredging reach, Figure 1, is the longest single dredging reach and has been maintained, since 1987, to a depth of 45 ft relative to Mean Low Gulf Southwest Pass (MLG^{SWP}), equivalent to a depth of 48.5 ft below Mean Lower Low Water (MLLW). This reach extends from Venice, Louisiana, at River Mile (RM) 10 Above Head of Passes (AHP), down the Mississippi River to Head of Passes (HOP) at RM 0.0, then through Southwest Pass and the Southwest Pass Bar Channel to the Gulf of Mexico at RM 22 Below Head of Passes (BHP). The majority of the sediment entering this reach is diverted by distributaries with less than half of the remainder being deposited and subsequently removed by dredging as presented in Figure 2. Annual dredging quantities in this reach averaged 19.4 million cubic yards (yd^3) from 1970 to 2008 (Sharp, et. al. 2013).

The remainder of the locations requiring periodic maintenance dredging are river crossings, shown in Figure 3, in the upper 120 miles of the Ship Channel. Four downstream crossings have been maintained to a depth of 45 ft relative to the Low Water Reference Plane (LWRP) since December of 1987. The upstream Ship Channel crossings from Baton Rouge at RM 232.4 AHP to RM 181 AHP have been maintained to a depth of 45 ft relative to the LWRP since December of 1994. Total annual dredging quantities for the crossings averaged 18 million yd^3 from 1995 to 2016. Over the decade ending in 2016, annual dredging in the crossings averaged 22 million yd^3.[1]

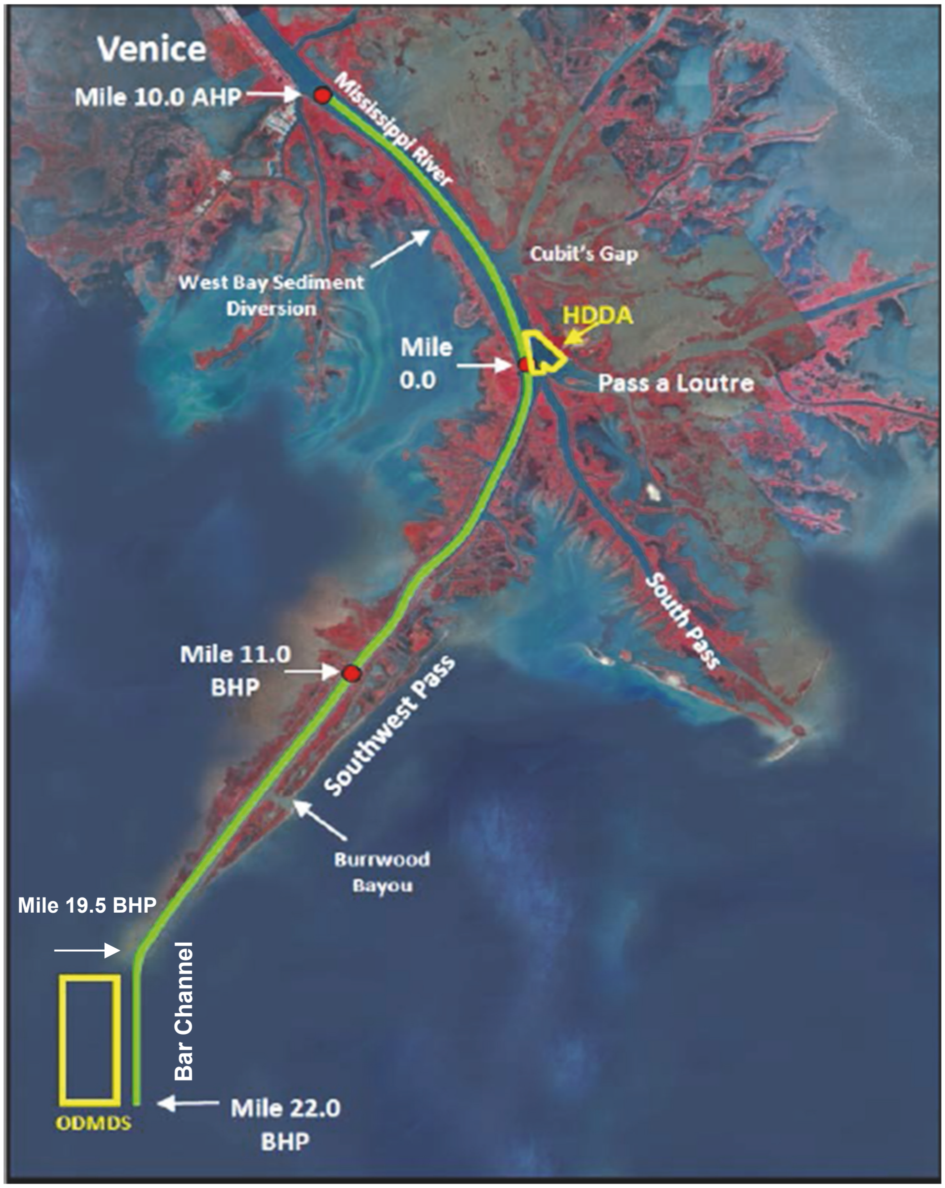

Figure 1. The Southwest Pass dredging reach extends from Venice (RM 10 AHP) through Southwest Pass and the Bar Channel (RM 22 BHP). The upper five miles of this reach seldom requires dredging. Typically, dredged material from the lower half of the Pass (below RM 11 BHP) is placed in the offshore disposal site (ODMDS) and material from upstream locations is placed at the head of Pass a Loutre (HDDA). Material may also be placed adjacent to the channel for beneficial use.

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[1] Personal communications, Michelle Kornick, 31 May 2017; Edward Creef, 9 May 2017; and Danny Wiegand, 8 June 2016.

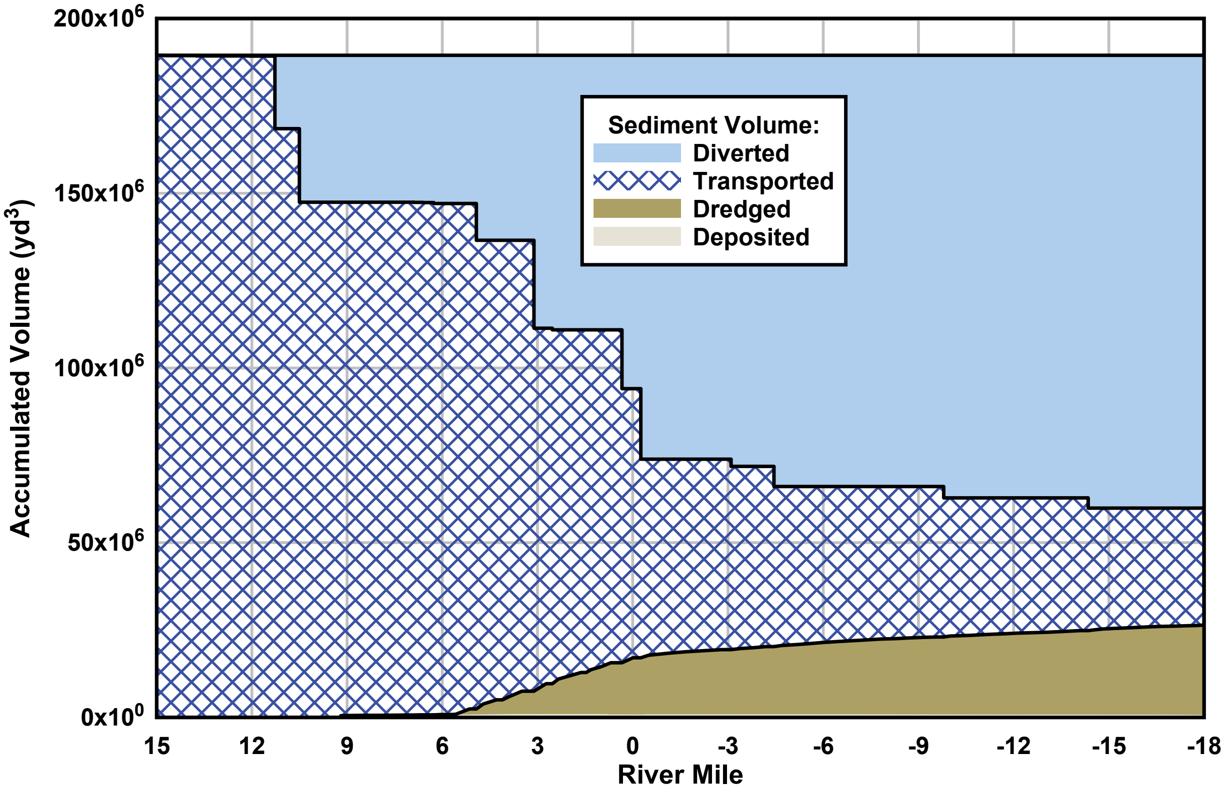

Figure 2. Average annual transport and fate of sediment entering the Southwest Pass dredging reach estimated from multi-decade 1D sedimentation model simulations. Annual variations in the estimated values are significant because the annual sediment inflow in wet years can be can be a factor of five larger than in dry years. The computed volume of deposition not removed by dredging, slightly less than one million cubic yards annually, is not visible at the scale of this graph.

Annual dredging requirements can vary greatly. In Southwest Pass, dredging requirements are strongly influenced by sediment supply. Thus, dredging requirements tend to be higher in years with significant floods or prolonged periods of higher than normal flow. Conversely, dredging requirements tend to be lower during years dominated by low to moderate flows. While sediment supply is a significant factor in dredging requirements at the crossings, other factors such as hydrograph shape and minimum annual river stages also influence requirements. For example, dredging of a crossing is more likely to be required after a rapid fall in stage than after a slow fall of similar magnitude. Additionally, field observations suggest that long-term changes in bed material characteristics may be influencing dredging requirements in the crossings.[1]

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[1] Personal communication with Mayo Broussard on 15 June 2016.

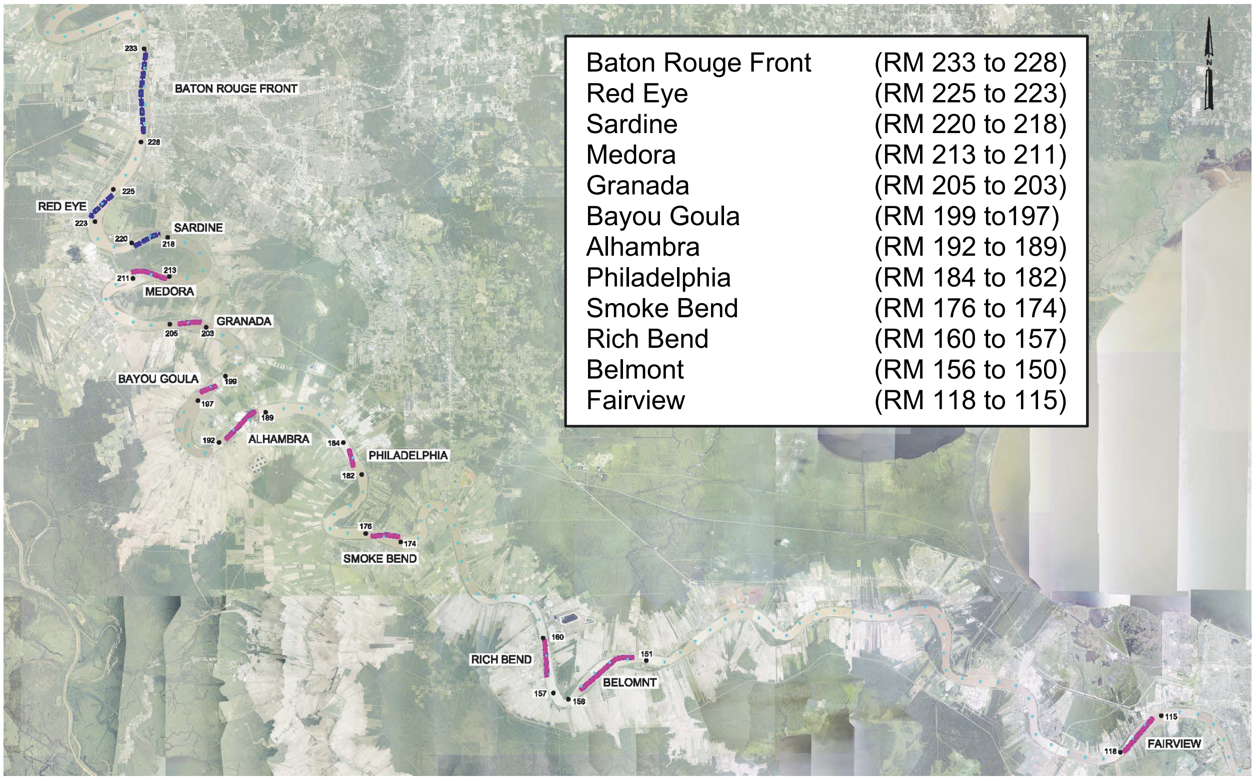

Figure 3. Ship channel crossings requiring periodic maintenance dredging.

MODEL DESCRIPTION: The 1D sedimentation model adopted for this study was developed for the Mississippi River Hydrodynamic and Delta Management Study[1] (MRHDMS) using the HEC-6T computer program (Thomas, 2002). HEC-6T is a proprietary computer program for 1D quasi-unsteady flow and sedimentation numerical modeling that supports medium- to long-term (years to decades) analysis of bed scour and deposition in rivers and reservoirs and provides several options for simulation of dredging operations. HEC-6T was derived from the USACE HEC-6 computer program (USACE, 1993). HEC-6T contains numerous additional features and physical process parameterizations, including some developed specifically for the MRHDMS and predecessor studies, not available in HEC-6.

The MRHDMS model was adapted from earlier models including the Mississippi Valley Division (MVD) Regional Model[2], the West Bay Sediment Diversion 1D Model (Sharp, et

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[1] Thomas, William A., Trawle, Michael J., and Heath, Ronald E. (in preparation). Executive Summary, HEC-6T One-dimensional Model Study, Mississippi River Hydrodynamic and Delta Management Study, US Army Corps of Engineers.
[2] Copeland, Ronald R. and Lombard, Leslie. (2009 Draft). Numerical Sedimentation Investigation, Mississippi River, Vicksburg to Pilots Station, US Army Corps of Engineers, New Orleans, LA.

al, 2013), and the Myrtle Grove Diversion Model[1]. The current model extends from Tarbert Landing at RM 306 AHP downstream through Southwest Pass to the Jetties at RM 18 BHP. All of the models in this series are based on cross-section data extracted from the 1991-92 Mississippi River Comprehensive Hydrographic Survey and have been extensively validated as described in the above references. Observations considered during model validation included (1) reported stages at long-term gages throughout the model domain, (2) bed material gradations, (3) suspended sediment concentrations at Belle Chase (4) volumes of deposition and erosion between surveys, including data from the 2004 Mississippi River Comprehensive Survey, and (5) volumes of channel maintenance dredging

Of particular importance to this study, fine sediment erosion and deposition parameters in the MVD Regional Model were adjusted to reproduce cumulative dredging trends in the Southwest Pass reach from 1991 to 2002. The Myrtle Grove Diversion Model added dredging of the deep draft crossings. The model developed for the Mississippi River Hydrodynamic and Delta Management Study incorporated changes in the HEC-6T program that permitted evaluation of the effects of subsidence and eustatic sea level rise. Additionally, all elevation data was adjusted to the North American Vertical Datum of 1988. Consistent with previous 1D model studies, this study assumes that front protection and natural levees along the Southwest Pass Dredging Reach will be maintained, and that existing diversions of flow and sediment will be maintained at current levels.

During this study, it was determined that the Myrtle Grove Diversion Model had been circumstantiated to an incomplete record of dredging volumes from Calendar Year (CY) 1992 to 2002 in the deep draft crossings.[2] The average annual volume of deep draft crossing dredging computed by the Myrtle Grove Diversion Model was approximately 8 million yd^3, and the distribution of dredging at individual dredging sites was considered reasonable given the information available at that time. In contrast, dredging records made available during this study (presented in Figure 4) indicate that the average annual volume of deep draft crossing dredging from Fiscal Year (FY) 1992 to 2002 was 15.4 million yd^3.[3] That time period includes dredging operations conducted for extension of the 45 ft channel to the Port of Baton Rouge. Excluding FY 1994, the peak year of construction, from the data reduces the average annual volume to 14.0 million

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[1] Thomas, William A. 2012. HEC-6T Sediment Study, Allocation of Water and Sediment Resources, Myrtle Grove Diversion for Land Building, Mobile Boundary Hydraulics, Clinton, MS.

[2] Personal communication, William Thomas, 11 May 2017.

[3] The HEC-6T model reports dredging volumes by dredging site on a calendar year basis. Historical dredging was reported on a fiscal year basis. While this makes annual comparisons difficult, decadal averages were assumed to be reasonably comparable.

yd^3. Through FY 2015, the average annual volume of dredging in the crossings increased by about 60% after the channel was deepened from 40 to 45 ft.

Attempts were made, within the time and cost constraints of this study, to adjust dredging parameters to reproduce historical dredging volumes and patterns in the deep draft crossings. Parameters adjusted included the lateral distribution of deposition at each dredging site, discharge thresholds for initiation of dredging, and dredge production rates at each site. Computed average annual dredging from CY 1992 to 2002 with the final set of parameters was 16.5 million yd^3. From CY 1995 to 2015, computed average annual dredging was 17.3 million yd^3 as compared to a reported 16.7 million yd^3 for FY 1995 to 2105. Unfortunately, the adjusted model compares poorly to individual dredging sites with almost all of the computed dredging concentrated in 5 crossings: Redeye, Medora, Bayou Goula, Alhambra, and Belmont. These 5 sites account for slightly over 2/3 of reported dredging after construction of the 45 ft channel. The model significantly underestimates expected dredging at Baton Rouge Front, Sardine Point, and Granada. Additionally, some sites, including Redeye Crossing, demonstrated long-term declines in computed dredging requirements inconsistent with reported dredging.

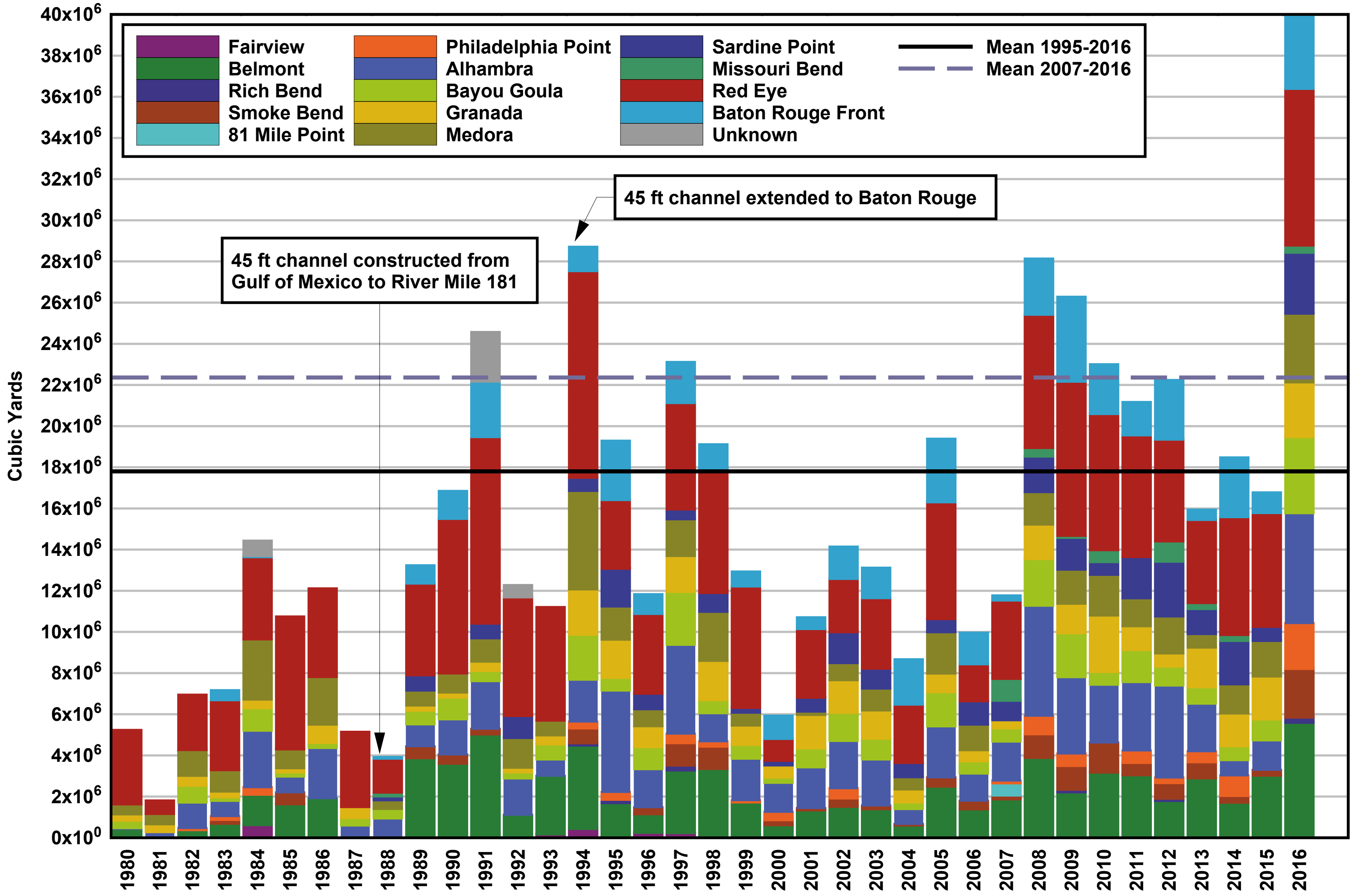

Figure 4. Reported dredging by Fiscal Year in each crossing. Reported dredging in 1994 includes construction of the 45 ft deep draft channel. Data for 2016 was not available during development and operation of the model.

METHODOLOGY: Long-term sedimentation processes were simulated for the 45, 48, and 50 ft draft channels and compared to estimate the relative change in required maintenance dredging at each dredging site over the project life. The comparisons were based on the final 50 years of each model simulation. Daily inflows at the upstream boundary of the model were derived from the historical record from 1954 through 2003 adjusted for current operations at the Old River Control Complex (ORCC). Sediment inflows at the upstream boundary were computed for each grain size class from a rating curve derived from analysis of suspended sediment measurements at Tarbert Landing from 1974 to 2008 excluding data from 1987 to 1989[1]. Gulf water levels at the downstream boundary of the model were adjusted monthly to account for seasonal changes in the level of the Gulf of Mexico. Simulations for each channel depth were conducted for no eustatic sea level rise and for the rates proposed by the National Research Council (NRC) 1 and NRC 3 curves (0.5 and 1.5 meter increases in sea level in year 2100, respectively) as presented in Figure 5. Simulation of the no eustatic sea level rise condition represents a worst case for deposition in that channel deepening produces the largest relative change in navigation channel depth. (The difference between the zero rate and linear rate is less than 6 inches in year 2100.) Additionally, modeling a no eustatic sea level rise condition permits identification of sedimentation changes introduced solely by sea level rise in the NRC 1 and 3 simulations. The model includes an estimate of spatially varying subsidence rates which are automatically applied to model geometry during the simulation.

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[1] Ibid, Thomas, 2012.

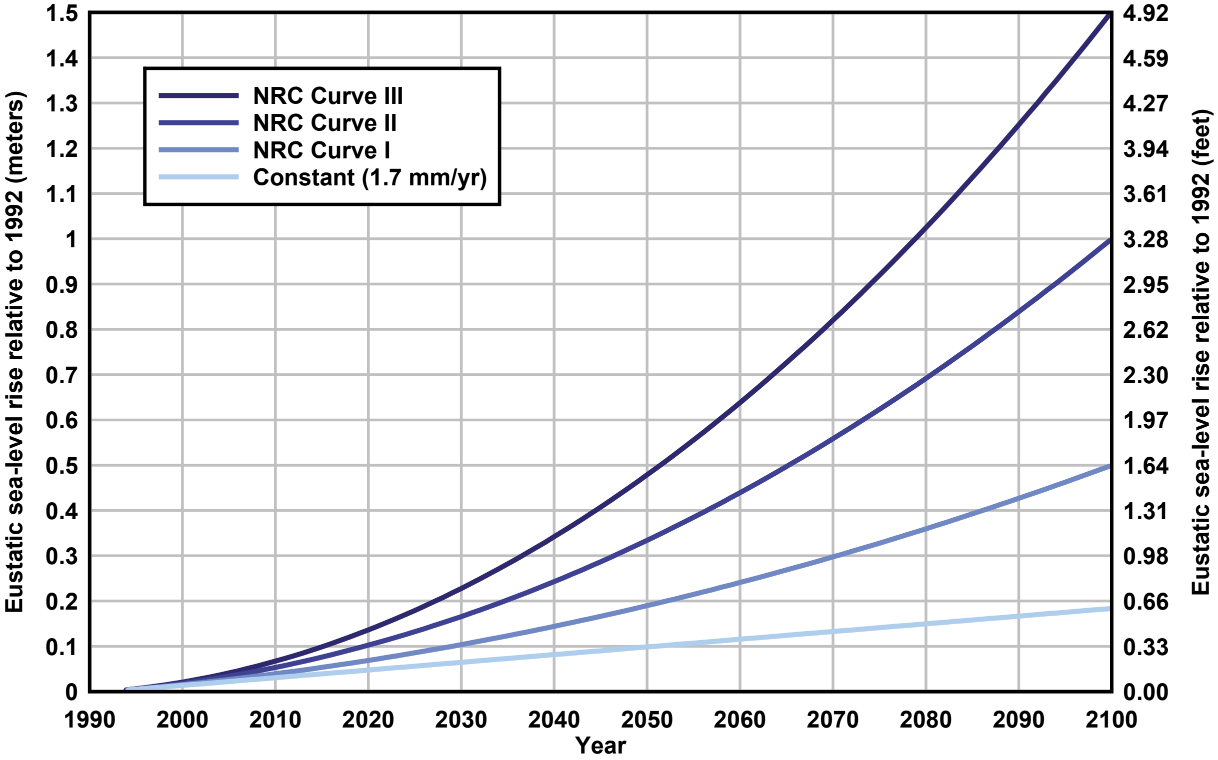

Figure 5. Eustatic sea level rise estimates.

For this study, all of the historical dredging templates used in the model were adjusted as needed to incorporate design channel widths, side slopes, and invert elevations.[1] At the time of model construction, template invert elevations in the Southwest Pass dredging reach were referenced to MLG^{SWP}. Subsequent model studies, including the multi-dimensional model studies, used templates referenced to MLLW. Template invert elevations in the crossing reaches were referenced to the LWRP. In the 1D model, all template invert elevations were converted to NAVD88 as described in Table 1 and Table 2. The dredging templates used in the model and computed dredging volumes include advanced maintenance and over-dredging allowances. Advanced maintenance dredging creates space for storage of subsequent deposition below the authorized channel depth, reducing the frequency of dredging operations. The over-dredging allowance accounts for additional volumes of material dredged to achieve the required depth of dredging. Dredging template elevations were not adjusted for eustatic sea level rise during the model simulations. Thus, computed dredging quantities near the end of

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[1] Personal communications, Richard Broussard, 12 April 2016, Danny Wiegand, 26 April 2016, and Joshua Hardy, 27 April 2017.

the 50-year simulation are probably over-estimated for the NRC 3 scenario and, to a much lesser extent, for the NRC 1 scenario.

Table 1. Dredging Template Summary for Southwest Pass

Dredging Reach	Southwest Pass		
River Mile	11.0	2.0	17.8 BHP
* MLG^{SWP} to NAVD 1988 (ft)	-3.2	-3.2	-4.2
	Channel invert (ft) NAVD 1988		
45 ft channel	-48.2	-48.2	-49.2
48 ft draft	-51.2	-51.2	-52.2
50 ft draft	-53.2	-53.2	-54.2
Advanced Maintenance	6 ft		
Over-dredging allowance	2ft		
	Dredge cut invert (ft) NAVD 1988		
45 ft draft	-56.2	-56.2	-57.2
48 ft draft	-59.2	-59.2	-60.2
50 ft draft	-61.2	-61.2	-62.2
Bottom width	750 ft		
Side slopes	1 on 5		
* MLG^{SWP} may be estimated by linear interpolation between RM 17.8 BHP and RM 2.			

The 45 ft channel dredging template used in the reach above HOP is typically wider and significantly deeper than the templates used in previous HEC-6T models. In contrast, in the reach downstream of HOP, about 1/3 of the older templates are significantly wider and initial invert elevations vary over a 9 ft range with only some sections being slightly deeper than the new 45 ft channel dredging template. The computed average annual volume of dredging in the Southwest Pass dredging reach for the 45 ft channel is about 14% greater than the volume computed by the MRHDMS model with nearly all of that increase occurring upstream of Pilottown (RM 2).

Table 2. Dredging Template Summary for Crossings

Dredging Reach	Crossings				
River Mile	231	204	183	153	117
*Low Water Reference Plane (ft) NAVD 1988	2.5	1.9	1.6	1.2	0.8
	Channel invert (ft) NAVD 1988				
45 ft channel	-42.5	-43.1	-43.4	-43.8	-44.2
48 ft draft	-45.5	-46.1	-46.4	-46.8	-47.2
50 ft draft	-47.5	-48.1	-48.4	-48.8	-49.2
Advanced Maintenance	3 ft				
Over-dredging	2ft				
	Dredge cut invert (ft) NAVD 1988				
45 ft draft	-47.5	-48.1	-48.4	-48.8	-49.2
48 ft draft	-50.5	-51.1	-51.4	-51.8	-52.2
50 ft draft	-52.5	-53.1	-53.4	-53.8	-54.2
Bottom width	500 ft				
Side slopes	1 on 5				
*Consult 2007 definition of the LWRP to determine elevations at a specific crossing.					

Dredging operations are conducted in the model when deposition in the navigation channel exceeds a specified trigger elevation. Traditionally, the trigger elevation has been based on the amount of over-dredging allowed in the dredging template. This approach, referred to as the "*more aggressive dredging schedule*" yields a conservative estimate of potential deposition in the navigation channel but may force dredging in some locations where shoaling does not impede navigation. Additionally, by maintaining greater channel depths, this option may induce some deposition that would not occur in the prototype. A "*less aggressive dredging schedule*," where the trigger elevation was set 1 ft below the authorized depth, also was evaluated in this study. For both schedules, dredging operations in the crossings were only conducted when the Mississippi River discharge was less than 600,000 cubic feet per second (cfs), and sediment dredged from each crossing was reintroduced into the river at the first cross-section downstream of the dredging location. Sediment dredged from the Southwest Pass dredging reach was removed from the model.

Dredging Impacts: Computed average annual dredging quantities over the 50-year project life and computation of dredging indices for 45, 48, and 50 ft draft channels and three and three rates of eustatic sea level rise are presented in Appendix A. The "*Dredging Index*" is the ratio of the computed dredging quantities for a test scenario at a specific set of locations to the corresponding quantities for a base condition identified in the table header. It describes the relative impacts of channel deepening on historical and projected future dredging and should be considered more reliable than absolute quantities computed by the model.

The volume of computed dredging in the Southwest Pass dredging reach (RM 18 BHP to 11 AHP) was relatively insensitive to channel deepening and relative sea level rise. Both dredging schedules produced similar results with the more aggressive dredging schedule producing slightly greater quantities but slightly smaller dredging indices. Under existing conditions, nearly all of the available sand and most of the silt transported into the reach is either diverted by distributaries or deposited in the channel. Thus, the primary effect of channel deepening in this reach is to reduce average channel velocities and shift deposition slightly upstream. Rising sea levels would also be expected to shift deposition upstream. Computed dredging volumes in this reach are probably more sensitive to estimates of water and sediment diversion from this reach than to the channel depth (See Figure 2).

It should be noted that the 1D model does not address potential increases in the extent or frequency of salinity intrusion due to channel deepening or relative sea level rise. The salt water wedge is present throughout the year in Southwest Pass and will, during low flow conditions, intrude upstream of Head of Passes. Fine sediments tend to flocculate when fresh water encounters saline water, enhancing sediment deposition. Increased frequency and extent of salinity intrusion could increase the contact area between fresh and saline water. However, such increases are most likely during low flow periods when fine sediment concentrations are relatively low.

Computed dredging quantities in the crossings are much less reliable than computed quantities in the Southwest Pass reach. At individual sites where the model is under-predicting dredging requirements for the 45 ft channel, large values of the dredging index should not be considered predictive of expected behavior. For the individual sites where computed quantities for the 45 ft channel were within the range of historical observations, the model indicated significant increases, 50% to 200%, in the dredging index when the channel was deepened to 48 or 50 ft.

Since the model estimates of dredging at individual crossings were not reliable, the best available option to account for the potential increase in the sediment trap efficiency of a deeper channel is to apply the estimated dredging index to recent historical dredging requirements.

Modeling results suggest that the observed increase in dredging in the crossings over the last decade may not be entirely due to increased river flows. Little and Biedenharn (2014) suggest that this reach of the river switched from a degradational or equilibrium state to an aggradational state in the 1990's. Additional studies are needed to determine what factors are responsible for this shift and if the shift is likely to persist into the future.

Stage Impacts: Daily stage profiles in the Lower Mississippi River were computed with HEC-6T, over a 50-year period for authorized channel depths of 45, 48, and 50 feet. To estimate the impacts of varying channel depth, computed stage profiles through Southwest Pass and in a 25 mile reach above Head of Passes are presented in Figure 6 to Figure 9 for selected river discharges at the beginning and end of the 50-year simulation. The simulation included bed profile adjustments due to sedimentation processes and maintenance dredging required to maintain the navigation channel. The model geometry was developed from the 1992 comprehensive bathymetric survey and was calibrated to observed water surface profiles and channel morphology during the 1992-2004 time period.

Computed stage profiles at the beginning and end of the 50-year simulation are presented for three index flows. The model extends over 300 miles upstream to Tarbert Landing, and the flows are described in terms of the river discharge at the upstream boundary of the model. Computed flows throughout the model are adjusted to account for diversions of water and sediment. In descending order, the index flows represent a major flood event, a near bank-full flow, and a typical low flow.

The computed stage profiles presented in Figure 6, Figure 7, and Figure 9 include approximately 0.75 ft of eustatic sea level rise during the 50-year simulation period. (This estimate of eustatic sea level rise was based on the NRC 1 curve; the corresponding estimate for the NRC 3 curve would be approximately 2.2 ft.) This increase in the mean level of the Gulf of Mexico accounts for almost all of the increase in stage from the beginning to the end of the simulation. In the prototype, the increase in stage due to sea level rise may be moderated by increased flow diversions at existing distributaries. The existing 1D model does not include estimates of these potential changes in diversion rates.

The computed stage profiles for a maintained navigation channel depth of 45 ft are presented in Figure 6. The slope of the stage profile increases with increasing river discharge. The overall bed slope through this reach is adverse; however, the bed slope in the sub-reach downstream of RM 5, which is routinely dredged, is relatively flat compared to sub-reach upstream. The acceleration of flow into a shallowing river, partially offset by distributary induced reductions in flow, accounts for the steeper water surface slope upstream of RM 5.

As presented in Appendix A, computed dredging in the sub-reach upstream of RM 5 is relatively small; and therefore, individual cross-sections in this sub-reach are dredged less frequently than in the downstream sub-reach. Computed fluctuations in the stage profile between RM 5 and RM 11 are attributable primarily to transitions between cross-section that have not experienced sufficient deposition to trigger dredging and dredged cross-sections.

Because the model forces the velocity head to a near zero value at the downstream boundary, there is a small reduction in computed stage, roughly proportional to the velocity head, immediately upstream of the downstream model boundary.

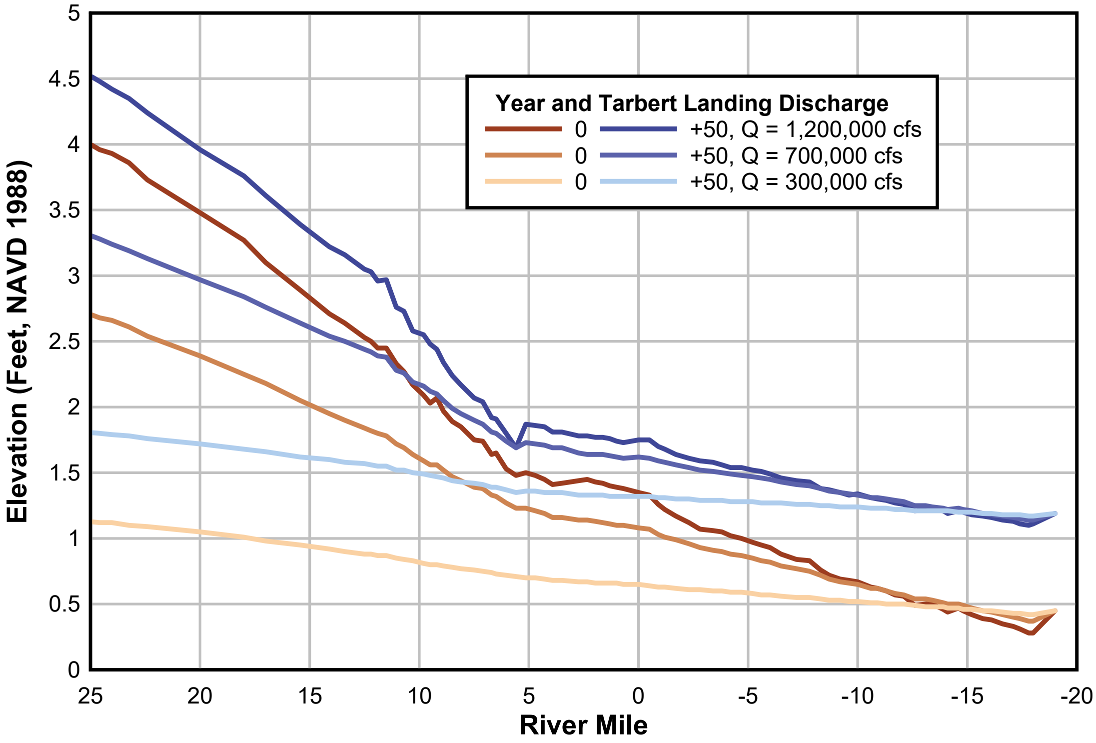

Figure 6. Computed stage profiles are shown for selected flows at the beginning and end of the project for an authorized depth of 45 feet MLG. The primary driver for stage increases over the life of the project is eustatic sea level rise (NRC 1 curve).

Computed stage profiles at the beginning and end of the 50- year simulation for an authorized depth of 50 ft are presented in Figure 7 for the same flows. Again, almost all of the increase in stage during the simulation may be attributed to eustatic sea level rise.

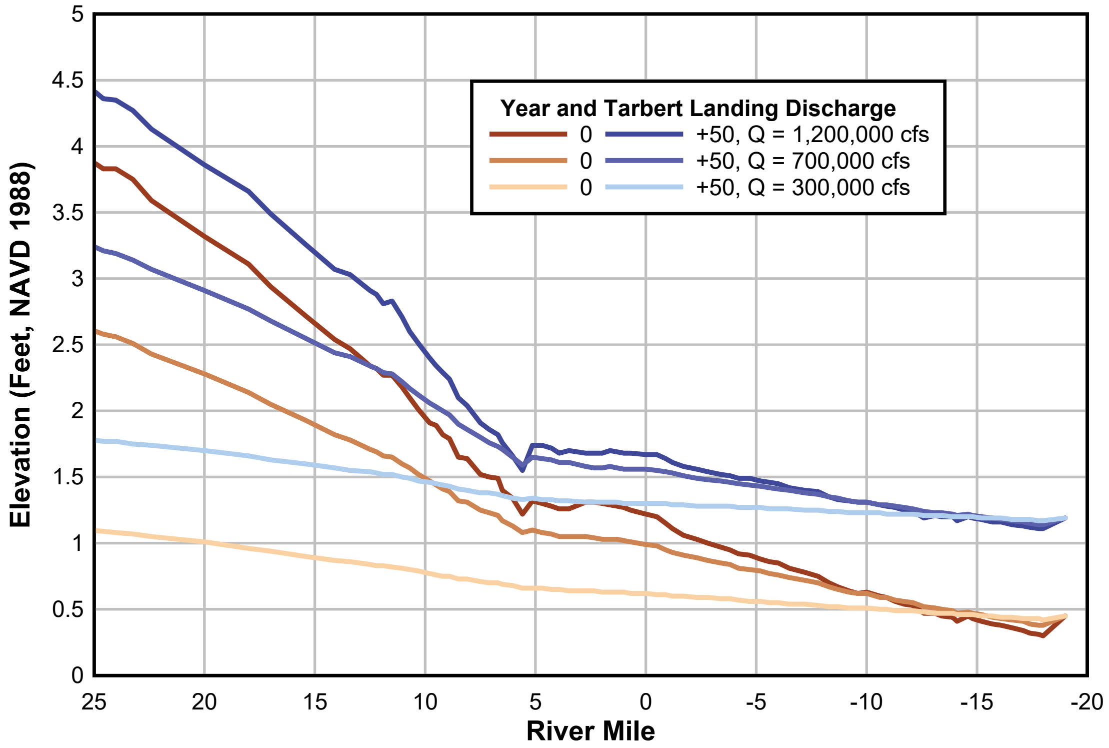

Figure 7. Computed stage profiles are shown for selected flows at the beginning and end of the project for an authorized depth of 50 feet MLG. The primary driver for stage increases over the life of the project is eustatic sea level rise (NRC 1 curve).

The initial (Year 0) stage profiles for the 45 and 50 ft channels are compared in Figure 8. As compared to the 45 ft channel, increasing the authorized depth to 50 ft results in a small decrease in stage throughout this reach. For low flows, the decrease in stage is insignificant. For flood flows, the decrease is typically less than 0.2 ft with the largest decreases occurring between the West Bay Sediment Diversion at River Mile (RM) 4.7 and Venice (RM 10.5). Stage profiles for an authorized channel depth of 48 ft would be expected to plot between the 45 and 50 ft profiles shown in Figure 8.

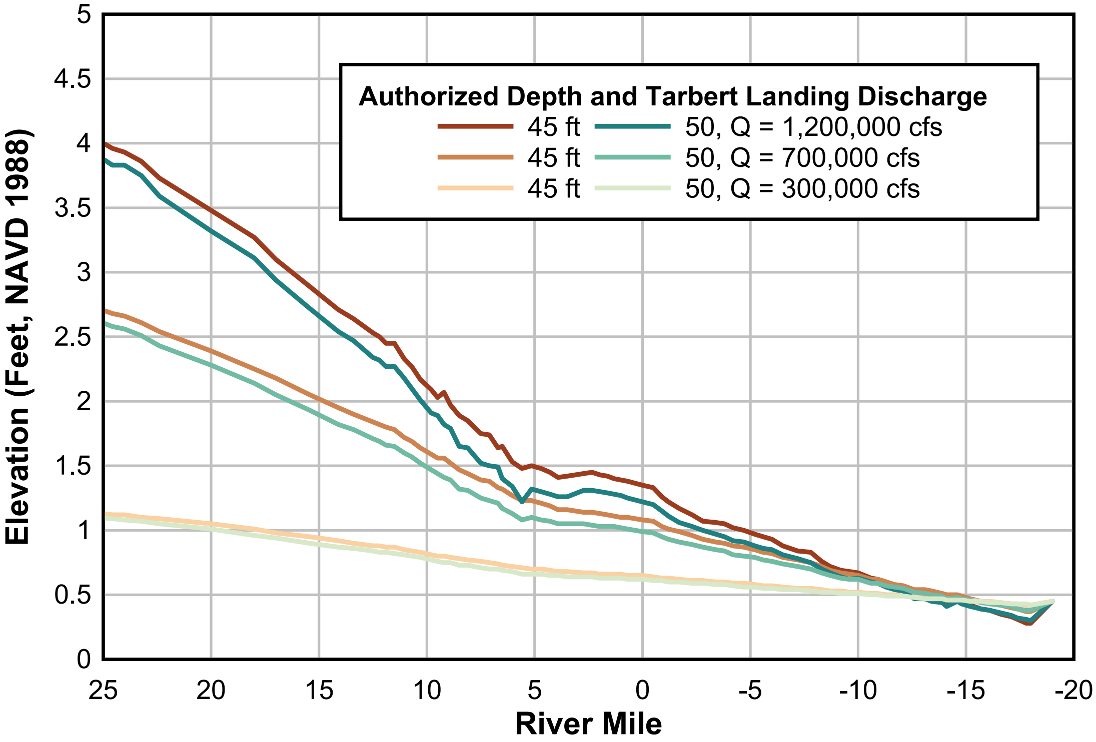

Figure 8. Increasing the authorized channel depth from 45 to 50 ft slightly lowers the initial computed stage profile at the start of the simulation. The difference in stage is insignificant at low flows and typically less than 0.2 ft for flood flows.

The final (Year 50) stage profiles for the 45 and 50 ft channels are compared in Figure 9. The response to increased navigation channel depths is similar but slightly smaller than the response indicated in the initial stage profiles presented in Figure 8. This difference in response can be attributed largely to eustatic sea level rise which caused a general decrease in water surface slope. Some of the difference may also be attributed to variations in sediment erosion and deposition and the timing of simulated dredging events during these two model simulations. Both the computed decreases in stage and water surface slope imply corresponding decreases in mean channel velocity.

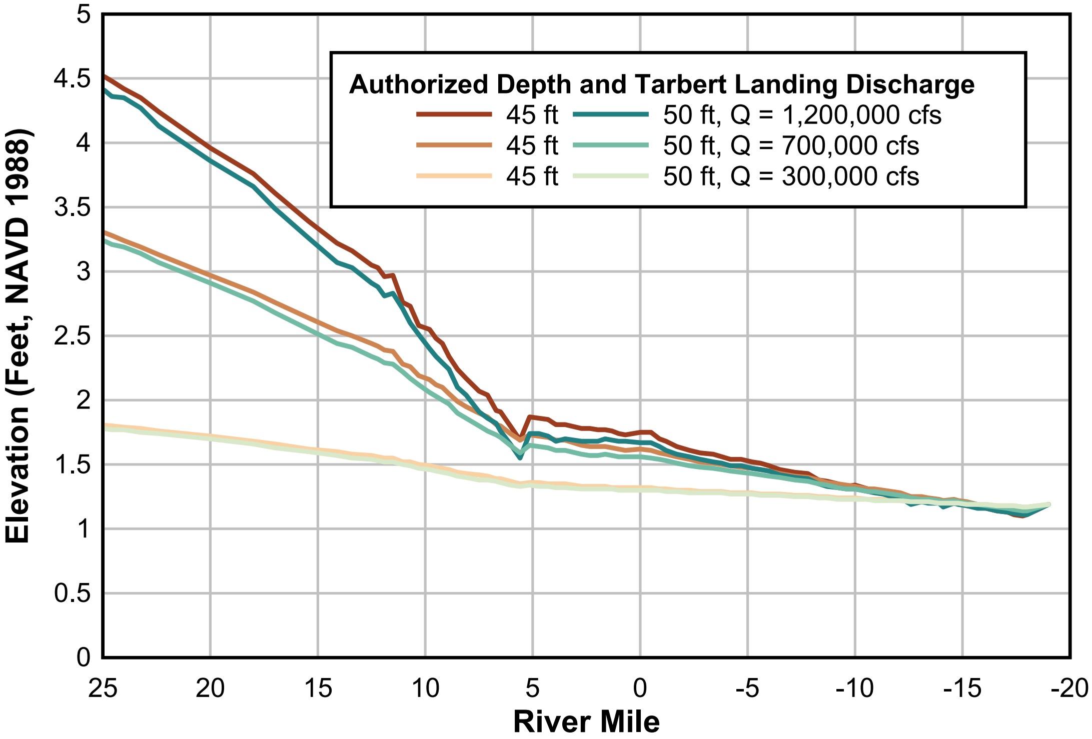

Figure 9. Year 50 water surface profiles. The computed reduction in stage due to deepening of the navigation channel persists throughout the 50 year model simulation. The magnitude of the reduction is slightly less at the end of the simulation.

SUMMARY AND RECOMMENDATIONS: The Mississippi River Hydrodynamic and Delta Management Study 1D (HEC-6T) Sedimentation Model was modified to evaluate the potential impacts of deepening the Mississippi River Ship Channel on maintenance dredging requirements. Projected increases in dredging in the Southwest Pass Dredging Reach (downstream of RM 11 AHP) attributable to deepening were small compared to the variability attributable to annual variations in flow and sediment load. The primary impact of deepening was to shift deposition and subsequent dredging upstream. An upstream shift in deposition also is the primary response of the system to eustatic sea level rise. The model does not address potential increases in the extent or frequency of salinity intrusion due to channel deepening or eustatic sea level rise, which may influence the rate of fine sediment deposition. Also, the model does not consider any potential changes in the magnitude of diversion flows at existing diversions due to relative sea level rise.

Model projections indicate the potential for significant increases in maintenance dredging requirements in the crossings attributable to channel deepening. However, model adjustments evaluated within the time and cost constraints of this study did not produce a satisfactory reproduction of the historical distribution of dredging among the various crossings. Excluding crossings where dredging requirements for the existing channel are significantly underestimated from the model estimate suggests potential increases in the range of 50% to 200% in response to deepening. The lower end of this range correlates to the observed increase in historical dredging coincident with deepening of the channel from 40 to 45 ft and thus probably indicates an upper limit, equivalent to a dredging index of 1.6, to potential increases in crossing maintenance dredging attributable to proposed deepening to 50 ft.

Future sedimentation modeling efforts on the Lower Mississippi River should extend the validation period to include extreme flood and drought events in 2011, 2012, and 2016. Model development and validation should incorporate bathymetry from the 2013 comprehensive survey along with an updated analysis of the sediment load rating curve at Tarbert Landing and flow and the flow and sediment diversion measurements at existing diversions. Additionally, future modeling efforts should attempt to reproduce long-term (decadal) deposition rates in each dredging reach and provide insights into potential causative mechanisms responsible for recent increases in dredging in deep-draft crossings.

Changes in operation of the Old River Control Complex represent one of a number of factors that could be responsible for an increase in dredging and a reported change in the characteristics of the dredged material. MRG&P Report 6, ORCC Sedimentation Investigation, concluded that current sediment diversions are inadequate and ERDC/CHL TR-14-5, Mississippi River Geomorphic Assessment, indicates that downstream reaches are aggradational. Definitive attribution remains elusive because the complex system is responding to multiple changes, including a record flood (2011), an extreme drought (2012), construction of channel training works (Smithland Crossing and Redeye Crossing), and other influences. Given the cost of channel maintenance, further investigation of the causes and possible mitigation is certainly merited.

REFERENCES:

Heath, Ronald E., Gary L. Brown, Charles D. Little, Thad C. Pratt, Jay J. Ratcliff, David D. Abraham, David Perkey, Naveen B. Ganesh, Keith Martin, and David P. May. Aug 2015. "Old River Control Complex Sedimentation Investigation," U.S. Army Corps of Engineers, Engineer Research and Development, MRG&P Report 6, Vicksburg, Mississippi. http://acwc.sdp.sirsi.net/client/en_US/search/asset/1045347

Little, Charles D. and Biedenharn, David S. 2014. Mississippi River Hydrodynamic and Delta Management Study (MRHDM) – Geomorphic Assessment. ERDC/CHL TR-14-5, U.S. Army Engineer Research and Development Center, Vicksburg, MS http://acwc.sdp.sirsi.net/client/en_US/search/asset/1035581

Sharp, Jeremy, Little, C., Brown, G., Pratt, T., Heath, R., Hubbard, L., Pinkard, F., Martin, K., Clifton, N., Perky, D., and Ganesh, N. 2013. West Bay Sediment Diversion Effects. ERDC/CHL TR-13-15, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://acwc.sdp.sirsi.net/client/en_US/search/asset/1032362

Thomas, William A. 2002. Sedimentation in Stream Networks (HEC-6T), User's Manual, Mobile Boundary Hydraulics, Clinton, MS.

U.S. Army Corps of Engineers (USACE). 1993. HEC-6, Scour and Deposition in Rivers and Reservoirs, User's Manual. CPD-6. Davis, CA: USACE, Institute for Water Resources, Hydrologic Engineering Center.

ADDITIONAL INFORMATION: This letter report was prepared by Ronald E. Heath, Research Hydraulic Engineer at the US Army Corps of Engineers, Engineer Research and Development Center, Coastal & Hydraulics Laboratory. Questions about this letter report can be addressed to the lead author at 601-634-3592 or *Ronald.E.Heath@usace.army.mil*.

Appendix A

Dredging Index Computation from 50-Year HEC-6T Model Dredging Estimates

Computed dredging volumes shown in the following tables are 50-year averages (2020-2069) based on historical mean daily flows from 1954 through 2003 adjusted for current operations at Old River. The tables differ only in the rates of eustatic sea level rise specified in the model.

Notes:

1. **Less Aggressive Dredging Schedule (**AD45_1, AD48_1, and AD50_1**):** Initiate dredging in the model when deposition reaches a level 1 foot below the authorized depth. This option minimizes required dredging (reasonable assumption for Southwest Pass). *This option greatly under-estimates historical dredging in the crossings.*

2. **More Aggressive Dredging Schedule (**AD45_2, AD48_2, and AD50_2**):** Initiate dredging in the model when deposition exceeds the over-dredging allowance (2 ft) within the dredging template. This option provides a better estimate of long-term deposition within the dredging template but may force dredging in some locations where shoaling does not impede navigation.

3. Dredging in the crossings is initiated only when the river flow is less than 600,000 cfs and the dredging rate is limited to 60,000 cubic yards per day at each site. Dredged material is reintroduced into the water column downstream of the cross-section being dredged.

4. Below River Mile 11 AHP, all dredged material is removed from the system, i.e., the model assumes that the material deposited at the head of Pass a Loutre does not enter Southwest Pass.

5. Dredging volumes include advance maintenance and over-dredging.

No eustatic sea level rise

		Annual Dredging Volume (cubic yards)							Dredging Index (Relative to AD45_1)				Dredging Index (Relative to AD45_2)		
		Less Aggressive Dredging Schedule			More Aggressive Dredging Schedule				Less Aggressive Dredging Schedule				More Aggressive Dredging Schedule		
Site	**X-Sections (River Miles)**	**AD45_1**	**AD48_1**	**AD50_1**	**AD45_2**	**AD48_2**	**AD50_2**		**AD45_1**	**AD48_1**	**AD50_1**	**AD45_2**	**AD45_2**	**AD48_2**	**AD50_2**
Southwest Pass	*18 BHP to HOP*	9,249,697	9,196,621	9,340,536	9,202,605	9,111,326	8,992,813		1	0.99	1.01	0.99	1	0.99	0.98
Head of Passes	*HOP to 2 AHP*	5,423,569	5,394,361	5,847,960	5,546,219	5,900,214	5,942,173		1	0.99	1.08	1.02	1	1.06	1.07
Fairway at Pilottown	*2 to 5 AHP*	9,080,457	11,304,653	11,930,486	11,412,626	12,731,314	13,434,688		1	1.24	1.31	1.26	1	1.12	1.18
Venice	*5 to 11 AHP*	5,000	11,542	16,612	14,706	24,091	31,796		1	2.31	3.32	2.94	1	1.64	2.16
Southwest Pass	*18 BHP to 11 AHP*	23,758,723	25,907,177	27,135,594	26,176,156	27,766,945	28,401,470		1	1.09	1.14	1.17	1	1.06	1.09
Fairview Crossing	*115.2 to 117.2*	-	-	-	-	-	381								+
Belmont Crossing	*152.6 to 155.1*	13,245	1,445,756	2,931,260	389,913	3,188,345	4,007,590		1	109.16	221.31	29.44	1	8.18	10.28
Rich Bend	*157.9 to 159.5*	-	-	146,820	-	193,400	1,062,486				+			+	+
Smoke Bend	*174.5 to 175.9*	-	426,492	1,353,494	70,628	1,601,950	1,958,031			+	+	+	1	22.68	27.72
Philadelphia Point	*181.72 to 183.6*	-	2,434	7,597	-	4,862	3,149			+	+			+	+
Alhambra	*189.4 to 190.9*	2,987,079	5,021,225	6,389,132	4,219,799	7,122,552	7,091,901		1	1.68	2.14	1.41	1	1.69	1.68
Bayou Goula Crossing	*197.5 to 198.4*	2,226,999	3,128,710	4,562,694	2,700,511	5,219,146	6,338,988		1	1.40	2.05	1.21	1	1.93	2.35
Granada	*203.3 to 206.6*	-	-	9,138	1,501	2,577	4,163				+	+	1	1.72	2.77
Medora Crossing	*211.6 to 212.3*	2,533,628	4,305,504	6,181,416	4,310,246	6,205,676	7,238,344		1	1.70	2.44	1.70	1	1.44	1.68
Sardine Point	*218.7 to 219.9*	-	-	3,387	-	-	-				+				
Red Eye Crossing	*223.4 to 225.4*	209,942	2,858,373	6,912,075	1,693,565	6,603,990	9,139,896		1	13.62	32.92	8.07	1	3.90	5.40
Baton Rouge Front	*228.1 to 232.7*	-	-	-	-	4,694	1,433							+	+
Wilkerson Point	*233.9 to 234.5*	-	1,800	-	710	-	843			+		+	1		1.19
Crossings	*152.6 to 234.5*	7,970,893	17,190,293	28,497,013	13,386,873	30,147,193	36,846,825		1	2.16	3.58	1.68	1	2.25	2.75
Total		31,729,616	43,097,470	55,632,607	39,563,029	57,914,137	65,248,295		1	1.36	1.75	1.25	1	1.46	1.65

+ Dredging was computed for FWP condition, but not FWOP condition.

- Dredging was computed for FWOP condition, but not FWP condition.

Intermediate eustatic sea level rise (NRC 1)

		Annual Dredging Volume (cubic yards)						Dredging Index (Relative to AD45_1)				Dredging Index (Relative to AD45_2)		
		Less Aggressive Dredging Schedule			More Aggressive Dredging Schedule			Less Aggressive Dredging Schedule				More Aggressive Dredging Schedule		
Site	**X-Sections (River Miles)**	**AD45_1**	**AD48_1**	**AD50_1**	**AD45_2**	**AD48_2**	**AD50_2**	**AD45_1**	**AD48_1**	**AD50_1**	**AD45_2**	**AD45_2**	**AD48_2**	**AD50_2**
Southwest Pass	*18 BHP to 0.5 BHP*	9,465,182	9,318,507	9,405,579	9,365,859	9,174,291	9,027,595	1	0.98	0.99	0.99	1	0.98	0.96
Head of Passes	*HOP to 1.5 AHP*	5,387,797	5,503,834	5,808,605	5,617,060	5,919,837	5,823,594	1	1.02	1.08	1.04	1	1.05	1.04
Fairway at Pilottown	*2 to 5 AHP*	9,298,868	11,339,982	12,259,007	11,672,360	12,854,554	13,611,081	1	1.22	1.32	1.26	1	1.10	1.17
Venice	*5 to 11 AHP*	9,671	25,751	24,001	26,182	29,834	30,748	1	2.66	2.48	2.71	1	1.14	1.17
Southwest Pass	*18 BHP to 11 AHP*	24,161,518	26,188,074	27,497,192	26,681,461	27,978,516	28,493,018	1	1.08	1.14	1.16	1	1.05	1.07
Fairview Crossing	*115.2 to 117.2*	-	-	-	-	-	433							+
Belmont Crossing	*152.6 to 155.1*	-	1,418,729	3,124,369	548,870	3,363,272	4,039,445		+	+	+	1	6.13	7.36
Rich Bend	*157.9 to 159.5*	-	-	113,813	-	222,823	1,046,694			+			+	+
Smoke Bend	*174.5 to 175.9*	-	450,526	1,354,754	75,782	1,687,483	2,002,032		+	+	+	1	22.27	26.42
Philadelphia Point	*181.72 to 183.6*	-	2,433	-	-	3,560	1,850		+				+	+
Alhambra	*189.4 to 190.9*	2,438,682	4,923,146	6,114,825	4,416,351	6,600,408	7,278,225	1	2.02	2.51	1.81	1	1.49	1.65
Bayou Goula Crossing	*197.5 to 198.4*	1,735,232	3,223,863	4,926,292	2,794,238	5,268,874	6,562,383	1	1.86	2.84	1.61	1	1.89	2.35
Granada	*203.3 to 206.6*	-	2,188	1,663	886	4,689	6,769		+	+	+	1	5.29	7.64
Medora Crossing	*211.6 to 212.3*	2,577,892	5,027,555	5,683,441	3,780,566	6,359,640	7,249,703	1	1.95	2.20	1.47	1	1.68	1.92
Sardine Point	*218.7 to 219.9*	-	-	3,363	-	2,942	-			+			+	
Red Eye Crossing	*223.4 to 225.4*	281,122	3,177,504	6,375,843	1,041,975	7,399,138	10,080,422	1	11.30	22.68	3.71	1	7.10	9.67
Baton Rouge Front	*228.1 to 232.7*	1,897	2,768	2,750	1,545	2,244	8,219	1	1.46	1.45	0.81	1	1.45	5.32
Wilkerson Point	*233.9 to 234.5*	-	-	3,327	-	-	721			+				+
Crossings	*152.6 to 234.5*	7,034,825	18,228,712	27,704,440	12,660,214	30,915,072	38,276,463	1	2.59	3.94	1.80	1	2.44	3.02
Total		31,196,342	44,416,786	55,201,632	39,341,674	58,893,588	66,769,481	1	1.42	1.77	1.26	1	1.50	1.70

+	Dredging was computed for FWP condition, but not FWOP condition.
-	Dredging was computed for FWOP condition, but not FWP condition.

High eustatic sea level rise (NRC 3)

		Annual Dredging Volume (cubic yards)						Dredging Index (Relative to AD45_1)				Dredging Index (Relative to AD45_2)		
		Less Aggressive Dredging Schedule			More Aggressive Dredging Schedule			Less Aggressive Dredging Schedule				More Aggressive Dredging Schedule		
Site	**X-Sections (River Miles)**	**AD45_1**	**AD48_1**	**AD50_1**	**AD45_2**	**AD48_2**	**AD50_2**	**AD45_1**	**AD48_1**	**AD50_1**	**AD45_2**	**AD45_2**	**AD48_2**	**AD50_2**
Southwest Pass	*18 BHP to 0.5 BHP*	9,724,410	9,568,653	9,595,220	9,498,547	9,295,049	9,147,036	1	0.98	0.99	0.98	1	0.98	0.96
Head of Passes	*HOP to 1.5 AHP*	5,464,283	5,499,985	5,750,556	5,592,122	5,981,170	5,944,914	1	1.01	1.05	1.02	1	1.07	1.06
Fairway at Pilottown	*2 to 5 AHP*	9,680,046	11,456,188	12,390,832	11,601,234	13,031,642	13,337,566	1	1.18	1.28	1.20	1	1.12	1.15
Venice	*5 to 11 AHP*	7,788	18,702	26,191	26,132	28,073	38,939	1	2.40	3.36	3.36	1	1.07	1.49
Southwest Pass	*18 BHP to 11 AHP*	24,876,527	26,543,528	27,762,799	26,718,035	28,335,934	28,468,455	1	1.07	1.12	1.14	1	1.06	1.07
Fairview Crossing	*115.2 to 117.2*	-	-	-	-	-	-							
Belmont Crossing	*152.6 to 155.1*	2,534	1,333,318	3,023,315	352,139	3,260,315	3,966,061	1	526.11	1192.96	138.95	1	9.26	11.26
Rich Bend	*157.9 to 159.5*	-	-	88,885	-	177,031	1,113,547			+			+	+
Smoke Bend	*174.5 to 175.9*	2,902	402,405	1,398,612	71,864	1,542,550	2,014,768		+	+	+	1	21.46	28.04
Philadelphia Point	*181.72 to 183.6*	-	2,428	7,443	-	6,052	4,427		+	+			+	+
Alhambra	*189.4 to 190.9*	2,944,355	5,213,549	6,252,197	4,652,811	6,389,170	7,301,500	1	1.77	2.12	1.58	1	1.37	1.57
Bayou Goula Crossing	*197.5 to 198.4*	2,090,132	3,541,576	4,803,650	3,204,357	5,027,525	6,296,747	1	1.69	2.30	1.53	1	1.57	1.97
Granada	*203.3 to 206.6*	-	2,987	7,679	2,503	7,125	6,256		+	+	+	1	2.85	2.50
Medora Crossing	*211.6 to 212.3*	2,794,059	5,160,313	6,667,880	4,064,767	6,230,623	7,560,119	1	1.85	2.39	1.45	1	1.53	1.86
Sardine Point	*218.7 to 219.9*	-	-	-	-	-	3,038							+
Red Eye Crossing	*223.4 to 225.4*	373,371	3,708,820	8,148,070	1,224,646	6,980,973	9,715,735	1	9.93	21.82	3.28	1	5.70	7.93
Baton Rouge Front	*228.1 to 232.7*	1,897	-	2,766	1,684	1,373	8,876	1	0.00	1.46	0.89	1	0.82	5.27
Wilkerson Point	*233.9 to 234.5*	-	-	717	-	849	4,168			+			+	+
Crossings	*152.6 to 234.5*	8,209,250	19,365,396	30,401,214	13,574,771	29,623,585	37,995,243	1	2.36	3.70	1.65	1	2.18	2.80
Total		33,085,777	45,908,924	58,164,013	40,292,807	57,959,520	66,463,698	1	1.39	1.76	1.22	1	1.44	1.65

+ Dredging was computed for FWP condition, but not FWOP condition.

- Dredging was computed for FWOP condition, but not FWP condition.

Mississippi River Ship Channel
Gulf to Baton Rouge, LA
Integrated General Reevaluation Report
And Supplemental Environmental Impact Statement

Appendix H

Annex 2

Multi-Dimensional Modeling of Proposed Channel Deepening Alternatives for the Lower Mississippi River Using Adaptive Hydraulics (AdH)

April 2018

ERDC TR-XX-DRAFT

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Multi-Dimensional Modeling of Proposed Channel Deepening Alternatives for the Lower Mississippi River Using Adaptive Hydraulics (AdH)

Gary L. Brown, Marielys Ramos-Villanueva, Ronald E. Heath

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DRAFT report

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Under

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Abstract

This report contains the results of a multi-dimensional numerical model analysis of proposed channel deepening alternatives for the Lower Mississippi River. The model used for the study is an existing application of the Adaptive Hydraulics Model (Adh) linked to the SEDLIB sediment transport library. This application has been verified for hydrodynamics and sediment transport in the Lower Mississippi River, as a product of the Mississippi River Hydrodynamic and Delta Management Study. For this study, the model was re-verified against dredging data, tro ensure that the model accurately represents the depositional behavior at the crossings. Then the model was simulated for both existing and proposed conditions, and the modeled change in the required dredging at each of the crossings was evaluated.

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Figures and Tables

Figures

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Preface

This study was conducted for the New Orleans District of the US Army Corps of Engineers. The technical monitor was Leslie Lombard.

The work was performed by the Coastal and Hydraulics of the U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Lab (ERDC-CHL). At the time of publication, Dr. Robert T. McAdory was Chief, CEERD-HF-E; Dr. Ty V. Wamsley was Division Chief, CEERD-HF; and Dr. Cary A. Talbot, CEERD-HF-HG was the Technical Director for the Flood and Coastal Storm Damage Reduction Research Program. The Deputy Director of ERDC-CHL was Dr. Jeffrey R. Eckstein and the Director was Mr. Jose Sanchez.

COL Bryan S. Green was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
angstroms	0.1	nanometers
atmosphere (standard)	101.325	kilopascals
bars	100	kilopascals
British thermal units (International Table)	1,055.056	joules
centipoises	0.001	pascal seconds
centistokes	1.0 E-06	square meters per second
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
fathoms	1.8288	meters
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
kilotons (nuclear equivalent of TNT)	4.184	terajoules
knots	0.5144444	meters per second
microinches	0.0254	micrometers
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (force)	4.448222	newtons

Multiply	By	To Obtain
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per inch	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
slugs	14.59390	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (force) per square foot	95.76052	kilopascals
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (nuclear equivalent of TNT)	4.184 E+09	joules
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
yards	0.9144	meters

1 Introduction

1.1 Background

The 255 mile long Mississippi River Ship Channel extends from Baton Rouge, Louisiana to the Gulf of Mexico and provides deep-draft access to the largest port complex in the United States of America. Annually, the port complex serves an average of 11,000 deep-draft vessels and handles 450 million tons of cargo. Although the authorized navigation depth of the Ship Channel is 55 feet (ft), the navigation depth is currently maintained to 45 ft. The US Army Engineer New Orleans District is evaluating the feasibility of deepening the channel.

Since typical channel depths in most of this reach of the Mississippi River exceed the maintained channel depth, maintenance dredging is required only in relatively short and distinct locations. The Southwest Pass dredging reach, Figure 1.1, is the longest single dredging reach and has been maintained to a depth of 45 ft relative to Mean Low Gulf (MLG) since 1987. Annual dredging quantities in this reach from 1970 to 2008 averaged 19.4 million cubic yards (yd3). The remainder of the locations requiring periodic maintenance dredging are river crossings, shown in Figure 1.2, in the upper 120 miles of the Ship Channel. These crossings have been maintained to a depth of 45 ft relative to the Low Water Reference Plane (LWRP) since 1995. Total annual dredging quantities for the crossings averaged 16 million yd3 from 1999 to 2015.

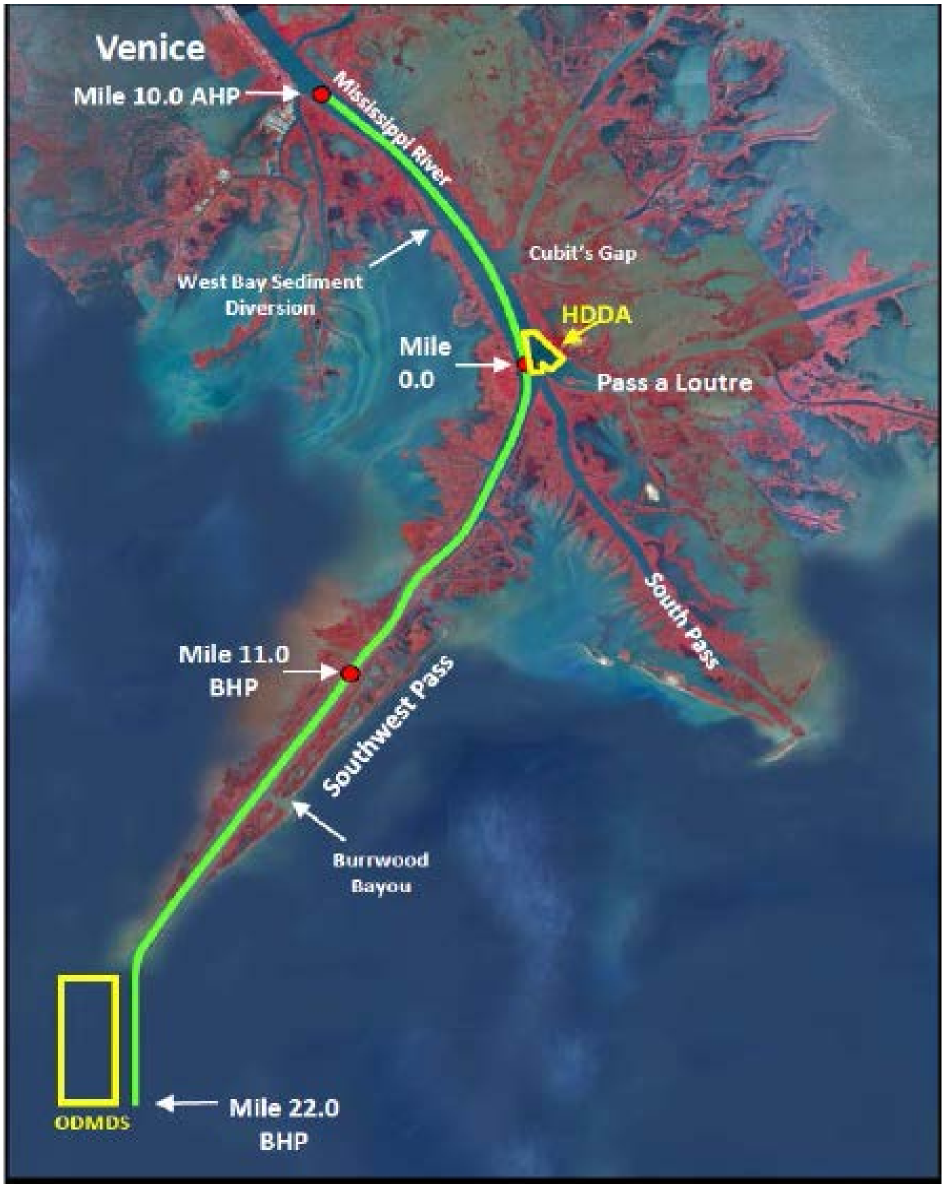


Figure 1.1: Location Map of Southwest Pass Reach where Periodic Dredging is Required.

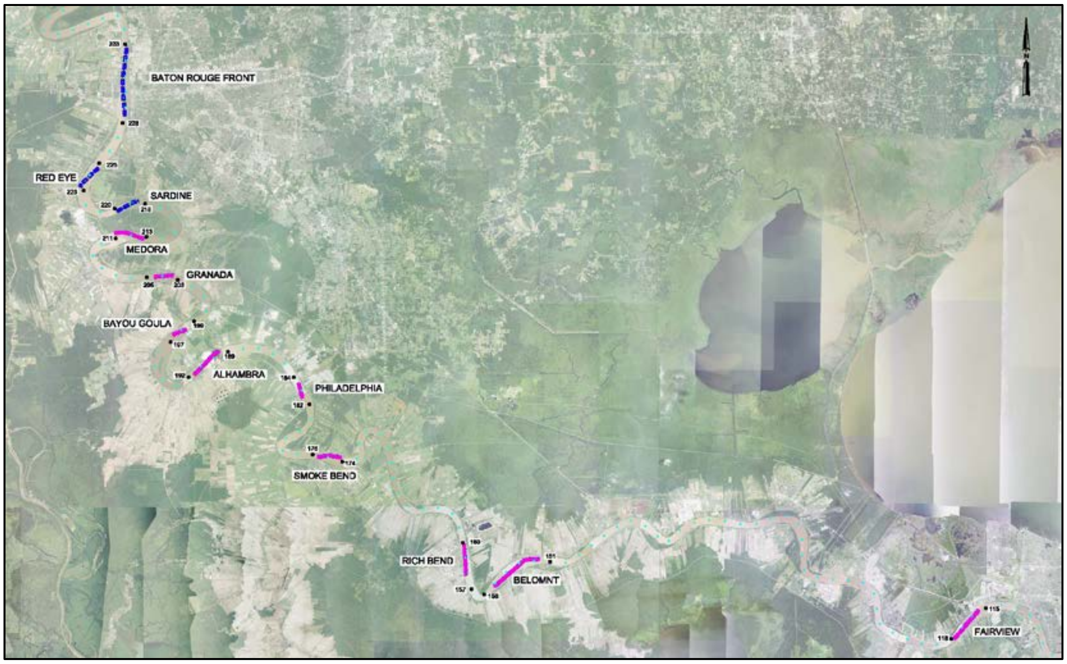


Figure 1.2:Location Map of Lower Mississippi River Crossings where Periodic Dredging is Required.

1.2 Scope of This Study

This study consists of an assessment the potential impacts of several proposed deepening alternatives on the dredging requirements for the Lower Mississippi River. This assessment was conducted with the use of an existing Adaptive Hydraulics (AdH) model of the Lower Mississippi River, that was developed and verified against observations as a product of the Mississippi River Hydrodynamic and Delta Management Study. The study consists of the following tasks.

- Verification of the existing model against observed dredging volumes for the crossings in the Lower Mississippi River
- Simulations for the existing conditions, the Tentatively Selected Plan (TSP), and 2 additional deepening alternatives, and evaluation of system responses to the deepening alternatives by comparison of the alternatives to the existing conditions simulations. The simulations are described in Table 1:
- Evaluation of the sensitivity of the alternative comparisons to various eustatic sea level rise conditions.

The simulations are described in Table 1.1:

Table 1-1:Description of Alternatives

Alternative	Crossings Upstream of Port of South Louisiana	Crossings Downstream of Port of South Louisiana	Southwest Pass
Existing Conditions	-45 ft LWRP	-45 ft LWRP	-48.5 ft MLLW
TSP	-45 ft LWRP	-50 ft LWRP	-50 ft MLLW
Alt 3	-50 ft LWRP	-50 ft LWRP	-50 ft MLLW
Alt 3e	-48 ft LWRP	-50 ft LWRP	-50 ft MLLW

2 Numerical Model Development

2.1 Adaptive Hydraulics Model

AdH is a finite element model that is capable of simulating three-dimensional Navier-Stokes equations, two and three-dimensional shallow water equations, and groundwater equations. It can be used in a serial or multiprocessor mode. The uniqueness of AdH is its ability to dynamically refine the domain mesh in areas where more resolution is needed at certain times due to changes in the flow conditions. AdH can simulate the transport of conservative constituents, such as dye clouds, as well as sediment transport and is coupled to bed and hydrodynamic changes. The ability of AdH to allow the domain to wet and dry within the marsh areas as the tide changes is fitting for the shallow marsh environment.

For this study, the two-dimensional shallow water module of AdH was utilized with linkage to the sediment library, SEDLIB. SEDLIB is a sediment transport library developed at ERDC. (Brown, 2012a, b). It is capable of solving problems consisting of multiple grain sizes, cohesive and cohesionless sediment types, and multiple layers. It calculates erosion and deposition processes simultaneously, and simulates such bed processes as armoring, consolidation, and discrete depositional strata evolution.

The AdH /SEDLIB sediment model contributes several capabilities to the analysis, including:

- Quasi-3D flow and transport formulations, which use analytical and semi-empirical methods of approximate the 3D character of the flow and sediment transport phenomena (Brown 2008). These formulations mean that the fully 3D approach, and its attendant computational burden, can be avoided without losing all of the 3D information to the depth-averaging process.

- These methods include the ability to model the effects of helical flow through a river bendway on the suspended and bedload sediment transport by utilizing the bendway vorticity transport algorithm given by Bernard (1992).

- The SEDLIB module is equipped to simulate multi-grain class suspended load and bedload sediment transport phenomena. It is also equipped to handle generalized multi-grain class bed processes, including armoring, sorting, erosion to a solid boundary, and the storage of discrete depositional strata.

- The unstructured model mesh employed by AdH permits very high resolution in areas of interest, and high fidelity resolution of shoreline geometry.
- The ability to extend the boundaries sufficiently far from the project area, with appropriate efficient resolution, so as not to prescribe the answer will ensure that the results are not biased by judgments concerning boundary conditions.

More details of the two-dimensional shallow water module of AdH and SEDLIB can be found at https://chl.erdc.dren.mil/chladh

The model application used here is a model of the entire Lower Mississippi River, extending from the Old River Control structure to the Gulf of Mexico. This model was developed as a product of the Mississippi River Hydrodynamic and Delta Management Study (Brown et. al. 2015). The model mesh, showing the entire model domain , is depicted in Figure 2.1.

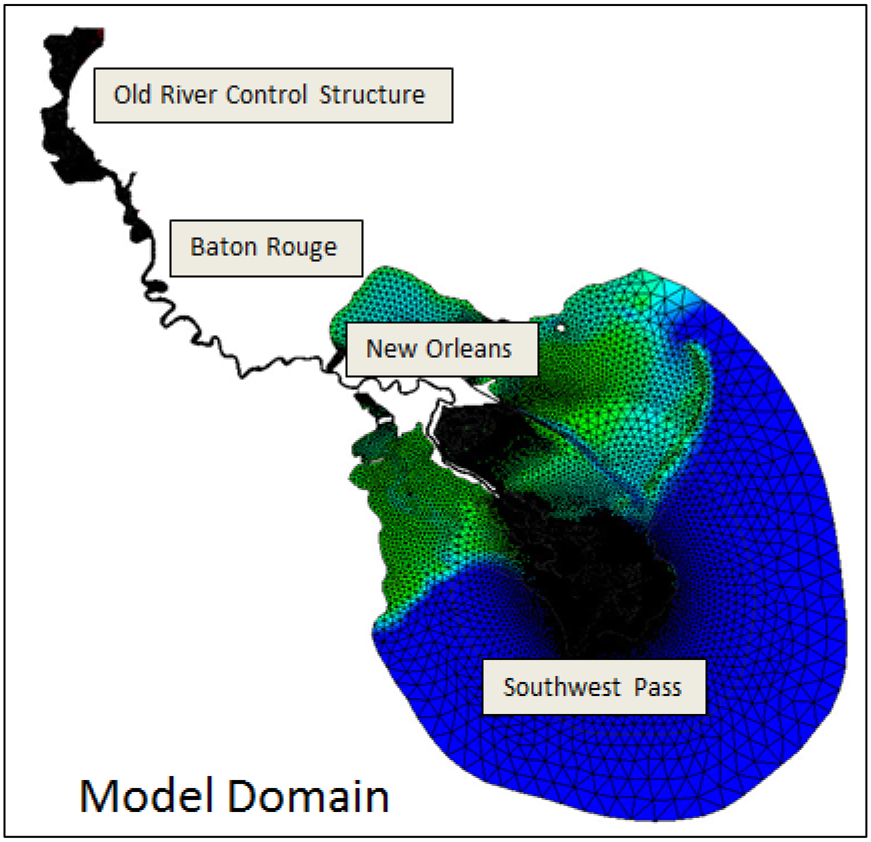


Figure 2.1:The Full Model Domain and Computational Mesh

2.2 Mesh development

In order to ensure that dredging in each of the crossing was properly modeled, the model mesh was refined such that the exact geometry of the dredging template for each crossing was resolved in the mesh. Figure 2.2 shows how this additional resolution captures the dredging template at several crossings. The figure also shows how the model resolves several other important features within the river, including dikes, revetments, and the batture.

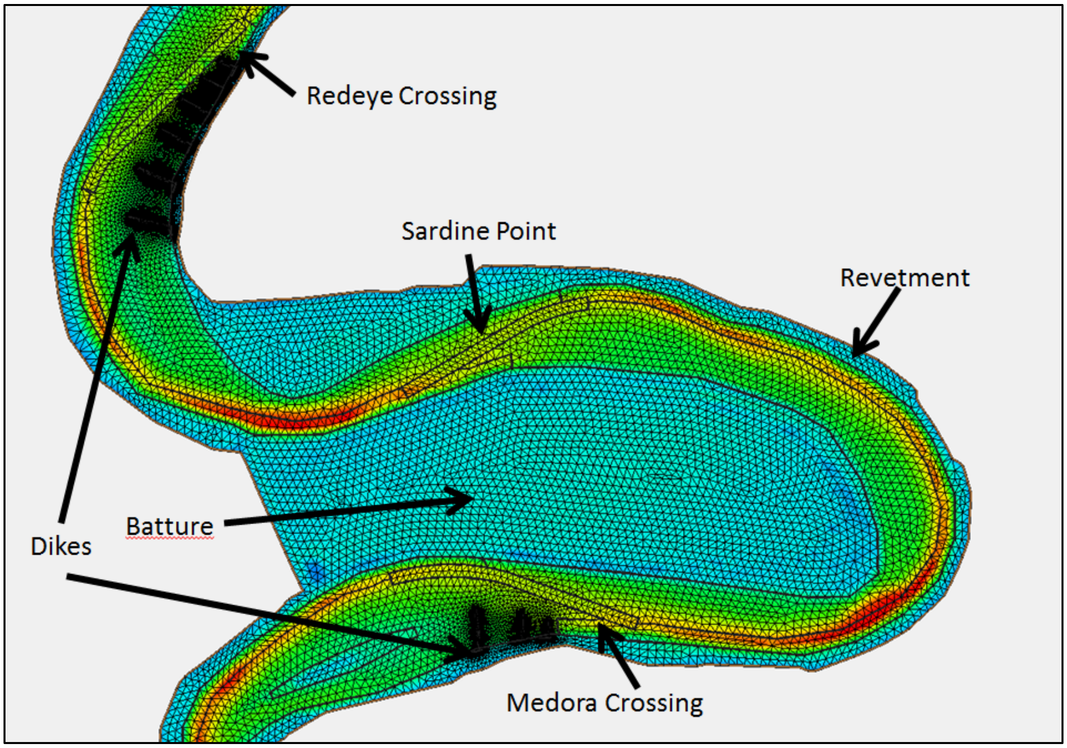


Figure 2.2: Example of model resolution of the crossings

2.3 Model boundary conditions

The model boundary conditions are a simplified version of the bodaunry conditions applied for the Mississippi River Hydrodynmic and Deltha Management Study. The following is a brief discussion of the applied boundary conditions. A more detailed discussion of the sources and methods used to generate these boundary conditions is given in Brown et al, 2015).

2.3.1 Mississippi River Inflow

The upstream inflowing discharge is taken from observations at the USGS observation range at Baton Rouge. For this study, the model simulation period was taken from the observations for 2008-2010. Figure 2.3 shows the Mississippi River discharge for model's upstream boundary condition over this three-year period.

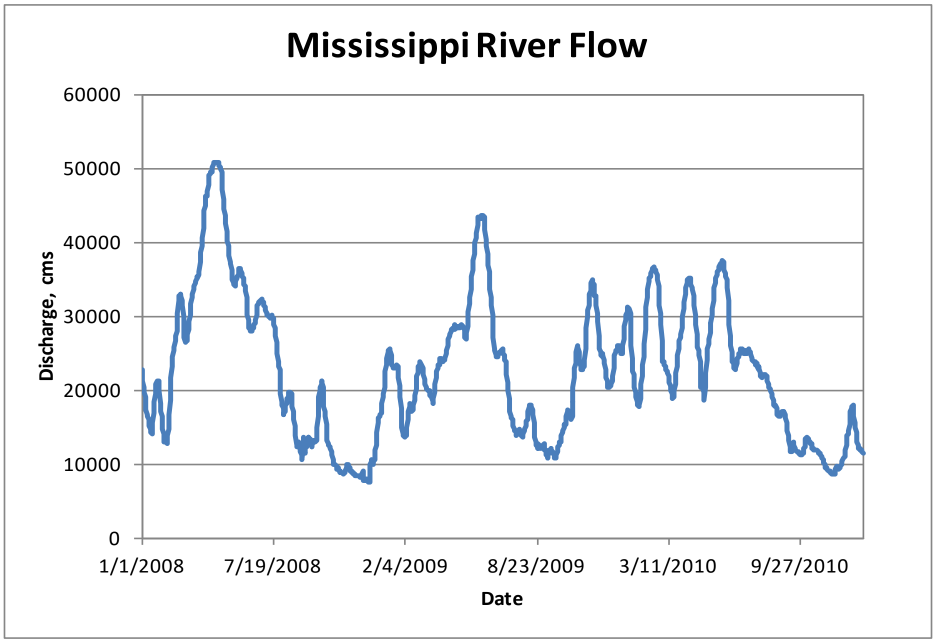


Figure 2.3: Mississippi River Discharge, as observed at Baton Rouge by the USGS.

2.3.2 Bonnet Carre Discharge

The Bonnet Carre diversion and spillway is an integral part of the Mississippi River and Tributaries (MR&T) Project for flood control. It is designed to be operated when the Mississippi river discharge exceeds 1.25m cfs at Tarbert Landing. For the model simulation period of 2008-2010, the Bonnet Carre spillway was only opened during the flood of 2008. This discharge schedule is applied in the model (see Figure 2.4).

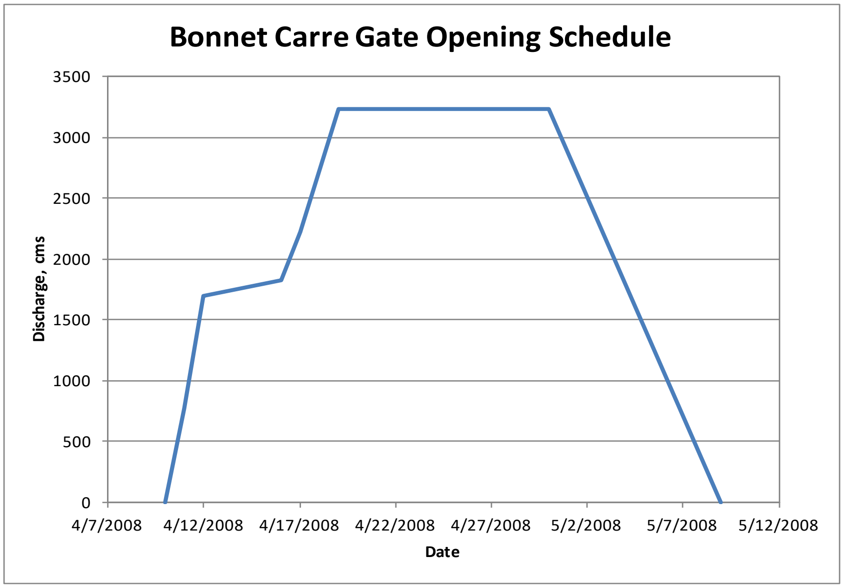


Figure 2.4:Diverted Discharge at Bonnet Carre during the Flood of 2008

Note that the Bonne Carre spillway is known to lead significant discharge during high water, even when the structure is not in operation. For these simulations, however, this leakage was neglected.

2.3.3 Gulf Water Surface Elevation: Influence of Sea Level Rise

For these simulations, a spatially and temporally constant water surface elevation was applied at the downstream boundary. This water surface elevation was determined by observations of the mean sea level of the gulf, and adjusted for various predictions of eustatic sea level rise.

The scenarios are each analyzed for 3 separate sea level elevation conditions, as per USACE guidance on sea level rise (ETL 111-2-1). :

- the projected elevation of eustatic sea level based on the historic rate
- the projected elevation of eustatic sea level based on the high estimate of the accelerated rate (The NRC I curve).
- the projected elevation of eustatic sea level based on the high estimate of the accelerated rate (The NRC III curve).

These 3 conditions result in 3 separate mean sea level elevations at the downstream boundary, for each of the target years for the analysis:

year 0 (2025) and year 50 (2075). These 3 sea level conditions for 2 target years yields 6 future sea level conditions. The predicted eustatic sea level conditions for yr0 and yr50, as per USACE guidance computation methods, are given in Table 2.1.

Table 2-1: Projected Mean Sea Level Elevations at the Gulf Boundary as per USACE Guidance

ESLR Scenario	**Mean Sea Level Elevation (relative to NAVD88, 1992 epoch** **YR 0 (2025) meters**	**Mean Sea Level Elevation (relative to NAVD88, 1992 epoch** **YR 50 (2075) meters**
Low Rate (Historic)	.056	0.141
Intermediate Rate (NRCI)	.086	0.328
High Rate (NRCIII)	.179	0.919

To minimize the number of scenario analyses necessary to satisfy the guidance requirement, it is desirable to reduce the number of YR0 eustatic sea level conditions from 3 to 1. Since the range of the 3 values given for year 0 is relatively small (0.179 – 0.056 = 0.123 meters), and since the projections given by the guidance are not modeled projections per se, but rather approximations of the potential range of sea level outcomes, it is reasonable to reduce the number of scenario analyses required by selecting a single value of the YR0 sea level for analysis. For this effort, it was determined that the single value selected should be the value that results from the historic (low) rate (i.e. 0.056 meters). The selection of this value ensures that the difference in projected sea level from year 0 to year 50 for all of the scenarios is a maximum difference. This, in turn, ensures that the modeled impacts of eustatic sea level rise are maximized, yielding a conservative analysis (with respect to impacts)

2.3.4 Subsidence

Note that the imposed eustatic sea level rise conditions do not take into account the influence of subsidence on the apparent change in sea level (i.e. relative sea level rise). Observations indicate that there is significant subsidence in the Lowermost Mississippi River, in some places as high a 20mm/year. The subsidence is known to vary spatially and (possibly) temporally, and there is significant uncertainty in the magnitude of the subsidence at any given location. In addition, deposition of sediment in the riverbed can compensate for this subsidence, or even exceed the rate of subsidence and exhibit net aggradation. Finally, it is not known how relative sea level rise will affect the stability of the river bankline in the future: whether existing outlets will expand, whether new outlets will form, or whether repairs/closures to these outlets will be implemented. Given the complexity of these uncertainties, the imposition of assumed rates of subsidence and/or predicted rates of shoaling on the riverbed elevations in order to generate estimates of the future condition of the riverbed is unlikely to yield results that improve the predictive capability of the model, Therefore, for this analysis, the effects of both subsidence and of morphologic (depositional and erosional) change on the riverbed elevation are neglected between YR0 and YR50. Rather, subsidence and morphologic change will only be modeled for the 3 years of analysis associated with each scenario. Note that this method of analysis will artificially increase the morphologic response to relative sea level rise, since we are not running the intervening years and allowing the morphology to gradually adjust to the changing RSLR. So although this method is an approximation of the response, it should be a conservative approximation (with respect to dredging).

To address the uncertainty in the subsidence, one additional sensitivity run is also provided. The YR50 run for the NRCI sea level condition is rerun with the full subsidence for the intervening 50 years included in the bed elevations. This represents the bed elevaiton assuming no deposition of sediments: hence, together with the other simulations, it should bracket the effects of the potential bathymetric change due to the combined effects of subsidence and morphologic change.

2.3.5 Sediment Boundary Conditions and Bed Initialization

The sediment is modeled in terms of discrete grain classes that are introduced at the upstream Mississippi River boundary and exist in the bed and water column of the model domain. The full range of classes that are found in the bed material, even in minute quantities, are represented in the model. This is done to ensure proper armoring of the river thalweg. The grain classes and their sizes are given in Table 2.2.

Table 2-2:Modeled sediment grain classes

SEDIMENT CLASS	ABBREVIATION	DIAMETER (mm)
Very Fine Sand	VFS	.088
Fine Sand	FS	.177
Medium Sand	MS	.354
Coarse Sand	CS	.707
Very Coarse Sand	VCS	1.41
Very Fine Gravel	VFG	2.83
Fine Gravel	FG	5.66

Note that the model simulations conducted for this study include only sand and gravel classes: silt and clay classes are omitted. Observations indicate that very little of the sediment that deposits in the crossings consist of this finer grained material. By contrast, significant quantities of finer grained material deposit in the lowermost reaches (i.e. Venice to Southwest Pass). However, the physical processes that govern this deposition are largely associated with salt wedge intrusion and the consequence influence of salinity on fine sediment flocculation. Since this model is not designed to model those processes, it was determined that the inclusion of results for fine grained sediments would imply as misleading confidence in the ability of the model to assess their behavior. Therefore, the fine grained sediments are omitted for this effort, although an approximate method is employed in the analysis of results to account for their influence.

- The sand and gravel sediments (noncohesive sediments) are modeled using the following transport functions:

  - Bedload transport - van Rijn (1984) , modified for multiple grain classes by Kleinhans and van Rijn (2002)
  - Suspended Load – Wright and Parker (2004)
  - Hiding factor – Egiazaroff (1965)

The inflowing sediment boundary is represented with an equilibrium boundary condition. This means that the boundary condition applies a sediment inflow boundary that is consistent with the transport functions. This boundary condition is used, in lieu of observations, for the following reasons:

- The observed data are not segregated into discrete grain classes: the use of observed data would require an approximation of this partitioning which introduces significant error.
- Inconsistencies between observed concentrations and the concentrations calculated by the transport functions can result in significant erosion or deposition of sediment at the inflow boundary
- The model upstream of Baton Rouge is run with a fixed bed: this allows the model to adjust to any spurious sediment loads introduced at the boundary without influencing the conveyance capacity of the river.

The sediment bed is initialized as follows:

- The initial bed consists of 6 bed layers.
- The top 4 bed layers are “zero thickness” layers: these are used to store depositional layers.

- The bottom two layers are defined by an elevation horizon: that is their thickness varies spatially, and is defined by the difference between the defined elevation of the top of the bed layer, and the local elevation of the bed. The elevation horizon is defined as equal to the NAVD88 elevation of the bottom of the layer.

- The grain composition of each layer is taken from data collected in the river. These compositions represent typical gradations in the river for lateral bars and point bars (top layer sediment) and deep thalweg sediments (bottom layer sediment)

- The initial elevation horizons and corresponding grain composition of the bed layers are given in

- :

- To complete initialization of the bed, the model was run for a full year (in this case, 2009) without allowing bed elevation to change. This initializes the bed gradation only, armoring the high energy areas (such as the thalweg) and adding sediment thickness to the low energy areas (e.g. point bars).

Table 2-3:Initial bed properties

Layer thickness and grain class identity	Fine sediment gradation layer (top layer)	Coarse sediment gradation layer (bottom layer)
Elevation horizon (bottom elevation of layer), meters	-18	-23 (on revetments) -200 (in main channel)
Very Fine Sand	.1	.09
Fine Sand	.1	.128
Medium Sand	.63	.60
Coarse Sand	.14	.162

Very Coarse Sand	.03	.01
Very Fine Gravel	.0	.009
Fine Gravel	.0	.001

2.3.6 Selection of Modified Porosity Parameter

In order to accelerate the run time required to perform the simulations, a modified porosity technique was employed. This technique is similar to techniques employed by other models, whereby modifications are made to the model equations to accelerate the morphologic response. Details of the modified porosity technique are given in Appendix A.

Since it is known that any acceleration factor has the potential to alter the predictive capability of the model, it is necessary to demonstrate that simulations performed with a selected acceleration factor yield results that are consistent with model simulations performed without the acceleration factor.

The modified porosity factor (MPF) chosen for this study was 4. Figure 2.5 demonstrates that the simulations performed with this acceleration factor yield a similar bed sediment mass response at each of the crossings to the response observed in the unmodified simulations. Hence, a MPF of 4 is deemed suitable for this study.

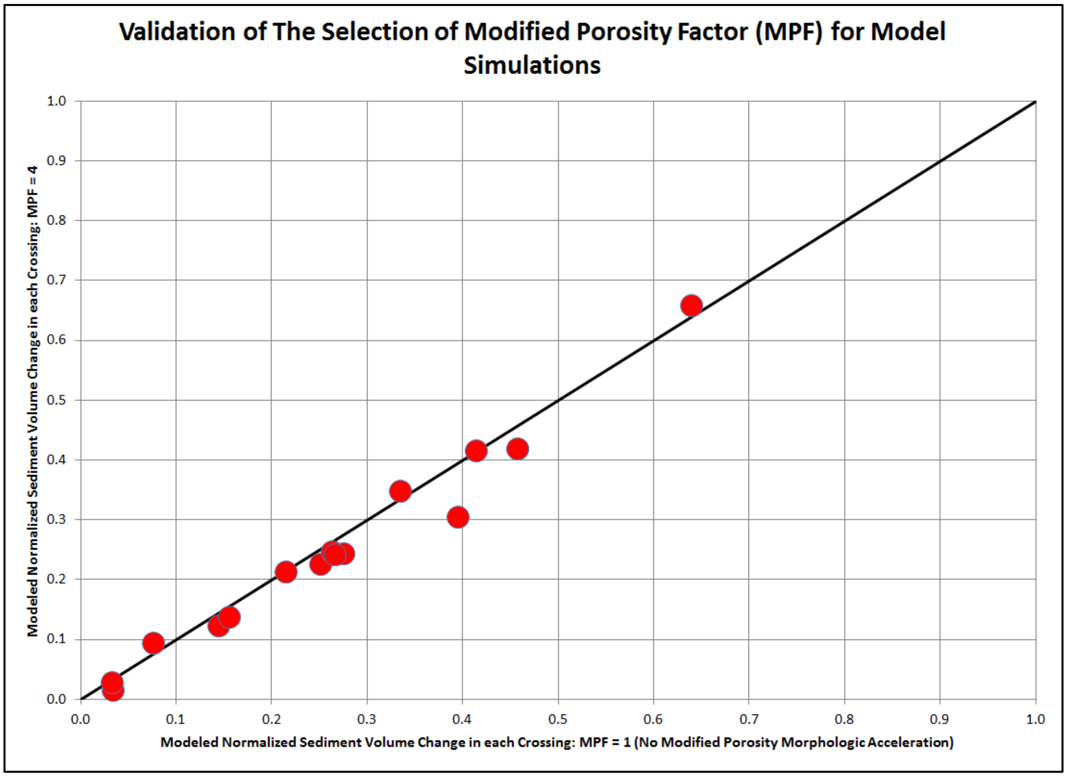


Figure 2.5: Validation of Modified Porosity Factor Selection

Note that all subsequent results, including the validation results, were performed with the MPF = 4.

3 Model Validation

The model used for this study has previously been validated against observations of stage and sediment load (Brown et al, 2015). Therefore, for this study, the validation was focused on the ability of the model to reproduce observed dredging quantities for the crossings that are regularly dredged in the Mississippi River. These crossings are shown in Figure 1.2. Note that, although model results are also reported for the lowermost river (Venice to Southwest Pass, shown in Figure 1.1) the dredging for this reach is associated with significant quantities of silt and clay sediments, which are not modeled in this study. Therefore, model validation is not evaluated for the lowermost river reaches.

3.1 Qualitative Analysis

Figure 3.1 depicts typical deposition patterns that are observed in the model. Several of the dredged crossings are shown in this image: From upstream to downstream, Redeye Crossing, Sardine Point, Medora Crossing, and Grenada Crossing. For clarity, only the deposition is shown in this image: scour is also evident in the model results. The results show a tendency for deposition in the crossings to be spatially non-uniform, where deposition is generally associated with either channel widening, or the encroachment of a point bar into the dredge cut.

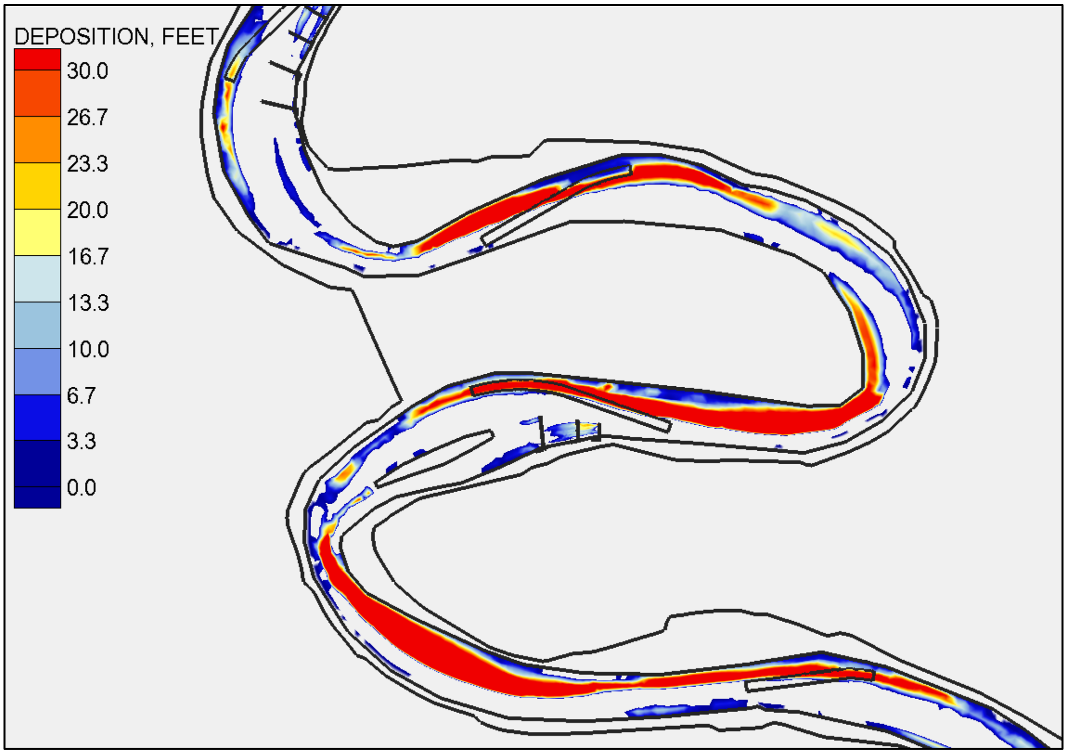


Figure 3.1: Example of Deposition Patterns in the Crossings from the AdH Model Results

3.2 Quantitative Analysis

Figure 3.2 depicts the observed and modeled dredged volume for each fo the crossings for FY2008-2010. Figure 3.3 depicts the cumulative dredged volume for all crossings for YR 2008-2010. The results show that the model predicts the cumulative volume accurately, but the model does not predict the distribution of deposition among the crossings consistently. Some crossings, such as Baton Rouge Front and Alhambra Crossing, are very well predicted. Others, such as Redeye Crossing and Philadelphia Crossing, are not.

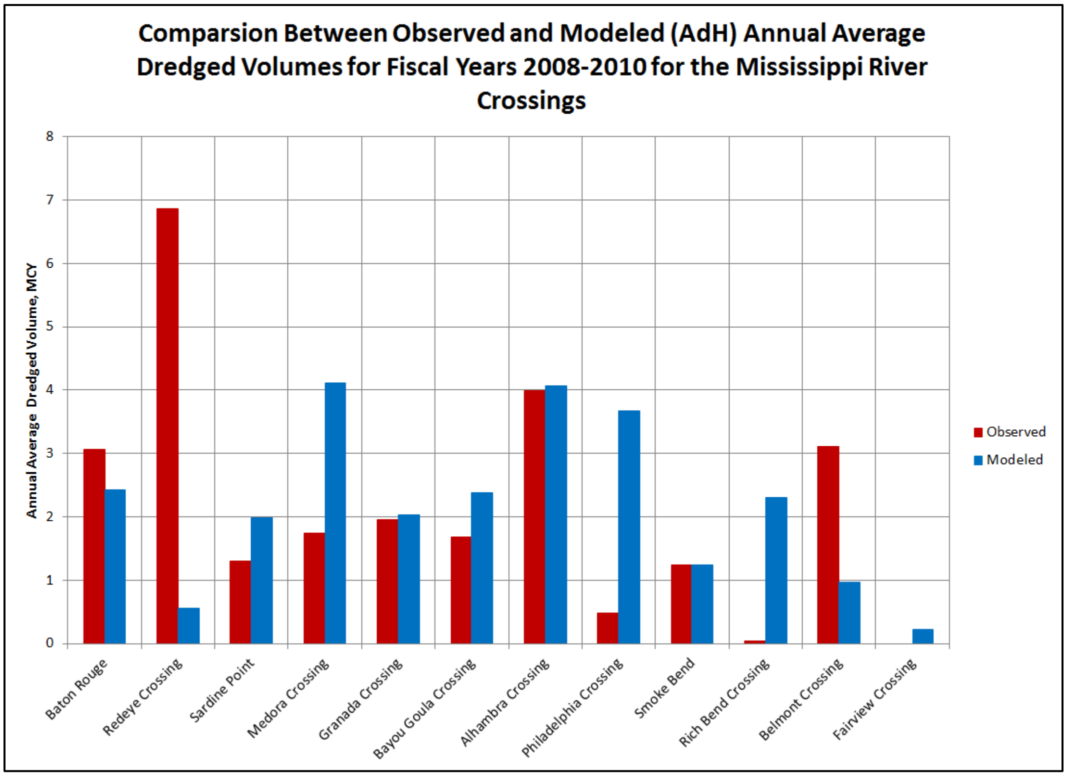


Figure 3.2: Observed and Modeled Average Annual Dredged Volume by Crossing for FY 2008-2010.

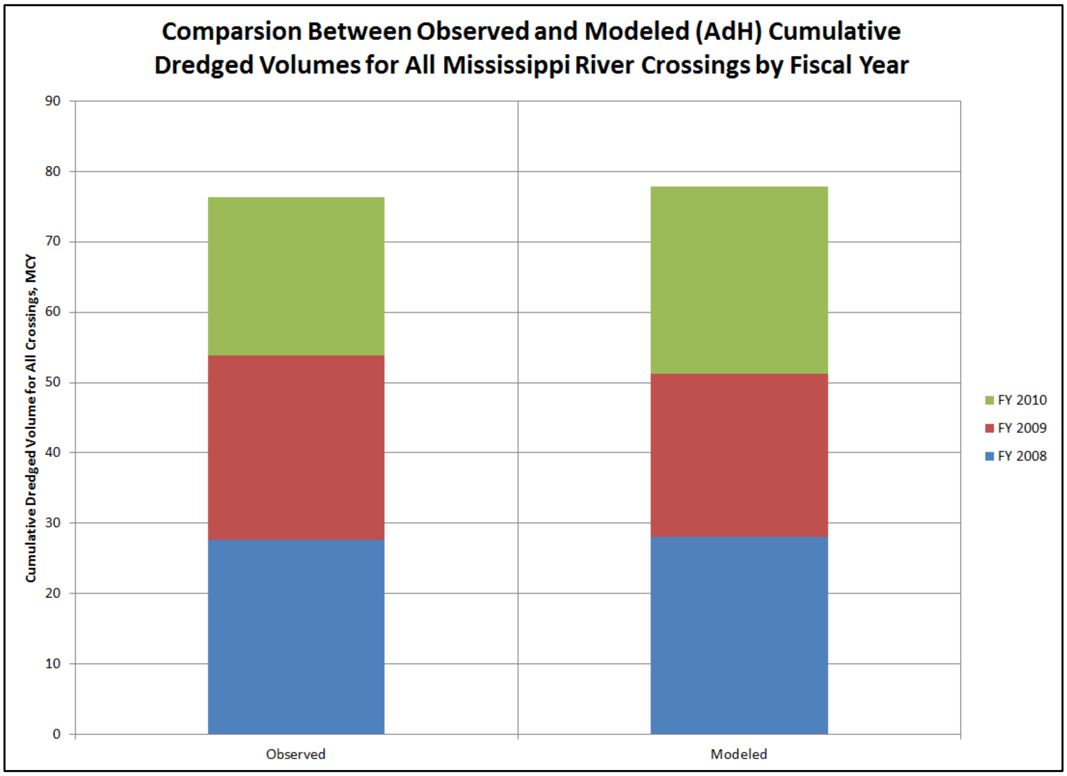


Figure 3.3: Observed and Modeled Cumulative Dredged Volume for all Crossings for FY 2008-2010

For several crossings where the prediction is not in close agreement with the observations, model results suggest that the deposition patterns are locally inaccurate, but regionally consistent. For example, the excess model deposition at Rich Bend Crossing appears to compensate for the defiti in deposition at Belmont Crossing. This tendency is also reflected in the close agreement between the cumulative and observed modeled results depicted in Figure 3.3.

Of particular concern, however, is the stark disagreement between the predicted and observed dredged volumes at Redeye Crossing. Redeye Crossing consistently represents the largest volume of dredged material observed for any of the crossings (excluding Southwest Pass, which is the largest by far for the entire Lower Mississippi River). Some possible explanations for this descrepany were discussed in a phone call with district personnel, and the following list of possibilities was generated (Mayo Broussard, personal communication, 2017).

- Dredging sometimes occurs immediately downstream of the defined dredge cut footprint, and this additional sediment is included in the accounting for the Redeye Crossing volume.

- Currents induced by the drawdown associated with vessel traffic can induce sloughing of material from the bankline and shallows into the channel. This vessel influence is not included in the modeling analysis

- The dredging frequency in the model is set at once per year (on October 1st). The dredging frequency in the prototype is often several times a year, and is generally during the falling hydrograph. This increased dredging frequency could potentially create capacity for more deposition.

The last of these potential issues (the discussion of dredging frequency) was investigated with a model sensitivity test. The model was run for one of the simulation years (2009), but the dredge frequency was altered such that continuous dredging occurred in the model. A sensitivity index was then calculated, which is equal to the volume dredged with continuous dredging divided by the volume dredged for one dredging event per year (Oct 1st). The results are shown in Figure 3.4

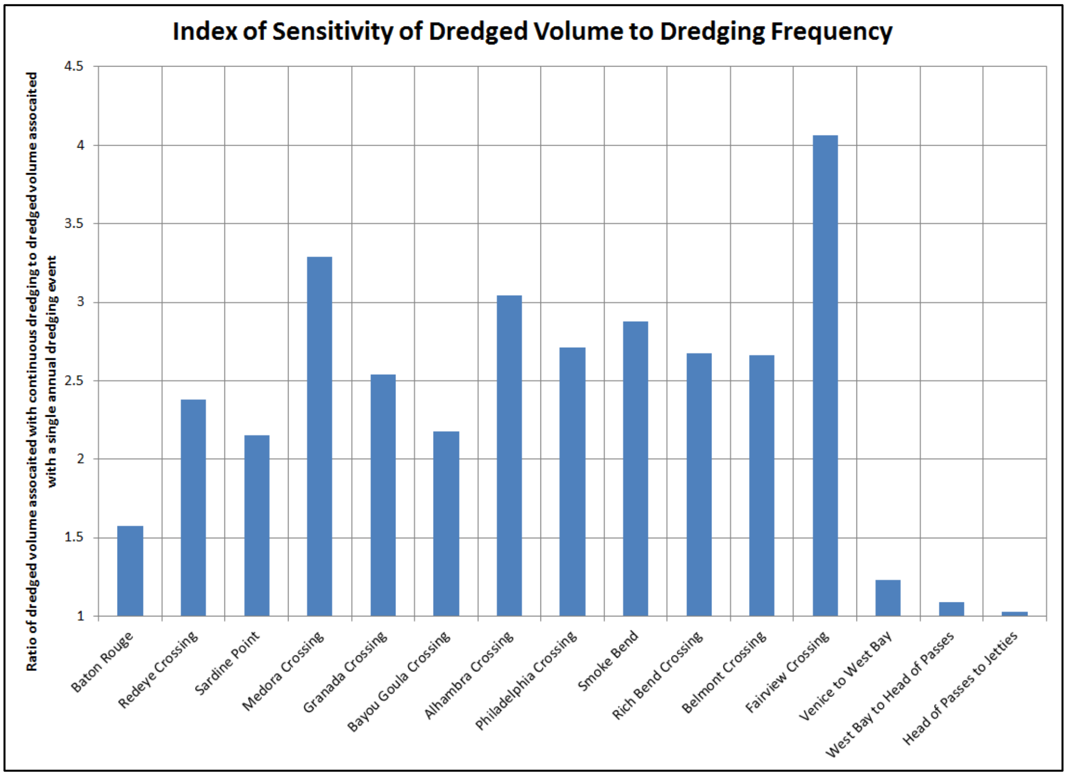


Figure 3.4: Model Sensitivity Test to Determine the Sensitivity of Modeled Dredged Volume to Dredging Frequency

These results indicate that there is a significant correlation between dredging frequency and dredged volume at almost all of the crossings (the exceptions are Baton Rouge Front and the Venice to Southwest Pass reaches). This means that reaches for which dredging is more frequent, such as Redeye Crossing, are expected to infill more rapidly than they would if they were dredged less frequently. This sensitivity represents an uncertainty in the modeling, since the spatial and temporal distribution of observed dredging is not recoded with sufficient detail to be replicated in the model.

To address these uncertainties, the model results for the plan conditions are reported in terms of relative changes in deposition, and they are supplemented with observed data in order to develop cumulative analyses of the results. The details of these procedures are given in the next chapter.

4 Model Results

4.1 Scenarios Analyzed

Table 1.1 lists the deepening scenarios that were analyzed for this study. Table 4.1 lists the entire set of model simulations that were performed. These model simulations were selected such that the impacts of the deepening scenarios could be analyzed for the full range of future potential relative sea level rise conditions that are required as per USACE guidance (see discussion in section 2.3 of this report).

Table 4-1: List of Model Simulations

Scenario	Dredging Condition	Sea Level Elevation	Duration of Simulation (yrs)
BA-YR0-L	Existing	YR 0 (2025):Historic Rate	3
TS-YR0-L	TSP	YR 0 (2025):Historic Rate	3
A3-YR0-L	Alt3	YR 0 (2025):Historic Rate	3
4E-YR0-L	Alt3e	YR 0 (2025):Historic Rate	3
BA-YR50-L	Existing	YR 50 (2075):Historic Rate	3
TS-YR50-L	TSP	YR 50 (2075):Historic Rate	3
A3-YR50-L	Alt3	YR 50 (2075):Historic Rate	3
AE-YR50-L	Alt3e	YR 50 (2075):Historic Rate	3
BA-YR50-M	Existing	YR 50 (2075):NRC I (Medium Rate)	3
TS-YR50-M	TSP	YR 50 (2075):NRC I (Medium Rate)	3
BA-YR50-H	Existing	YR 50 (2075):NRC III (High Rate)	3
TS-YR50-H	TSP	YR 50 (2075):NRC III (High Rate)	3
TS-YR50-S	TSP	YR 50 (2075):NRC I (Medium Rate) with net subsidence from YR0-YR50	3

4.2 Calculation of Dredging Indices

To address the uncertainties associated with the distribution of the deposition of sediment in the crossings (as discussed in the previous chapter), the model results for the scenario conditions are presented as follows:

The model results for base/plan comparisons for each crossing are reported in terms of a dredging index, which is given as follows:

$$I_D = \frac{V_{D.PLAN}}{V_{D.BASE}} \tag{1}$$

Where I_D is the Dredging Index, $V_{D.PLAN}$ is the volume of sediment dredged with plan channel depths implemented in the model, and $V_{D.BASE}$ is the volume of sediment dredged with existing channel depths implemented in the model. Note that both volume calculations are performed for the same boundary conditions, including sea level rise conditions. This is why “BASE” is used instead of “EXISTING”, since existing implies current sea level conditions.

As was noted previously, silt and clay sediments were not modeled for this study. However, a 1D analysis was conducted for a separate study, and this analysis did include silt and clay sediment classes, although the behavior of these sediments was highly calibrated (i.e. their behavior in this model cannot be said to be closely linked to the true physical processes that govern fine sediment deposition under stratified conditions.)

An inspection of the dredging indices that are associated with these fine sediment classes in the lowermost river reveals that they are very close to 1. Therefore, in order to generate results for the lowermost river, the dredging indices computed for this study for the sand classes were combined with an assumed dredging index for 1 for the silt and clay classes. This was done by computing a weighted average of the dredging index for each reach, weighted by an approximation (taken from the 1D results) of the fraction of sand deposited by reach. This fraction was determined to be as follows: for the Venice to West Bay Reach, 65% , for the West Bay to Head of Passes reach, 60% , and for the Southwest Pass Reach, 20%.

The model results for cumulative comparisons (i.e. all crossings) are computed in terms of a weighted average Dredging Index, where the indices for each crossing are weighted by the observed dredged volume for that crossing, based on observations for the years 1999-2015. The resulting computation is given in Equaiton 2.

$$I_{DC} = \frac{\sum_{i=1}^{i=ncross} \frac{V_{D.PLAN.i}}{V_{D.BASE.i}} V_{D.OBSERVED.i}}{\sum_{i=1}^{i=ncross} V_{D.OBSERVED.i}} \tag{2}$$

Where I_{DC} is the Cumulative Dredging Index for all Crossings, ncross is the total number of crossings (for this calculation, this does NOT include the lowermost river from Venice to Head of Passes), $V_{D.OBSERVED}$ is the observed volume of sediment dredged in crossing i from 1999 through2015.volume of sediment dredged with plan channel depths implemented in the model, and $V_{D.BASE}$ is the volume of sediment dredged with existing channel depths implemented in the model.

4.3 Dredging Indices for the Crossings and Lowermost River Reaches for Each Scenario: Yr0 Analysis

The dredging indices for each crossing and the lowermost river reaches are given in Figure 4.1 and Table 4.2 for the Yr0 analysis.

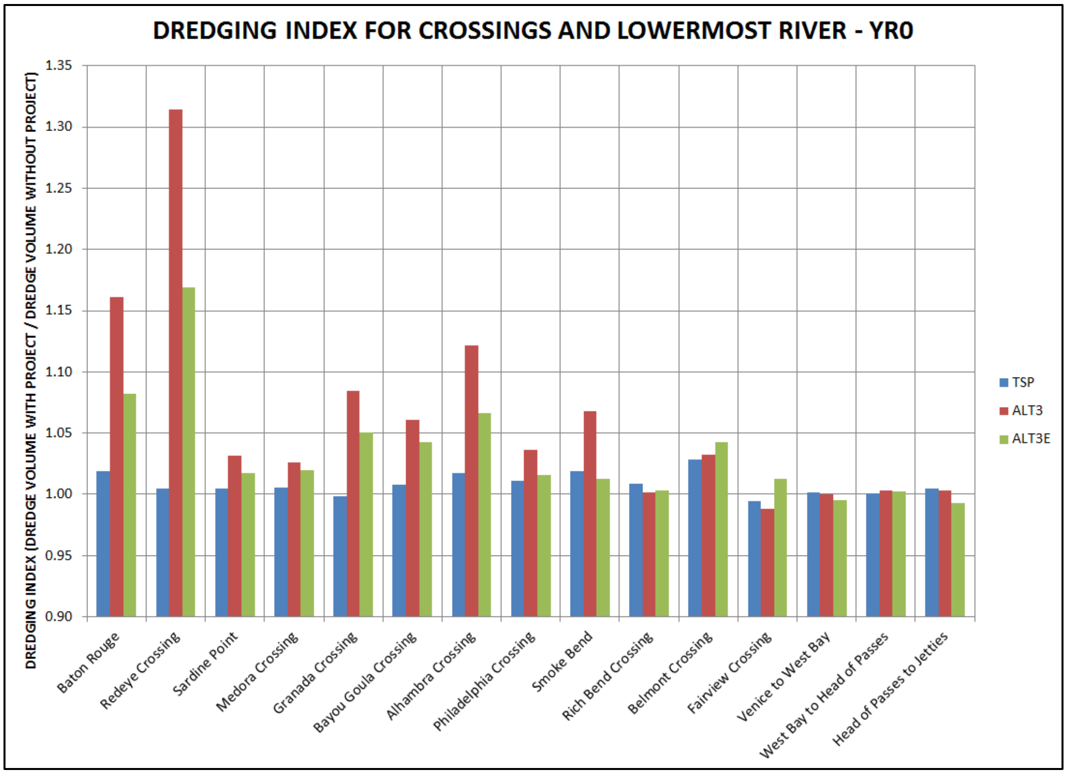


Figure 4.1: Dredging Indices for Each Crossing and the Lowermost River Reaches for the Yr0 Sea Level Analysis

Table 4-2: Dredging Indices for Each Crossing and the Lowermost River Reaches for the Yr0 Sea Level Analysis

Crossing/Reach	**TSP**	**ALT3**	**ALT3E**
Baton Rouge	1.02	1.16	1.08
Redeye Crossing	1.00	1.31	1.17
Sardine Point	1.01	1.03	1.02
Medora Crossing	1.01	1.03	1.02
Granada Crossing	1.00	1.08	1.05
Bayou Goula Crossing	1.01	1.06	1.04

Alhambra Crossing	1.02	1.12	1.07
Philadelphia Crossing	1.01	1.04	1.02
Smoke Bend	1.02	1.07	1.01
Rich Bend Crossing	1.01	1.00	1.00
Belmont Crossing	1.03	1.03	1.04
Fairview Crossing	0.99	0.99	1.01
Venice to West Bay	1.00	1.00	1.00
West Bay to Head of Passes	1.00	1.00	1.00
Head of Passes to Jetties	1.00	1.00	0.99

These results demonstrate that the implementation of the TSP has very little impact on dredging. The largest impacts for the TSP are observed at Belmont Crossing, with a dredging index of 1.03. The largest relative impacts to dredging (as measured by the dredging index) for any of the scenarios are seen at Redeye Crossing and Baton Rouge front. Specifically, the largest dredging indices are seen for the Alt3 simulations, which specify a 50’ channel from the Gulf to Baton Rouge. The largest single dredging index is for alt3 at Redeye Crossing, with a value of 1.31.

4.4 Dredging Indices for the Crossings and Lowermost River Reaches for the TSP scenario: Sea Level Rise Sensitivity

Figure 4.2 shows the dredging indices for the TSP for various future sea level rise conditions.

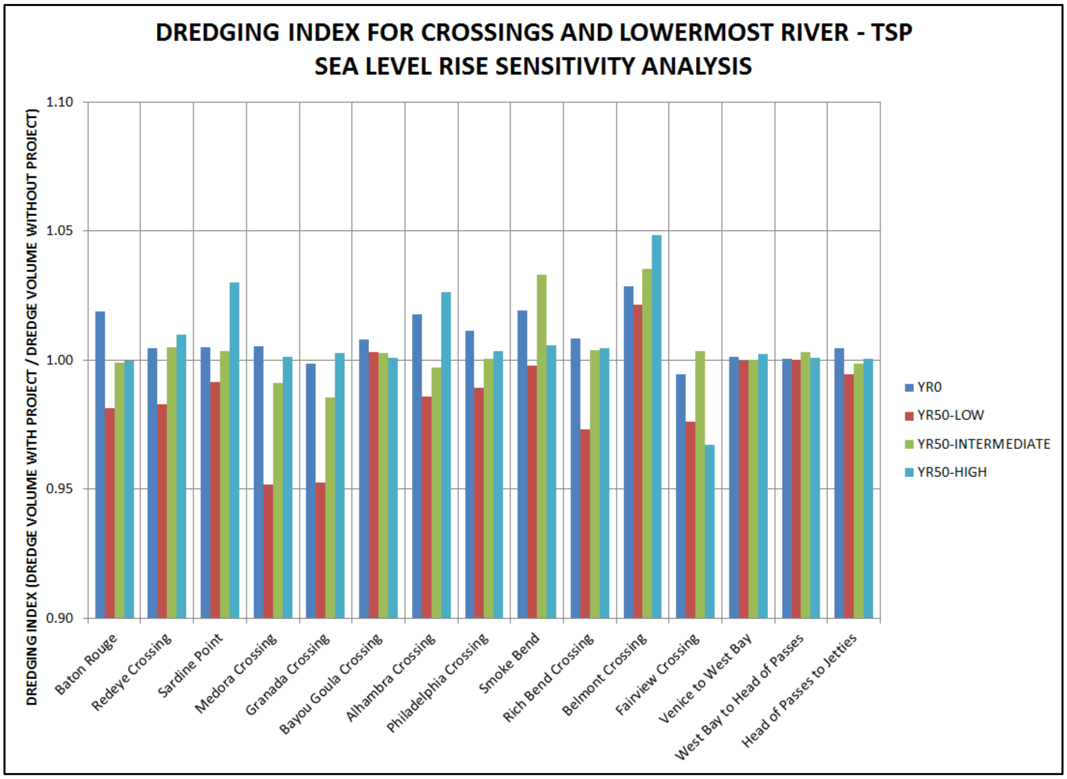


Figure 4.2: Dredging Indices for Each Crossing and the Lowermost River Reaches for the TSP scenario: Sea Level Rise Sensitivity Analysis

The analysis shows very little sensitivity to sea level rise for any of the future sea level changes. The largest changes are observed for the low future sea level rise condition, where there is a general reduction in the TSP dredging (relative to without project conditions) that is not observed for the other sea level conditions. The reason for this may be associated with a nonlinear influence on the distribution of sediment deposition associated with sea level, but this explanation is speculative. In any case, the magnitude of the influence of the sea level on all of the results is small, and therefore it is not necessary to identify the true cause of this behavior in order to assess the sensitivity of the scenario analyses to sea level.

The influence of sea level on deposition in the lowermost river is not obvious in these results, but this is primarily because this influence is primarily associated with changes to the sand deposition, which is only a fraction of the total input to the dredging indices for the lowermost river (see section 4.2 of this report). Figure 4.3 shows how the increase in sea level influences the deposition of sand in the lowermost river.

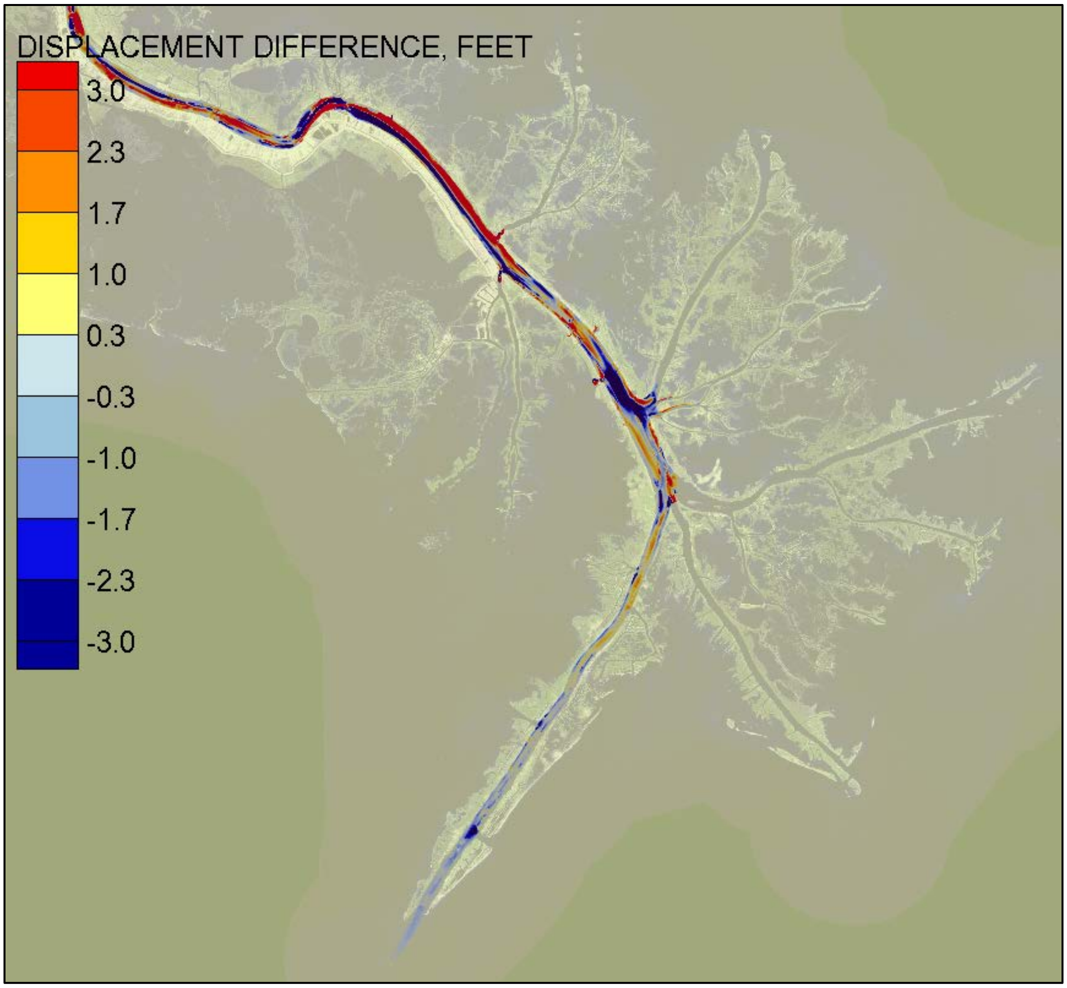


Figure 4.3: Sand Displacement Difference (YR50 NRCI ESLR minus YR0, existing dredge template) illustrating the influence of sea level rise on deposition patterns in the lowermost Mississippi River

Figure 4.3 illustrates that sea level rise causes deposition to migrate upstream in the lowermost river. This is due to 2 different factors: the increased sea level causes the backwater surface to migrate upstream, which in turn causes the locus of deposition in the lowermost river to migrate upstream, and the increase in sea level greatly increases the diversion capacity of the Ft St Philip and Bohemia Spillway diversions, which reduces the transport capacity of the river and cases the sand to deposit further upstream.

4.5 Cumulative Dredging Indices for the Crossings

Using Equation 4.2, cumulative dredging indices that are weighted by the observed dredging quantities are generated for the crossings. These are given in Table 4.3. These indices reflect the general trend observed in the analysis of the individual crossings: i.e. the TSP shows very small relative impacts, and the largest impacts are associated with the Alt3 simulations. The relatively large value of the index for Alt3 (1.16) reflects the influence of weighting the individual crossings by the observed dredging quantities for those crossings. This means, for example, that Redeye Crossing, which has the highest individual dredging index for all the crossings, is given significant weight in this computation, based on the historical dredging volume associated with this crossing.

Table 4-3: Cumulative Dredging Indices for All Crossings

Deepening Alternative	**YR-0 Sea Level**	**YR50-Sea Level, Historic Rate of Rise**	**YR50-Sea Level, NRCI Rate of Rise**	**YR50-Sea Level, NRCIII Rate of Rise**
TSP	1.03	1.01	1.02	1.03
ALT3	1.16	1.16		
ALT3-E	1.10	1.09		

Table 4.4 is a sensitivity analysis of the cumulative dredging index for the TSP associated with sea level rise, for the crossings. The RSLR Sensitivity Index, given in this table, is simply the dredging index for the given sea level condition divided by the dredging index for the yr0 sea level condition. This index, then, indicates how the influence of the TSP is altered by changes in sea level. This analysis also includes results for the subsidence sensitivity simulation. The analysis indicates that the influence of the TSP on dredging is relatively insensitive to the uncertainty in future sea level and/or subsidence.

Table 4-4: Sensitivity of Cumulative Dredging Index for All Crossings for the TSP analysis to uncertainty associated with future Sea Level and/or Subsidence

Target RSLR Condition	**RSLR Sensitivity Index**
YR50–Historic Rate of Rise – Without Subsidence	1.00
YR50-NRC1 Rate of Rise – Without Subsidence	0.97
YR50-NRCI Rate of Rise – With Subsidence	1.03
YR50-NRCIII Rate of Rise – Without Subsidence	0.99

5 Conclusions and Recommendations

This study consists of an assessment the potential impacts of several proposed deepening alternatives on the dredging requirements for the Lower Mississippi River. This assessment was conducted with the use of an existing Adaptive Hydraulics (AdH) model of the Lower Mississippi River, that was developed and verified against observations as a product of the Mississippi River Hydrodynamic and Delta Management Study. The study consists of the following tasks.

- Verification of the existing model against observed dredging volumes for the crossings in the Lower Mississippi River
- Simulations for the existing conditions, the Tentatively Selected Plan (TSP), and 2 additional deepening alternatives, and evaluation of system responses to the deepening alternatives by comparison of the alternatives to the existing conditions simulations
- Evaluation of the sensitivity of the alternative comparisons to various eustatic sea level rise conditions.

The validation results show that the model predicts the cumulative volume accurately, but the model does not predict the distribution of deposition among the crossings consistently. Some crossings, such as Baton Rouge Front and Alhambra Crossing, are very well predicted. Others, such as Redeye Crossing and Philadelphia Crossing, are not. To address this, the model results are presented in terms of relative impacts on dredging for the individual crossings (with the use of Dredging Indices), and all integrated results are presented in terms of Cumulative Dredging Indices that are weighted by historical dredging quantities.

The scenario analysis results demonstrate that the implementation of the TSP has very little impact on dredging. The largest impacts for the TSP are observed at Belmont Crossing, with a dredging index of 1.03. The largest relative impacts to dredging (as measured by the dredging index) for any of the scenarios are seen at Redeye Crossing and Baton Rouge front. Specifically, the largest dredging indices are seen for the Alt3 simulations, which specify a 50' channel from the Gulf to Baton Rouge. The largest single dredging index is for alt3 at Redeye Crossing, with a value of 1.31.

The sea level rise analysis show little sensitivity to sea level rise for the results, as determined by the relative impacts associated with the implementation of the scenarios. That is, the change in dredging associated with each scenario is not significant influenced by the sea level condition.

Sea level rise in the lowermost river does tend to cause an upstream migration of the location of sand deposition, but this has a relatively small impact on the total deposition due to the fact that sand is only a fraction of the total sediment deposited in the lowermost river.

It must be emphasized that assumptions concerning the behavior of deposition of silts and clays (primarily expected in the lowermost river) have bene extrapolated from a 1D analysis of the lowermost river, that was itself highly calibrated against observed dredging. The physics that governs this behavior is in fact a complex, nonlinear interaction between fine sediment supply and the position of the salt wedge. Hence, a detailed 3d analysis is necessary to define this fine sediment behavior, in order to ensure that the implementation of deepening will not result in significant changes to deposition patterns in the lowermost river.

The following recommendations are given as a suggested means to improve our understanding of the processes that govern deposition and morphologic change in the Lower Mississippi River.

- *A field study of deposition at Redeye Crossing*. Model results consistently underpredict the deposition at Redeye Crossing. This suggests that processes not represented in current models are responsible for a significant portion of the deposition. This may include, for example, bank sloughing due to suction from vessel induced drawdown. A thorough field study, including extensive sequential bathymetric surveys, would help to illuminate the causes of this deposition.

- *A numerical study of dredged material rehandling*. It is possible that a significant volume of sediment dredged in the crossings consists of material that was placed upstream from previous dredging. A numerical study of the degree to which this is occurring would be helpful, as well as some investigations of how these problems could be mitigated.

- *A detailed statistical investigation of potential correlation between the previous deepening to 45 feet and changes in dredging requirements*. Dredging records indicate a significant increase in dredging in the crossings that corresponds to the time of the previous deepening. However, a rigorous statistical study is needed to isolate this factor from other factors that can influence dredging (such as river discharge) to determine if there is a statistically significant correlation. If this correlation can be established, it can be used to inform the predictions of the potential for dredging changes associated with additional deepening.

6 References

Bernard, B., (1992) “Depth-Average Numerical Modeling for Curved Channels” Technical Report HL-92-9, U.S. Army Corps of Engineers, Engineering Research and Development Center, Vicksburg, MS.

Brown ,Gary L., Jennifer N Tate, Kimberly Pevey, Carol Richards, Cherie Price, Barbara Kleiss, 2015 “ Mississippi River Hydrodynamic Study: Multi-Dimensional Modeling: AdH/SEDLIB Multi-Dimensional Model Study. Coastal and Hydraulics DRAFT Technical Report.

Brown, Gary L, 2012a, “A Quasi-3D Suspended Sediment Model Using a Set of Correction Factors Applied to a Depth Averaged Advection Diffusion Equation”, proceedings, IIHR 3rd International Shallow Flows Symposium, University of Iowa, 2012.

Brown, Gary L, 2012b, “Modification of the bed sediment equations of Spasojevic and Holly (1993) to account for variable porosity, variable grain specific gravity, and nonerodable boundaries” proceedings, IIHR 3rd International Shallow Flows Symposium, University of Iowa, 2012.

Brown, Gary L. “Approximate Profile for Nonequilibrium Suspended Sediment” Vol. 134, No. 7, July 2008, pp. 1010-1014.

Egiazaroff L. V. (1965) “Calculation of Non-Uniform Sediment Concentration” Journal of Hydraulics Division, ASCE, 91(HY4), 225-248.

Kleinhans, M.G. and van Rijn, L.C.,2002, “Stochastic Prediction of Sediment Transport in Sand-Gravel Bed Rivers”, *Journal of Hydraulic Engineering,* Vol. 128, No. 4, April 2002.

van Rijn ,L.C. 1984, Sediment Transport, Part I: Bed Load Transport, J. Hydr. Engrg. 110, 1431 DOI:10.1061/(ASCE)0733-9429(1984)110:10(1431)

Wright, S., and Parker, G. (2004)."Flow resistance and suspended load in sand-bed rivers: simplified stratification model," Journal of Hydraulic Engineering, 130(8),796.

Appendix A: Morphologic Time-Scaling with Modified Porosity

Theoretical Foundation of Modified Porosity Scaling

In order to investigate the long term (multi-decadal) morphologic change, it is necessary to develop a means whereby morphologic change can be "accelerated" within the model. For quasi-steady conditions (i.e. slowly-varying conditions) a simple and straightforward method of estimating this acceleration is to scale the porosity of the sediment. Consider the basic equation of mass conservation for a sediment bed (for simplicity, this is shown for a bed consisting of one grain class only, but the same principles apply for a multi-grain class sediment bed).

$$D - E = \rho s \left(1 - p\right) \frac{\partial \eta}{\partial t} \qquad 1$$

That is, the deposition flux minus the erosion flux is equal to the density of sediment, times one minus the porosity, times the time rate of change of the bed elevation.

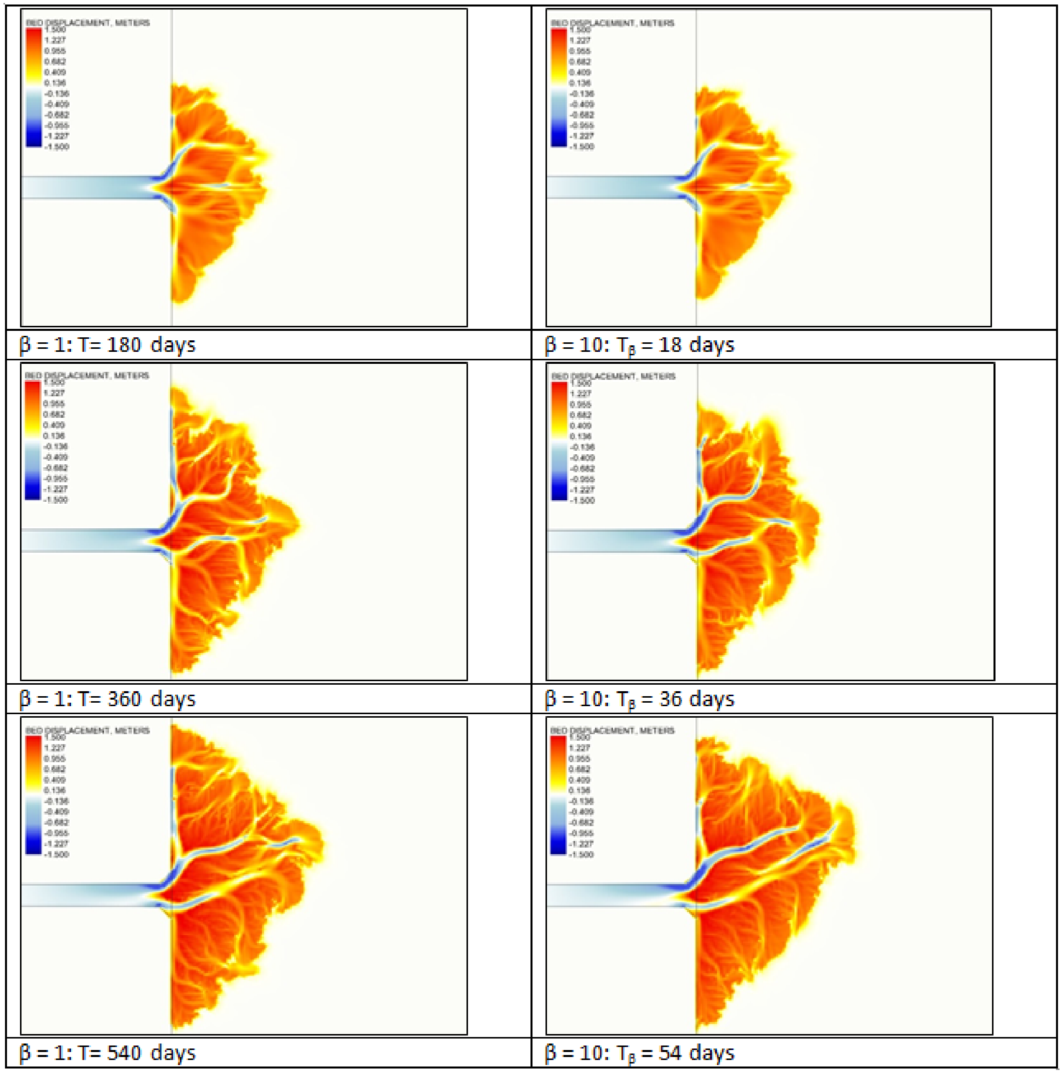
If we wish to accelerate the rate at which the same net flux (deposition minus erosion) will change the bed elevation by some acceleration factor β, we can substitute into Equation 1 and solve for the porosity necessary to achieve this acceleration (p_β).

$$D - E = \rho s \left(1 - p\right) \frac{\partial \eta}{\partial t} = \rho s \left(1 - p_\beta\right) \beta \frac{\partial \eta}{\partial t} \qquad 2$$

$$\boxed{p_\beta = 1 - \frac{1}{\beta}\left(1 - p\right)} \qquad 3$$

For example, for $p = 0.3$ and $\beta = 10$, $p_\beta = 0.93$.

Figure A.1 demonstrates how porosity scaling works for a wetland formed under steady inflow conditions.



$\beta = 1$: T= 180 days

$\beta = 10$: $T_\beta = 18$ days

$\beta = 1$: T= 360 days

$\beta = 10$: $T_\beta = 36$ days

$\beta = 1$: T= 540 days

$\beta = 10$: $T_\beta = 54$ days

Figure A.1. Demonstration of Porosity Scaling for a Wetland Formed by a Steady Inflow of Water and Sediment

Practical Limits of Modified Porosity Scaling

Note that porosity scaling is only strictly valid for steady flow conditions. When unsteady conditions are present, time scaling will scale the relative magnitude of the temporal terms in the mass and momentum equations by the same scale factor (β).

For a typical river hydrograph, using a value of β that is too large will result in significant changes in the velocities, due to rapid rise and fall of the hydrograph in the scaled condition. These changes will alter the erosion and deposition patterns of the river, and hence the porosity scaling method of time acceleration would yield invalid results.

If there are short period variations in the time series data for the inflow boundary and/or the stage boundary, it may be useful to filter these data to smooth these variations. Note, however, that this filtering should only be done if the short period variations are not significant factors in the morphologic evolution of the system.

There is no systematic way to determine what the maximum allowable value of β is for any given project. Therefore, for each project, it is important to perform a numerical test (such as the one demonstrated in Figure 1) to ensure that the selected value of β yields morphologic results that are sufficiently similar to the unscaled results to permit the use of porosity scaling for the project. The results of this test should be included in the project reporting.

The time series associated with the hydrograph data should be scaled by the inverse of β. For example, if β =10 and the total elapsed time of the hydrograph (T) is 10 years, then the total elapsed time of the scaled hydrograph(T_β) should be 10/10 = 1 year. This is how model performance is improved: since the model time step is unchanged, the model will run 10 times faster than it would have without the porosity scaling.

Regardless of the results of the sensitivity analysis, it is recommended that the value of β never exceed 10. This is because values larger than 10 result in very large values of scaled porosity, which in turn can result in asymptotic errors associated with the projection of bed change (note that Equation 1 is a function of (1 –p), which asymptotically approaches 0 for large values of p).

Inclusion of High Frequency Periodic Forcings (e.g. tides).

It has been noted that this scaling cannot be applied to high frequency variations, such as tidal conditions, because scaling this high frequency signal would dramatically alter the resulting velocities. However, if it is assumed that the influence of the high frequency signal is largely periodic, the signal can be modeled without scaling if the *number* of cycles within a simulation is scaled. For example, if β=10, T=10 years, and there are 360 cycles in 1 year (e.g. a 24hr tidal signal), the river and tide can be modeled within the same model as follows:

- River: $ß=10$, $T_{ß}$ =1 year
- Tide: $ß=1$, $T_{ß}$ =1 year, total number of tides modeled = 36.

Again, testing of these methods should be performed for any specific application before they are used to assess scenarios.

Mississippi River Ship Channel
Gulf to Baton Rouge, LA
Integrated General Reevaluation Report
And Supplemental Environmental Impact Statement

Appendix H

Annex 3

Mississippi River Ship Channel project 3D salinity intrusion analysis

April 2018

Mississippi River Ship Channel project 3D salinity intrusion analysis

Background

A Delft3D model developed under the LCA Mississippi River Hydrodynamic and Delta Management Study (MRH&DM) as recommended by the *Louisiana Coastal Area (LCA), Louisiana Ecosystem Restoration Study* (January 2005) will be used as the basis for a numerical model study of salinity intrusion impacts of the Mississippi River Ship Channel project. In particular, the model is a Delft3D model utilizing the Cartesian layering scheme option to define the vertical resolution of the model. This layering scheme was found to be crucial to rendering the saline density current or "salinity wedge" present in the lower Mississippi River during drought conditions. The model development is documented in "A Report on the Development, Calibration and Initial Application of a Delft3D *Z* Coordinate Model in the Mississippi Delta", July 2017 and "1st Addendum to "A Report on the Development, Calibration and Initial Application of a Delft3D *Z* Coordinate Model in the Mississippi Delta"", July 2017.

Model development, calibration and verification

The aforementioned Delft3D model grid developed for the MRH&DM study was modified for use in this study. The upstream river boundary, originally located at RM 75 near Belle Chasse, LA was extended upstream to RM 116 at Fairview crossing in order to provide the ability to analyze the furthest upstream intrusion of the saltwater density current. Depth information for this new section of grid between RM 75 and RM 116 was sourced from the 2D ADH model utilized in this study.

The upstream boundary discharge data source was changed from daily USACE discharge at Tarbert Landing to hourly USGS discharge at Baton Rouge. This change was made due to the closer proximity of the data to the upstream boundary and to remove any storage lag effects on the data that may occur during high water events when the overbank areas between Tarbert Landing and Baton Rouge may become inundated.

Other boundary data such as air temperature, wind, tides and water quality characteristics remained the same as that used in the MRH&DM study. The MRSC Delft3D grid coverage and bathymetry is shown in Figure 1.

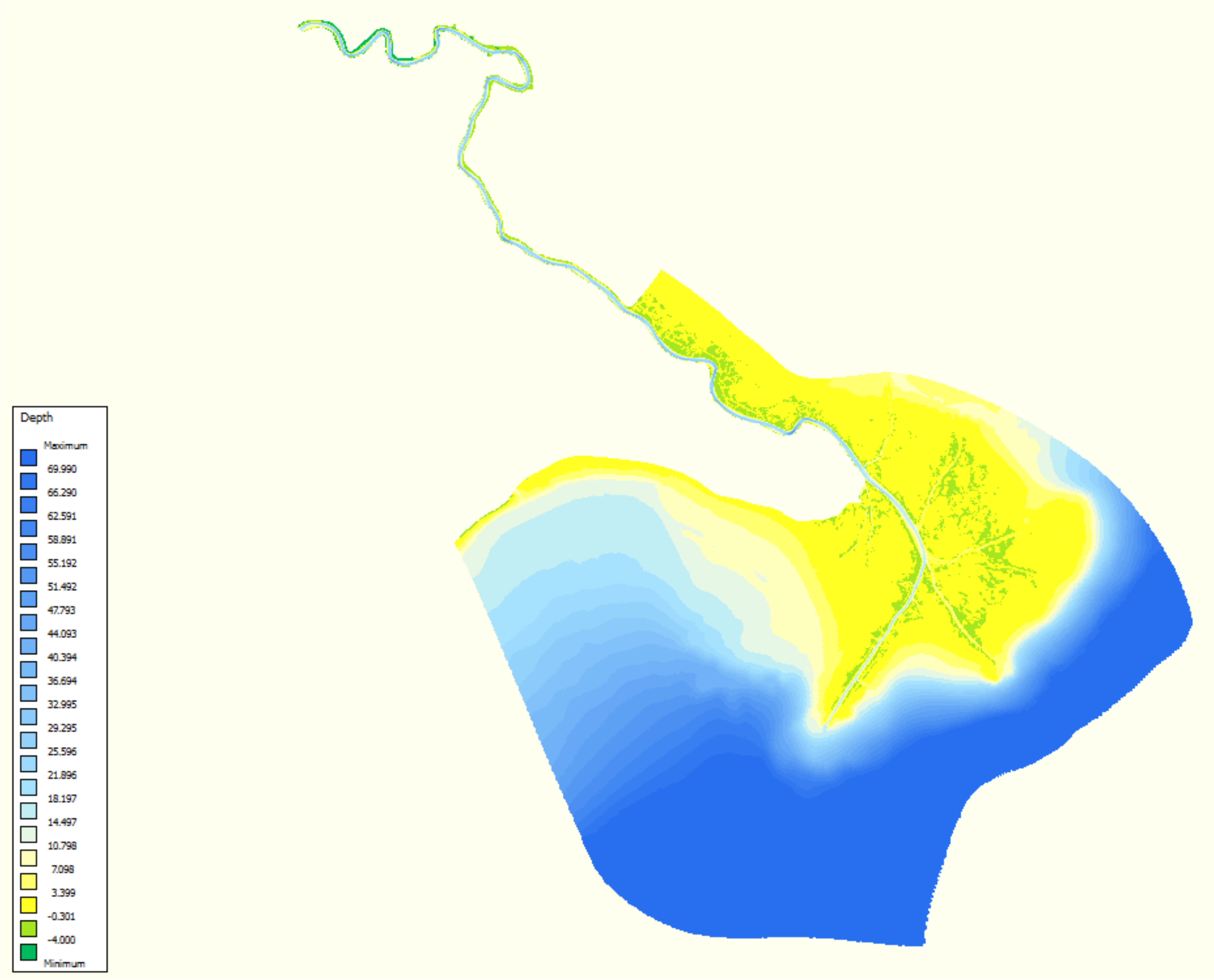


Figure 1 Expanded Delft3D grid bathymetry for the MRSC project.

The new model grid was calibrated to water levels referenced to NAVD88 (2009.55). Subsequent to development of the MRH&DM model, it was determined that the vertical reference NAVD88 (2004.65) geoid was erroneous in the Mississippi River Delta as documented in "Sensitivity Analysis on Storm Surge Modeling Results for the Lake Pontchartrain and Vicinity (LPV), West Bank and Vicinity (WBV) and New Orleans to Venice (NOV) Non-Federal Levee (NFL) Incorporation into NOV Hurricane Storm Damage and Risk Reduction (HSDRRS) Projects due to the Vertical Datum Update from NAVD88 (2004.65) to NAVD88 (2009.55)", July 2014. This recalibration of water level was accomplished solely by adjustment of the tide boundary condition water levels and adjustments to the bed frictions parameters as deemed necessary.

The vertical resolution of the model was increased from 14 to 16 horizontal levels in order to provide finer resolution in the region of the interface between the freshwater and saltwater layers. This was determined in the original study to be important in order to enable more accurate propagation of the saltwater density current and resolution of the salinity and temperature vertical profiles. The river is no deeper than 70 meters in the model domain, therefore, all bathymetry nodes in the Gulf of Mexico were raised to a depth of 70 meters where deeper in order to reduce the number of vertical levels required. Those deep portions of the model domain do not influence the model results in the river as salinity intrusion is generally controlled by the depths at the mouth of Southwest Pass which is no deeper than 16 meters. The vertical layer scheme selected for this study is summarized in Table 1.

Table 1 Vertical level design

Level number	Representative elevation range (meters NAVD88)	Level thickness (meters)
1	-70 to -52	18
2	-52 to -40	12
3	-40 to -32	8
4	-32 to -27	5
5	-27 to -24	3
6	-24 to -22	2
7	-22 to -20	2
8	-20 to -18	2
9	-18 to -16	2
10	-16 to -14	2
11	-14 to -12	2
12	-12 to -10	2
13	-10 to -7	3
14	-7 to -4	3
15	-4 to -1	3
16	-1 to free surface	varies

Adjustments were made to the turbulence length scale in order to provide a better match to observed salinity wedge intrusion data during the drought of 2012. This adjustment was necessary as the water levels in the Gulf of Mexico were changed to reflect the datum adjustment from NAVD88 (2004.65) to NAVD88 (2009.55).

Water level validation

A simulation of the 2012 drought period from 26 August 2012 through 16 December 2012 was performed in order to analyze model performance in comparison to observed data. Modeled water level is compared to recorded data at 14 sites along the Mississippi River and in the passes. An example comparison plot for the Mississippi River at Carrollton gage is shown in Figure 2. Hurricane Isaac made landfall around the end of August as can be observed in the water level record. No attempt was made to replicate this water level spike induced by storm surge as the focus of this study was salt water intrusion in the Mississippi River. Correlation plots are shown in Figures 3 and 4 for the Carrollton gage site for the entire simulation period and a shorter period without the Hurricane to remove the influence of the Hurricane from the statistics. Table 2 provides a summary of linear trend statistic data at the 14 gage sites that were used to validate model water level performance.

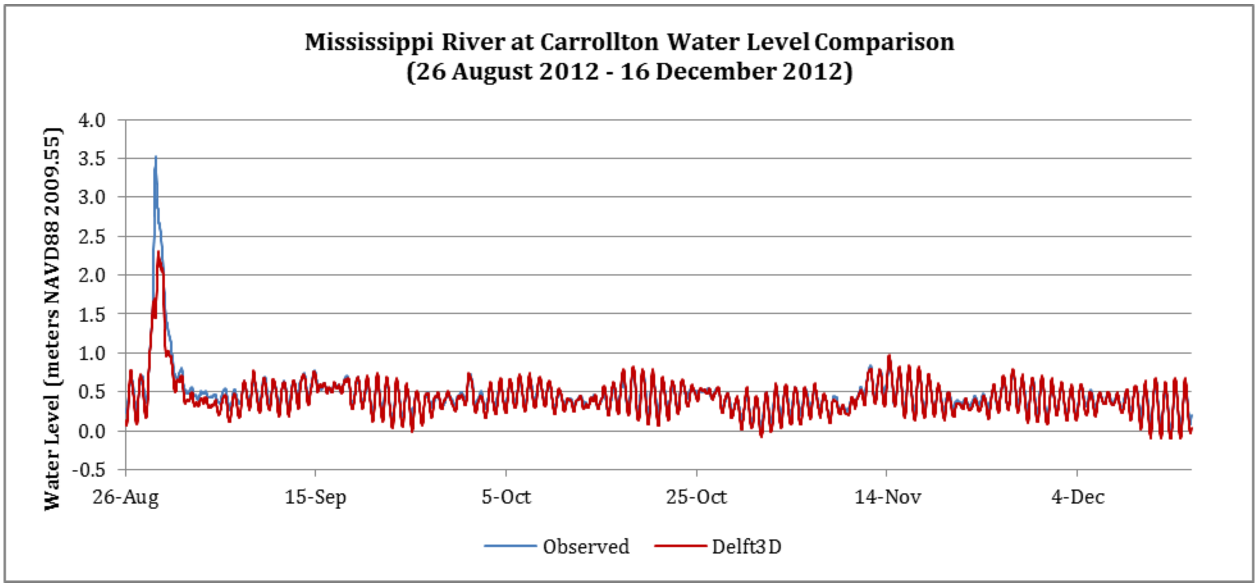


Figure 2 Water level comparison at Carrollton.

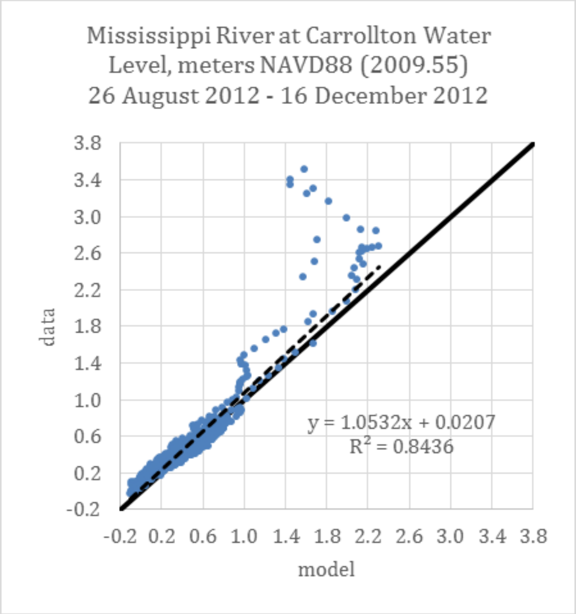


Figure 3

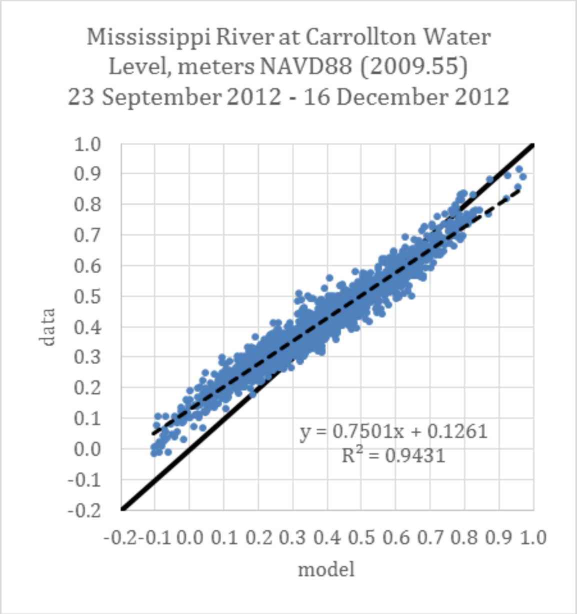


Figure 4

Table 2

Mississippi River Gage Location	Gage ID	RM	26 August 2012 – 16 December 2012 Trend	26 August 2012 – 16 December 2012 R^2	23 September 2012 – 16 December 2012 Trend	23 September 2012 – 16 December 2012 R^2
Carrollton	01300	102.8 AHP	1.0532x + 0.0207	0.84	0.7501x + 0.1261	0.94

Harvey Lock	01320	98.3 AHP	1.0257x + 0.0212	0.82	0.7299x + 0.1279	0.87
IHNC Lock	01340	92.7 AHP	1.0366x + 0.0081	0.83	0.7451x + 0.1058	0.87
Algiers Lock	01380	88.3 AHP	1.0326x + 0.0207	0.82	0.7532x + 0.1144	0.86
Belle Chasse (USGS)	07374525	75.8 AHP	1.0807x + 0.0201	0.83	0.7924x + 0.0606	0.92
Alliance	01390	62.5 AHP	1.1177x + 0.0539	0.82	0.8352x + 0.1241	0.90
West Pointe a la Hache *	01400	48.7 AHP	1.0742x + 0.0195	0.65	0.7104x + 0.0648	0.83
Empire	01440	29.5 AHP	1.1281x + 0.0156	0.83	1.0355x + 0.0003	0.81
Venice	01480	10.7 AHP	1.0470x + 0.0758	0.86	0.9988x + 0.0688	0.84
West Bay	01515	4.7 AHP	1.1639x + 0.0336	0.85	1.0064x + 0.0149	0.80
Head of Passes (South Pass)	01545	0.6 BHP	1.1118x + 0.0175	0.88	1.0043x + 0.0295	0.84
Southwest Pass at RM 7.5 BHP	01575	7.5 BHP	1.1554x + 0.0748	0.92	1.0741x + 0.0867	0.83
Southwest Pass at East Jetty	01670	18.2 BHP	1.0561x + 0.0235	0.94	1.0661x + 0.0214	0.93
South Pass at Port Eads **	01850	10.8 BHP	0.5563x + 0.0151	0.12	1.0620x + 0.0058	0.90

* The West Pointe a la Hache gage bottomed out at about 0.1 meters

** The Port Eads gage had technical issues which invalidate the data from 26 August – about 1 October

Salinity Verification

Van Dorn bottle samples were collected and processed in the 20-24 September 2012 time frame at various locations along the lower Mississippi River channel (Allison, 2014). A few of the salinity sample sets were compared to model results as shown in **Error! Reference source not found.**5-8. The model data shown in the plots represents the top of the hour results closest to the reported sample collection time noted on the plots.

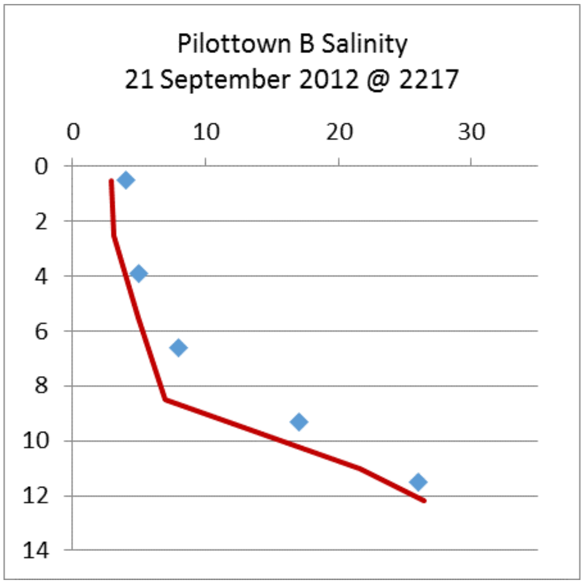
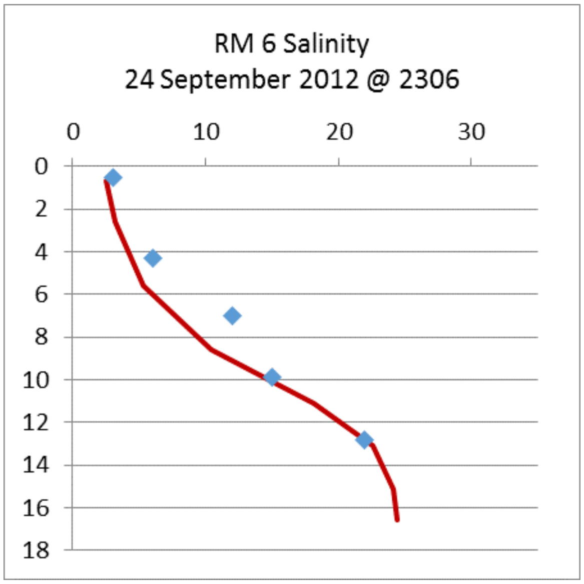


Figure 5



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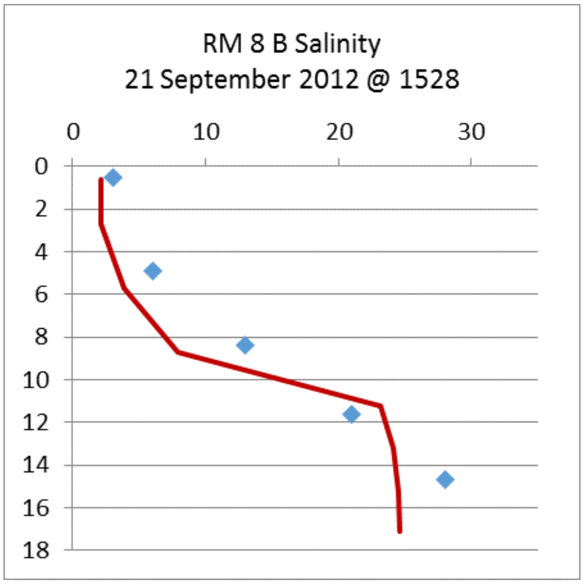

Figure 7

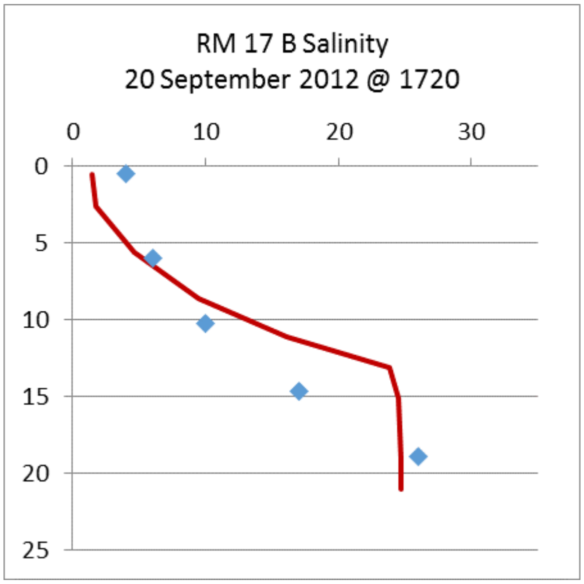

Figure 8

The USACE conducted in-river measurements of temperature, conductivity and depth along the thalweg of the channel to track the progress of the salinity wedge with a YSI Castaway CTD profiler. The following figures show the comparison of model results to the instrument derived salinity. The model data shown in the plots represents the top of the hour results closest to the instrument cast time.

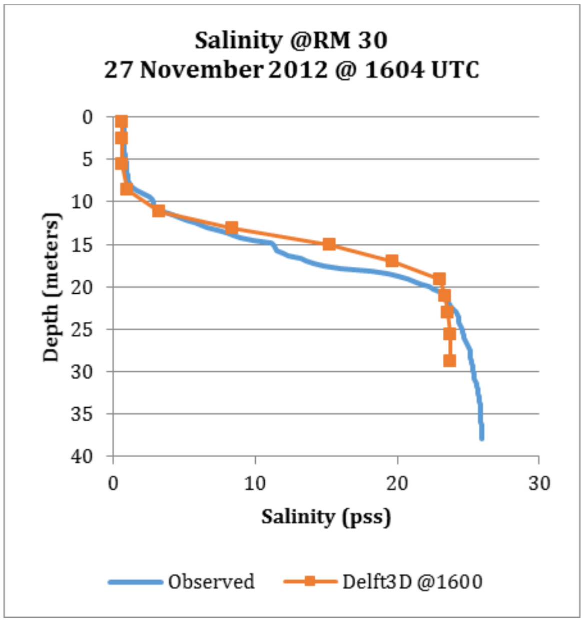

Figure 9

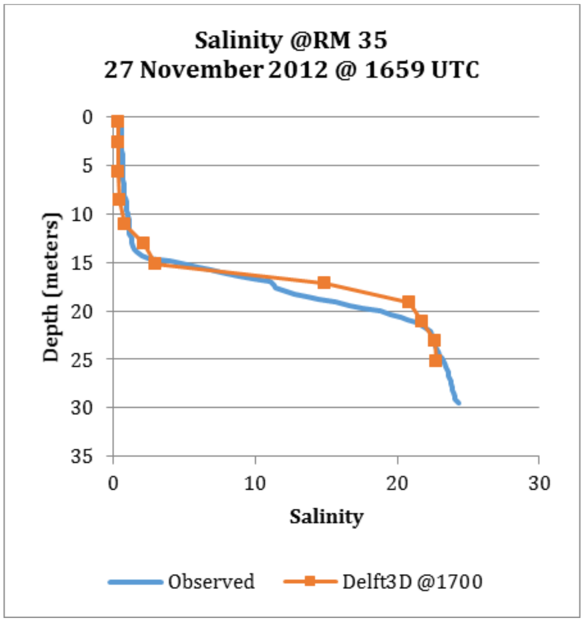

Figure 10

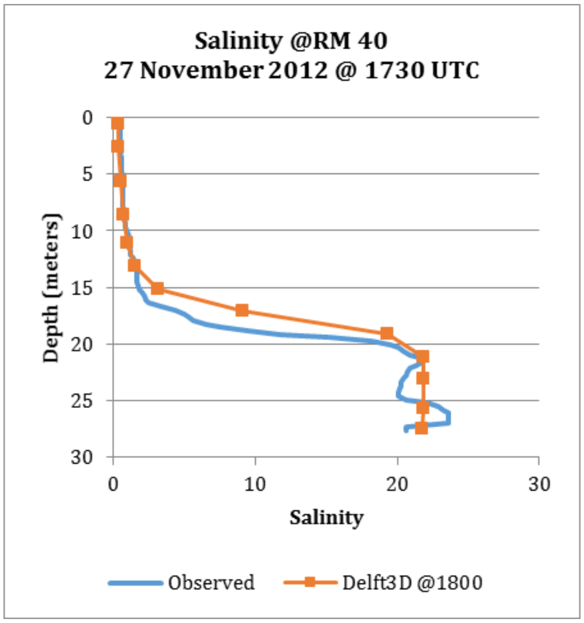

Figure 11

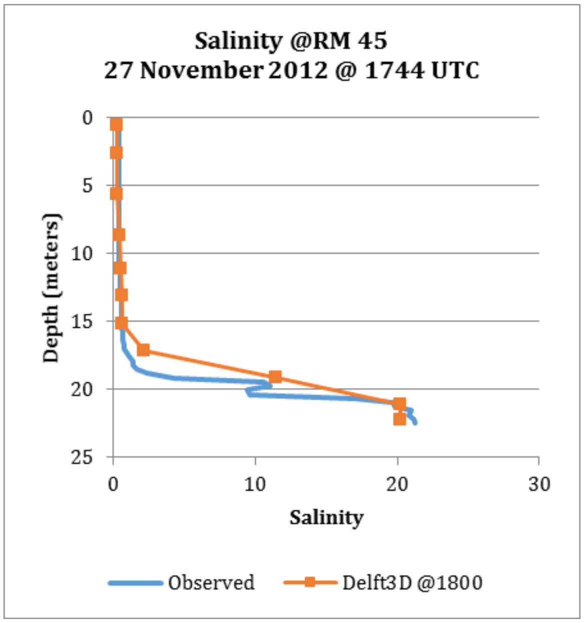

Figure 12

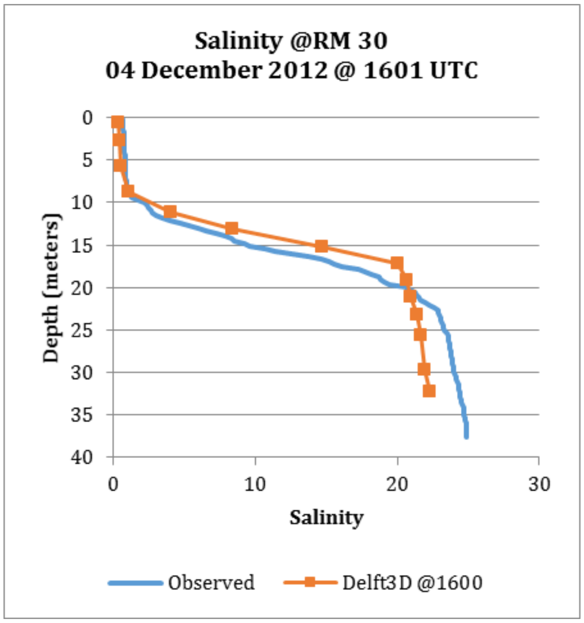

Figure 13

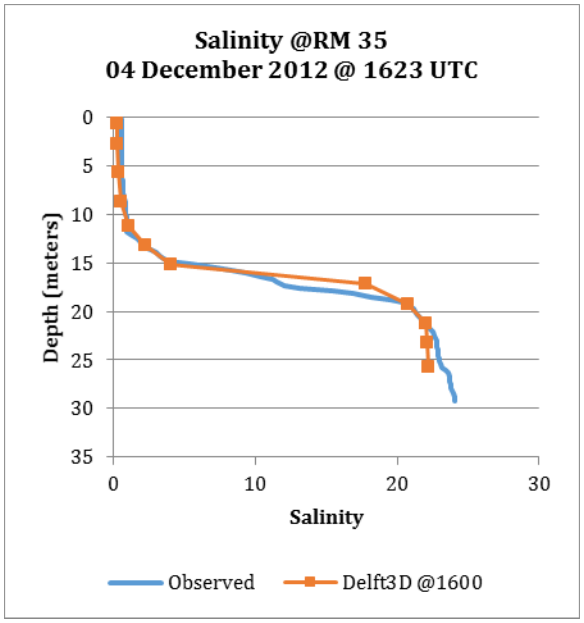

Figure 14

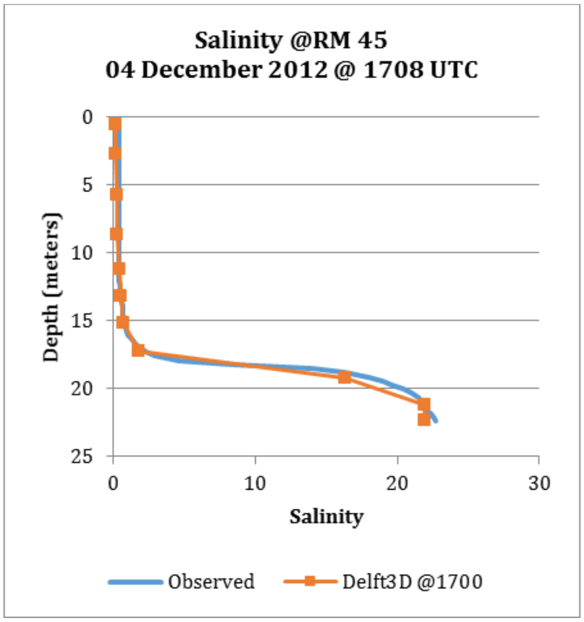

Figure 15

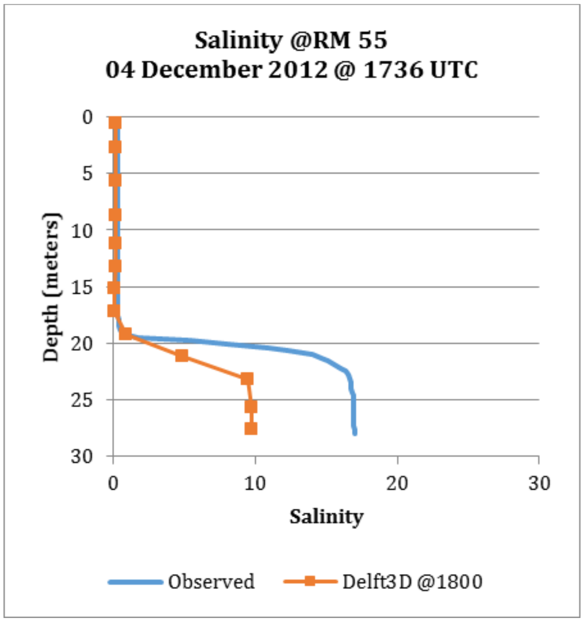

Figure 16

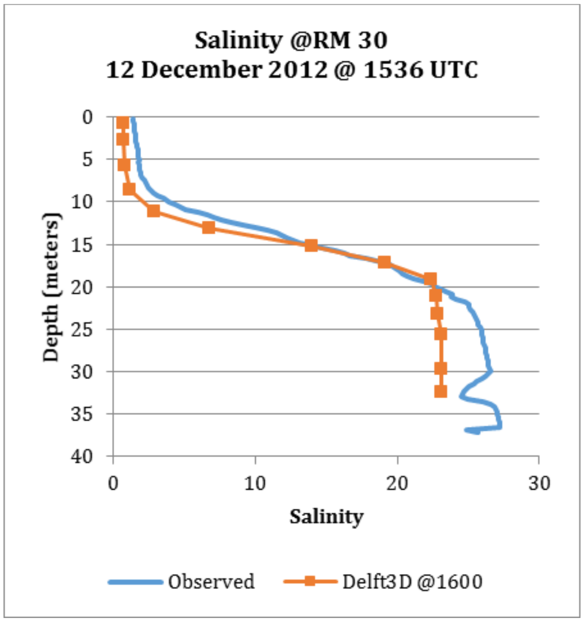

Figure 17

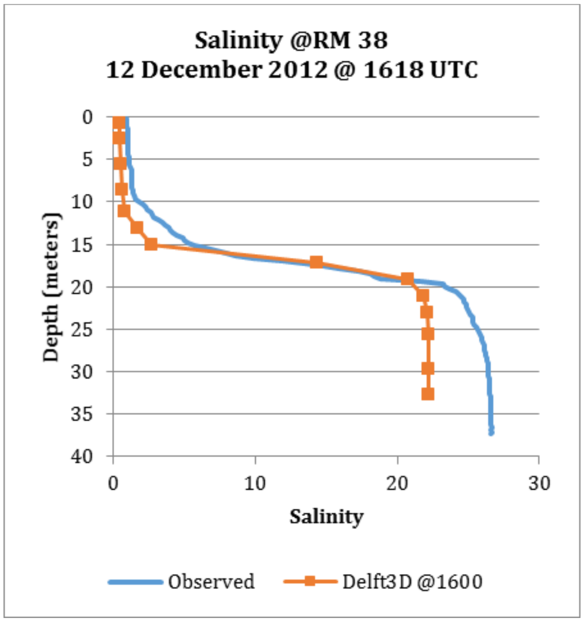

Figure 18

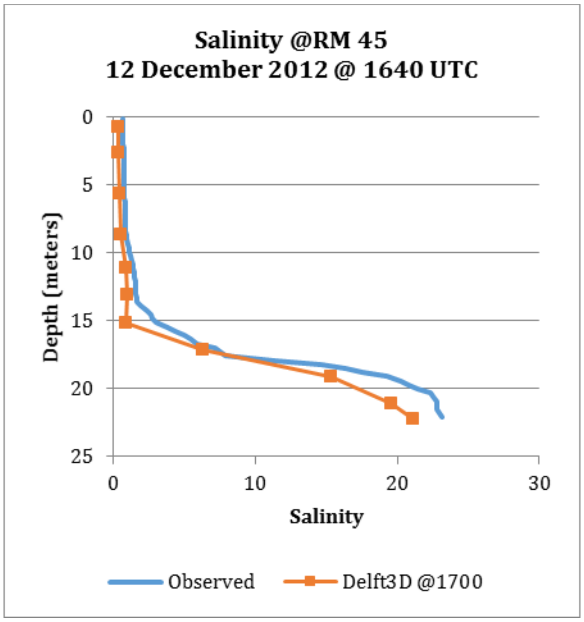

Figure 19

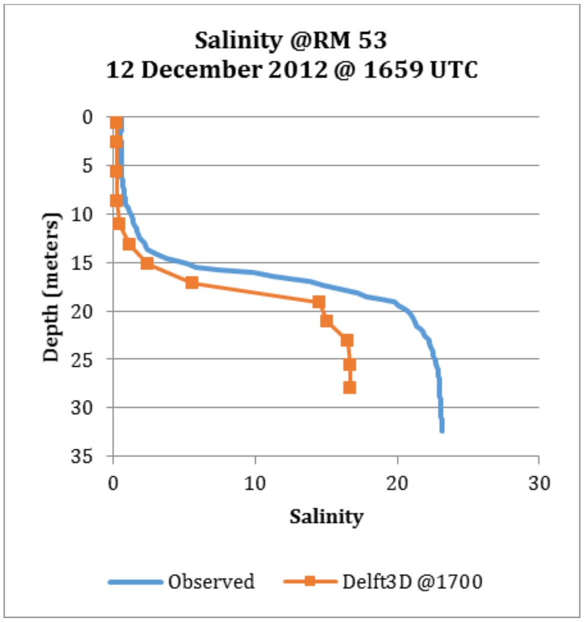

Figure 20

Salinity Concentration time series

Although a 4 week spin-up simulation was performed to initialize the model, analysis of the time series bottom concentration mid-river and downstream of the barrier sill indicates that a longer spin-up interval may improve model performance. As can be observed in RM 38 AHP and RM 60 AHP time series plots shown in Figure 21 and Figure 22, the model accuracy tended to improve over time. The model may require as much as 3 months of spin-up time to completely resolve the stratification and salinity environment in the river channel.

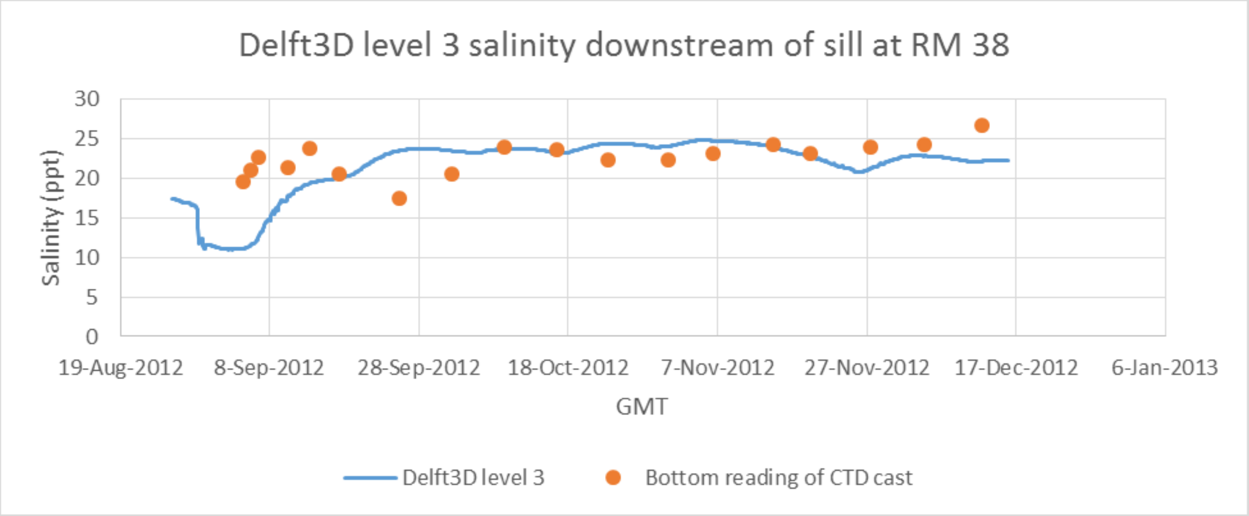

Figure 21

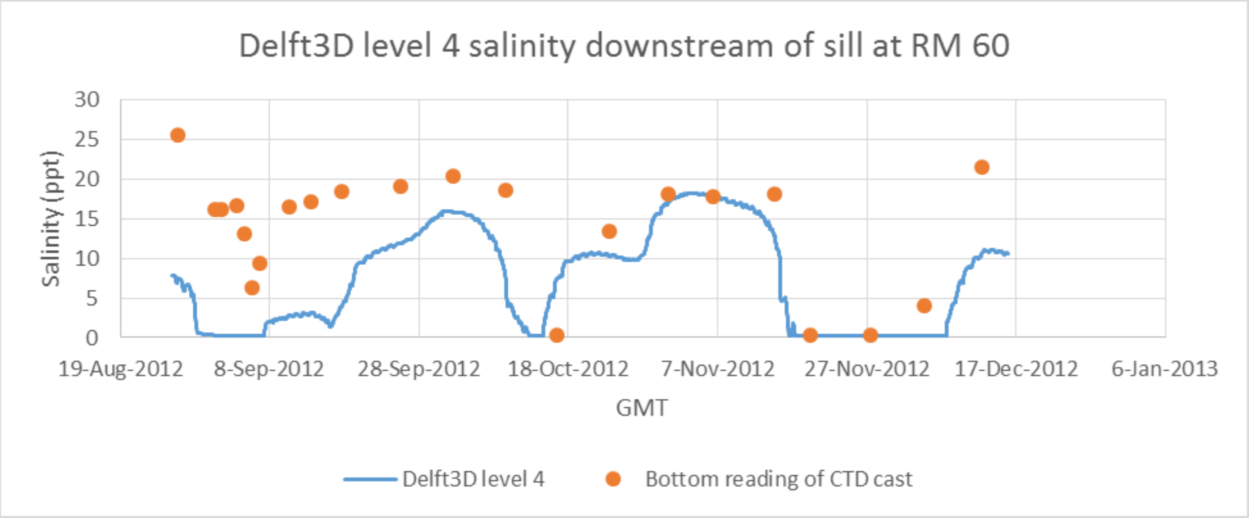

Figure 22

Project Alternative Analysis

Alternative Scenario Summary

Three future alternatives representing the year 2075 were evaluated with the calibrated model. The scenarios included a condition with the existing project depth of 48 feet without the barrier sill at RM 63.4 and the proposed 50 foot depth channel condition with and without the barrier sill. The actual Mississippi River Hydrograph at Baton Rouge from 6 May 2012 through 13 January 2013 from the USGS was applied as the upstream river boundary condition. Corresponding existing tide levels were adjusted with an addition of 0.11 feet which represents the projected eustatic sea level rise based on the historic rate in accordance with guidelines from EC 1165-2-212 Sea-level Change Considerations for Civil Works Programs. A summary of the boundary conditions used in the alternative analyses is shown in Table 3.

Table 3 Summary of model scenario conditions

Alternative Simulation No.	Navigation channel condition	Barrier sill condition	Mississippi River at Baton Rouge hydrograph	Tide level condition
1	-48 ft. MLLW	none	6 May 2012 – 13 Jan 2013	2012 + 2075 historic SLR (+0.11 m)
2	-50 ft. MLLW	none	6 May 2012 – 13 Jan 2013	2012 + 2075 historic SLR (+0.11 m)
3	-50 ft. MLLW	crown at 50 ft. below MLLW or -49.35 ft NAVD88 (2009.55)	6 May 2012 – 13 Jan 2013	2012 + 2075 historic SLR (+0.11 m)

Future grid bathymetry channel depth determination

The existing condition grid bathymetry was adjusted to account for dredging to maintain the future 48 foot and 50 foot project channel depths. The maintained channel depth is referenced to the MLLW tidal datum. In other words, a 50 foot project feature would include maintaining the navigable channel to a 50 foot depth below the MLLW datum at any given location within the project limits.

In order to determine the project depth at any given time, the sea level conditions at that time must be determined. The historic rate of eustatic sea level rise is determined in accordance with guidelines from EC 1165-2-212 Sea-level Change Considerations for Civil Works Programs. An addition of 0.11 feet is considered to represent an extension of the historic eustatic sea level rise rate to the year 2075.

The offset between MLLW and the NAVD88 (2009.55/OPUS) plane referenced to GEOID12A was determined on 10 July 2015 at the Southwest Pass Jetty gage site and the Venice, LA gage sites. These offsets and the eustatic addition were used to determine the channel bottom depths for the 48 foot and 50 foot channel depth future alternatives. An additional 8 feet of depth was added to account for advanced maintenance and overdredging excavation. A summary table of the process to determine the dredged channel bottom elevations for the MRSC 3D model scenarios is shown in Table 4.

Table 4

Channel Conditions	2075 Historic Rate Eustatic SLR addition (m) [A]	Depth (Project + 8 feet advanced maint & overdredging) (m) [B]	MLLW at Jetty on 10 July 2015, NAVD88 (2009.55) (m) [C]	Channel bottom elevation at Jetty, NAVD88 (2009.55) (m) [C–B+A]	MLLW at Venice on 10 July 2015, NAVD88 (2009.55) (m) [D]	Channel bottom elevation at Venice, NAVD88 (2009.55) (m) [D-B+A]
48 Foot Depth	0.11	17.07	-0.21	-17.17	0.09	-16.87
50 Foot Depth	0.11	17.68	-0.21	-17.78	0.09	-17.48

These channel bottom elevations were used to modify the navigation channel maintenance depth in the model. New surface models of the excavated channels were created with ArcGIS and the existing grid bathymetry was remapped with these new future channel surface models to represent future condition bathymetry in the model for the 48 foot and 50 foot project alternatives. The future channel surface models were linearly sloped between the Jetty and Venice using the elevations shown in Table 4.

Water Intake Salinity Results

The recommended maximum level of chloride in U. S. drinking water is 250 ppm at which point the water begins to have a detectable salty taste. The water intakes located at Boothville and Port Sulphur/ Pointe a la Hache are the most downstream intakes and thus most susceptible to fouling by salinity. A summary of Mississippi River freshwater intakes within the model domain is shown in Table 5.

Table 5 Mississippi River freshwater intakes

Freshwater Intake	River Mile AHP	East or West Bank	User	Owner
Boothville	19.0	West	Boothville Water Treatment Plant	Plaquemines Parish
Port Sulphur	49.0	West	Port Sulphur Water Treatment Plant	Plaquemines Parish
Pointe a la Hache	49.6	East	Pointe a la Hache Water Treatment Plant	Plaquemines Parish
Belle Chasse	75.5	West	Belle Chasse Water Treatment Plant	Plaquemines Parish
Dalcour	80.9	East	Dalcour Water Treatment Plant	Plaquemines Parish
Shell	82.9	East	Shell Oil	Shell Oil
Meraux	87.6	East	St Bernard Parish Water Treatment Plant	St. Bernard Parish
Domino	90.9	East	Domino Sugar	Domino Sugar
New Algiers	95.4	West	New Orleans Algiers Water Treatment Plant	New Orleans S&WB
Algiers	95.6	West	New Orleans Algiers Water Treatment Plant	New Orleans S&WB
Gretna	96.7	West	Jefferson Parish West Bank Water Treatment Plant	Jefferson Parish Water Department
Marrerro	99.3	West	Jefferson Parish West Bank Water Treatment Plant	Jefferson Parish Water Department
Westwego	101.5	West	Jefferson Parish West Bank Water Treatment Plant	Jefferson Parish Water Department
Oak Street	103.8	East	New Orleans Carrollton Water Treatment Plant	New Orleans S&WB
New River	104.1	East	New Orleans Carrollton Water Treatment Plant	New Orleans S&WB
Jefferson	105.4	East	Jefferson Parish East Bank Water Treatment Plant	Jefferson Parish Water Department

In order to estimate chloride concentration from computed salinity, the following conversion is used:

$$Cl^{-}(mg/L) = {}^{salinity\ (ppt)}/_{0.0018066}$$

The computed surface water chloride concentration at Boothville and Port Sulphur for the simulation period are shown in Figures 23 and 24. As can be seen in Figure 24, the barrier sill located at RM 63.4 has a significant impact on chloride reduction at Port Sulphur. The number of hours exceeding the water quality standard for the simulation period is summarized in Table 6.

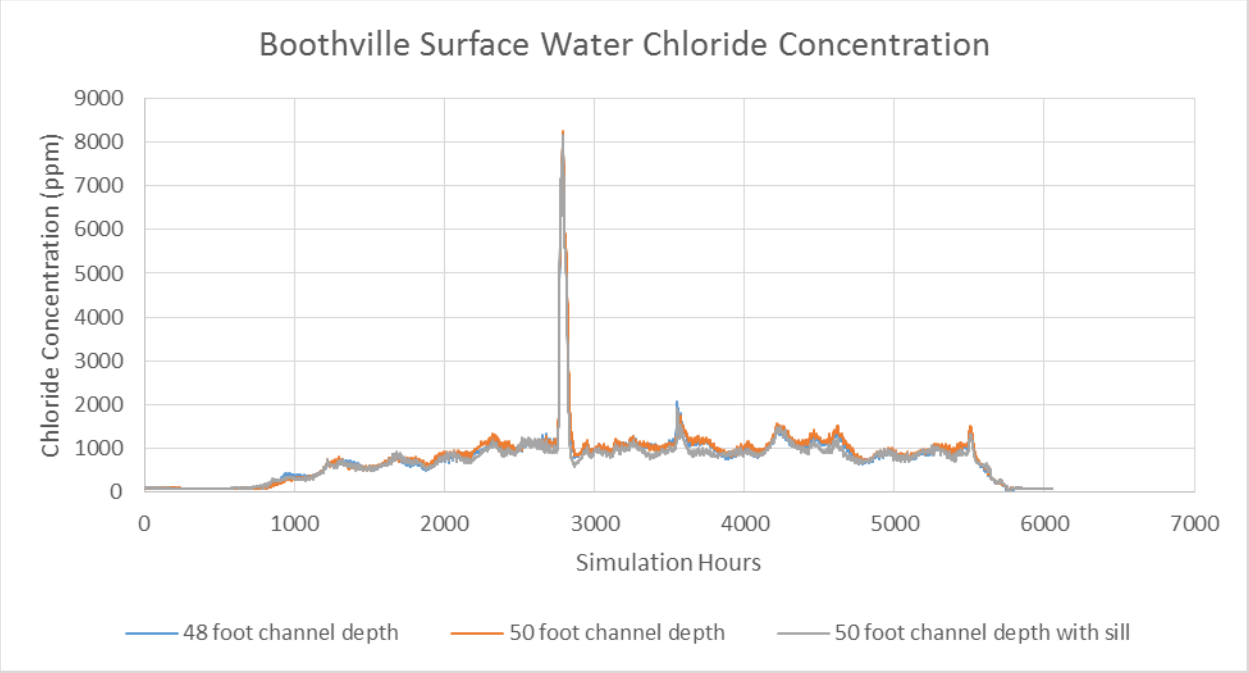

Figure 23 Computed chloride concentration at Boothville

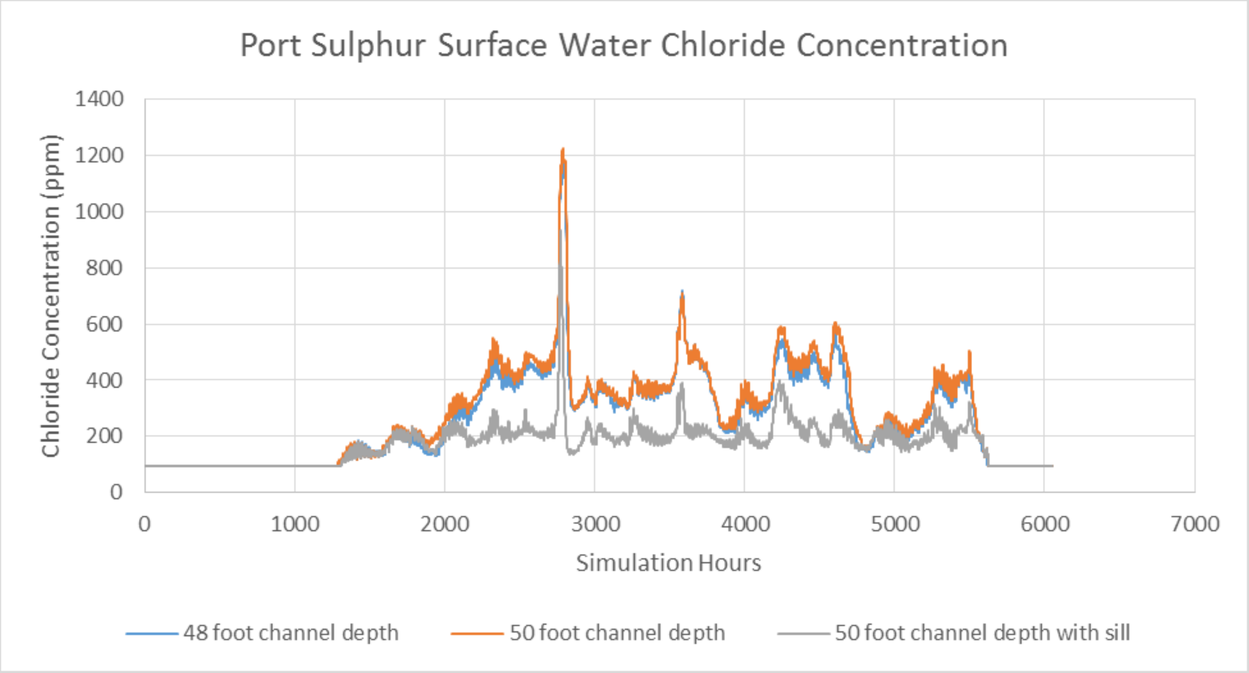

Figure 24 Computed chloride concentration at Port Sulphur

Table 6 Summary of duration above 250 ppm chloride

Alternative	Location	Duration (hours)	Location	Duration (hours)
48 Foot Depth Channel	Boothville	4788	Port Sulphur	2938
50 Foot Depth Channel	Boothville	4753	Port Sulphur	3096
50 Foot Depth Channel with barrier sill	Boothville	4843	Port Sulphur	515

Saltwater Wedge Duration and Extension

The toe of the saltwater wedge in the Mississippi River has been defined as the leading point of the wedge with a chloride concentration exceeding 5000 ppm (~ 9 ppt salinity). For purposes of tracking the toe of the wedge from the model results, the toe is also defined as the most upstream point of concentration exceeding 5000 ppm with a continuous source of salinity exceeding 5000 ppm all the way downstream to the source in the Gulf.

The salt wedge toe position is plotted in Figure 25 for the three simulations. Both of the scenarios without the barrier sill showed the toe of the wedge going no further upstream than the crossing at RM 90. In general, the duration of the presence of the wedge was somewhat longer for the 50 foot project over the 48 foot project condition, but the crossing proved to be a sufficient impedance preventing further upstream progression of the wedge even with the increased channel depth. Evaluation of model results for occurrences of the toe between RM 85 and RM 90 at the same daily time showed an additional 18 days with the 50 foot channel over the 48 foot channel. The wedge did not progress upstream past the barrier sill with 50 foot project conditions and 2012 drought river flow.

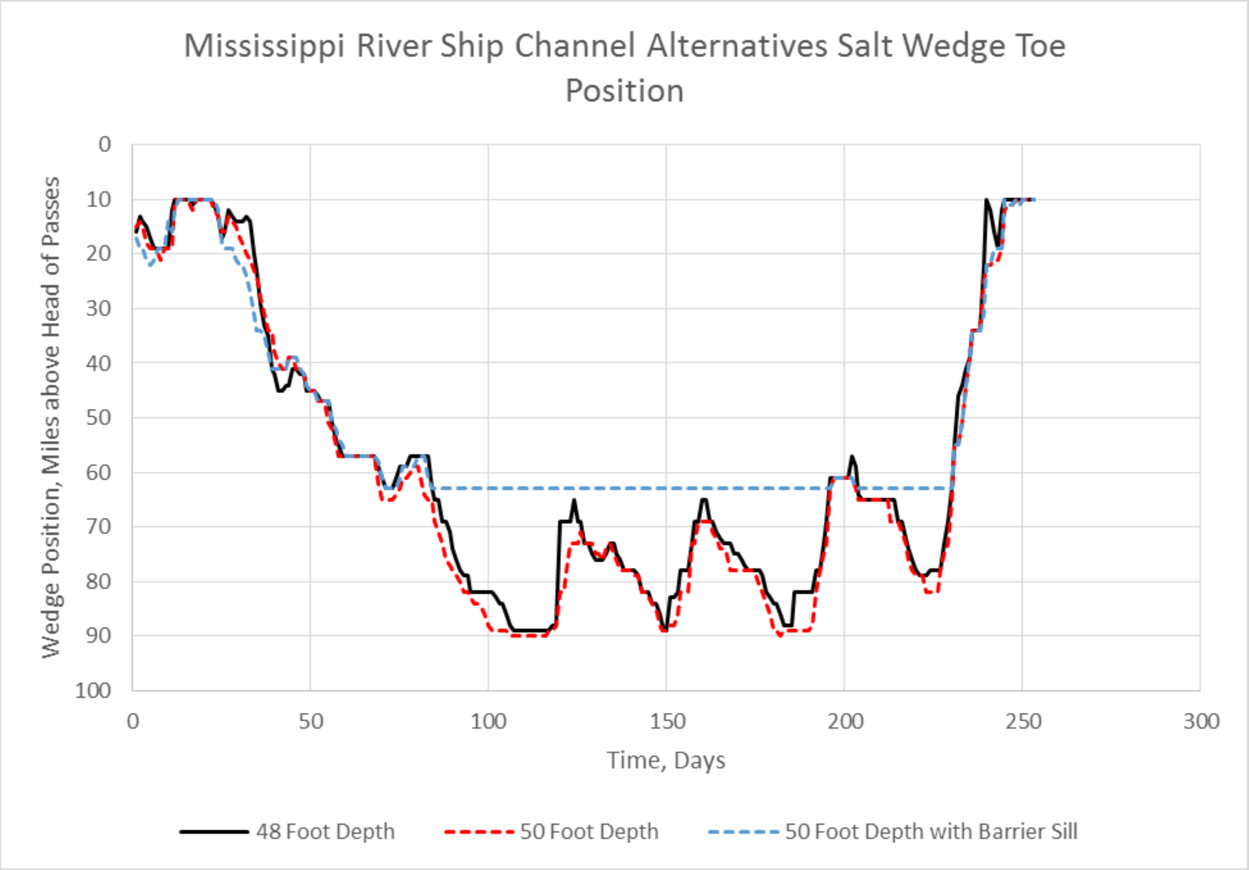

Figure 25

Summary

The tidal and river discharge boundary conditions that occurred during the 2012 drought were applied to a Delft3D model grid representing the modern Mississippi Delta extending from RM 116 to the Gulf of Mexico. The model utilized the Cartesian level option with 16 vertical levels. Future scenarios were developed to represent year 2075 conditions with elevated tides based on a projection of the historic rate of sea level rise and channel bottom elevations referenced to the elevated tidal datum. The scenarios included a condition with the existing project depth of 48 feet without the barrier sill at RM 63.4 and the proposed 50 foot depth channel condition with and without the barrier sill.

The toe of the saltwater wedge is defined as the leading point with a chloride concentration exceeding 5000 ppm. Both of the scenarios without the barrier sill showed the toe of the wedge going no further upstream than the crossing at RM 90. In general, the duration of the presence of the wedge was somewhat longer for the 50 foot project over the 48 foot project condition, but the crossing proved to be a sufficient impedance preventing further upstream progression of the wedge even with the increased channel depth. Evaluation of model results for occurrences of the toe between RM 85 and RM 90 at the same daily time showed an additional 18 days with the 50 foot channel over the 48 foot channel. The wedge did not progress past the barrier sill with 50 foot project conditions and 2012 drought river flow.

The recommended maximum level of chloride in U. S. drinking water is 250 ppm at which point the water begins to have a detectable salty taste. The modeled surface water salinity concentration was evaluated at the locations of the Boothville (RM 19.0 AHP) and Port Sulphur (RM 49.0 AHP) water treatment plants during the simulation in order to determine the possible impact of the project on these utilities.

At Boothville, the 50 foot project condition did not significantly alter the total duration of the time the chloride concentration would exceed 250 ppm, in fact the model results showed a very slight decrease in duration with 50 foot project conditions when the barrier sill was not in place at RM 63.4, 4753 hours for the 50 foot channel and 4788 hours for the 48 foot channel. The scenario with the barrier sill in place with the 50 foot project conditions showed the greatest duration of time with the chloride level exceeding 250 ppm during the low water event at Boothville, an additional 3.8 days compared to the 50 foot project alternative without the barrier sill.

At Port Sulphur, the duration of time the chloride concentration was over 250 ppm was 3096 hours, and 2938 hours for the 48 foot channel condition, or approximately 6.6 days longer for the 50 foot channel condition. The barrier sill greatly reduced the chloride concentration at Port Sulphur. The 50 foot project condition with the barrier sill in place showed a total of 515 hours with chloride concentration exceeding 250 ppm.

Mississippi River Ship Channel
Gulf to Baton Rouge, LA
Integrated General Reevaluation Report
And Supplemental Environmental Impact Statement

Appendix H

Annex 4

Letter Report: Mississippi River Channel Deepening Supplemental Report: Fate of Placed Dredged Material in the Lower Mississippi River Crossings

April 2018