Mid-Barataria Sediment Diversion

Hydraulic Report
30% Basis of Design and Value Engineering

Coastal Protection and Restoration Authority of Louisiana

August 2014

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30% Basis of Design and Value Engineering

Prepared for
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August 2014

Contents

Tables

Figures

1 General Introduction

This report discusses findings from the hydrodynamic analyses completed by HDR used to evaluate the value engineering (VE) options for the proposed Mid-Barataria Sediment Diversion (MBSD). Additionally, hydrodynamic analyses completed during the VE evaluation included Barataria Basin two-dimensional models to better identify Basin response to various diversion discharges.

The analyses described in this report to evaluate the VE alternatives and response of Barataria Basin include:

- Basin Hydrodynamics and Tailwater Analysis – Water surface elevations in the Barataria Basin during operation of the diversion are an important factor in the performance of any of the diversion configuration alternatives. Tailwater elevations at the outlet are a function of multiple factors: diversion flow rate, conditions near the outfall (which will vary over the life span of the diversion project due to initial erosion and then by subsequent delta formation), and wind conditions. For the purpose of these analyses, the tailwater was evaluated for only the first 5 years of operation using a fixed bed assumption. It was also assumed that the diversion would not be operated when significant wind speeds occur.
- Diversion Capacity – Each of the configurations examined have different hydrodynamic conditions associated with depth, shape, channel treatments, length of and shape of transitions, configuration of the inlet on the Mississippi River side of the system, and gate type/configuration. HEC-RAS and FLOW-3D were both used to define the range of potential system capacities.
- Sediment Transport and Scour Potential – Each configuration presents different flow characteristics. It was important to evaluate the channel performance relative to velocity and sediment transport characteristics to determine where deposition and scour were likely to take place.
- Inlet Performance – One of the key elements of the project from both a hydraulic performance perspective as well as constructability is the configuration of the inlet within the flow of the Mississippi River. The analyses performed were intended to evaluate the potential range of conditions that would exist with the alternative configurations that were explored.

1.1 Value Engineering Alternatives

In general, the VE process systematically seeks to improve the value of a project by evaluating the functions of various project components and determining whether alternative means/methods/systems can be used to achieve the same functions at an overall lower project cost.

The Coastal Protection and Restoration Authority of Louisiana (CPRA) asked HDR to conduct an abbreviated VE evaluation that included consideration of several design alternatives to the base project design. A *design alternative* generally refers to a targeted design flow and inlet configuration, while a *design version* refers to a group of VE concepts applied to that alternative. In total, eight diversion alternatives/versions were evaluated for cost estimating. The eight alternatives/versions are summarized below:

- Alternative 1, Version 1 – base design concept, 75,000 cubic feet per second (cfs) peak flow design, 300-foot bottom width channel, three open-channel inlets with gated structure, seven-bay gated back structure (described in detail in *Mid-Barataria Sediment Diversion Alternative 1, Base Design Report, 30% Basis of Design*)
- Alternative 2, Version 1 – 50,000 cfs peak flow design, 200-foot bottom width channel, two open-channel inlets with gated structure, five-bay gated back structure
- Alternative 3, Version 1 – 35,000 cfs peak flow design, 100-foot bottom width channel, one open-channel inlet with gated structure, three-bay gated back structure

Subsequent VE versions (designated with the “X.2” suffix in the drawing packages) included the following alternatives:

- Alternative 1, Version 2 – open channel inlet, three-gate diversion structure, 300-foot channel bottom width, seven-gate back structure, 75,000 cfs
- Alternative 2, Version 2 – open channel inlet, two-gate diversion structure, 200-foot channel bottom width, five-gate back structure, 50,000 cfs
- Alternative 3, Version 2 – two immersed tunnel inlets, two-gate diversion structure, 100-foot channel bottom width, three-gate back structure, 35,000 cfs
- Alternative 4, Version 2 – three-bay immersed tunnel inlet, three-gate structure, three box structures outlet, 100-foot channel bottom width, three-gate back structure, 35,000 cfs
- Alternative 5, Version 2 – three-bay immersed tunnel inlet, three-gate structure, three bored tunnels outlet, 100-foot channel bottom width, three-gate back structure, 25,000 cfs

Hydrodynamic analyses were completed to evaluate VE version concepts that would affect conveyance of flows and performance of the system. Table 1 summarizes all the VE concepts explored. Impacts to conveyance of flows caused by VE versions were limited to the following concepts:

- VE 2 – convey flow in pressure conduit
- VE 3 – reduce surcharge/eliminate articulated concrete block mat (ACBM)
- VE 4 – reduce or eliminate transition walls
- VE 5 – optimize inlet efficiency

Information and conclusions from the hydraulic analyses of the VE concepts is included in the following sections of this report. Full discussion of the VE concept geometry and configurations are presented in the *Mid-Barataria Sediment Diversion Value Engineering Report, 30% Basis of Design*¸ dated July 2014, by HDR.

Table 1. MBSD alternatives and VE concepts

Alternatives	VE 1: Construct in the Wet	VE 2: Convey Flow in Pressure Conduit	VE 3: Reduce Surcharge/ Eliminate ACBM	VE 4: Reduce or Eliminate Transition Walls	VE 5: Optimize Inlet Efficiency	VE 6: Eliminate Top 15 feet of Channel Built in Dry
Alternative 1, Version 2, open channel inlet, –40 feet msl invert (peak Q of 75,000 cfs)	Remove cast-in-place inlet channels; rely on coffer cellular walls with tremie floor for inlet channel	Not applicable	Set levee back farther from channel to reduce wick drains and surcharge volume	Modify diversion structure and back structure transition to eliminate wall systems	Not applicable	Applied
Alternative 2, Version 2, open channel inlet, –40 feet msl invert (peak Q of 50,000 cfs)	Remove cast-in-place inlet channels; rely on coffer cellular walls with tremie floor for inlet channel	Not applicable	Set levee back farther from channel to reduce wick drains and surcharge volume	Modify diversion structure and back structure transition to eliminate wall systems	Not applicable	Applied
Alternative 4, Version 2, immersed tube tunnel, –60 feet msl invert (peak Q of 25,000 to 35,000 cfs)	Cellular coffer system to support excavation; prefab tunnel sections barge-delivered; foundation system built in the wet or use prefab steel frame to sink in place and tremie concrete to form immersed tube tunnel	Eliminate rail bridge by maintaining existing rail right-of-way; use an immersed tube tunnel to transition flow in tunnel from –60 to –25 feet prior to diversion structure	Set levee back to reduce amount of wick drains and surcharge required	Modify diversion structure and back structure transition to eliminate wall systems	Modeling indicates immersed tube tunnel would extract more water from over sandbar and lower elevations in river, increasing sediment capture	Applied

Table 1. MBSD alternatives and VE concepts

Alternatives	VE 1: Construct in the Wet	VE 2: Convey Flow in Pressure Conduit	VE 3: Reduce Surcharge/ Eliminate ACBM	VE 4: Reduce or Eliminate Transition Walls	VE 5: Optimize Inlet Efficiency	VE 6: Eliminate Top 15 feet of Channel Built in Dry
Alternative 5, Version 2, –60 feet msl invert[a] (peak Q of 25,000 cfs)	Cellular coffer system to support excavation; prefab tunnel sections barge-delivered; foundation system built in the wet or use prefab steel frame to sink in place and tremie concrete to form immersed tube tunnel	Receiving pit/lift gate structure constructed in line with MR&T; tunnel used to convey flow under both rail and roadway, eliminating both bridges	Levees set back to reduce amount of surcharge; wick drains and erosion protection required	Tunnel system would use a different inlet/outlet system that would be constructed as part of receiving pits to create transitions	Immersed tube inlet efficiency is improved over open channel inlet	Applied

Notes: ACBM = articulated concrete block mat, cfs = cubic feet per second, MR&T = Mississippi River and Tributary, msl = mean sea level, VE = value engineering

[a] Other VE ideas for Alternative 5 include eliminating the pump station and integrating the back structure into the outlet transition from tunnel to open channel.

2 Hydraulic Analysis of VE Concepts

Hydraulic analyses identified refinements to the previously assumed hydraulic capacity of the alternatives. VE alternative channel geometry creates complex hydrodynamics that were evaluated with FLOW-3D. Peak diversion discharges calculated for each VE Alternative, associated with a 1,250,000 cfs Mississippi River discharge, are presented in Table 2. All hydraulic analyses presented in this report assumed tailwater elevations in Barataria Basin based on two-dimensional VE analysis of the Basin.

Table 2. Revised flow rates for the design alternatives

Alternative	FLOW-3D discharge[a] (cubic feet per second)
Alternative 1, Version 1	82,000
Alternative 1, Version 2	78,000
Alternative 2, Version 2	56,000

Table 2. Revised flow rates for the design alternatives

Alternative	FLOW-3D discharge[a] (cubic feet per second)
Alternative 4, Version 2	38,000
Alternative 5, Version 2	32,000

[a] These discharges were calculated in FLOW-3D using tailwater assumptions determined by HEC-RAS two-dimensional models, which were conducted at a value engineering level. They are subject to change based on refinements to tailwater, modeling geometries, and modeling methods. Assumes initial Barataria Basin conditions without land building (0 to 5 years).

VE concepts were analyzed by a number of hydraulic models and methods to identify critical issues with the geometry or configuration. Evaluations of the VE concepts were focused on identifying any design/cost implications that were not incorporated in the previously completed VE analysis.

2.1 VE Concept 4 – Eliminate Wall Systems

Hydraulic analyses were conducted to determine the impacts of eliminating the smooth transitions between rectangular and trapezoidal channel sections. These transitions were located at both the gate structure and the back structure in Alternative 1 Version 1. A comparison of flows in Table 2 reveals that there is an approximately 5 percent reduction in discharge in Alternative 1, Version 2. This reduction in discharge can be reasonably assumed to be the result of abrupt transitions between rectangular and trapezoidal channel sections. Figure 1 illustrates peak diversion velocity vector fields associated with the transition downstream of the gate structure for Alternative 1, Version 1 (left), and Alternative 1, Version 2 (right). Overall flow in Figure 1 goes from top to bottom.

Figure 1. Velocity vector field comparison – peak diversion (Mississippi River discharge at 1,250,000 cfs)

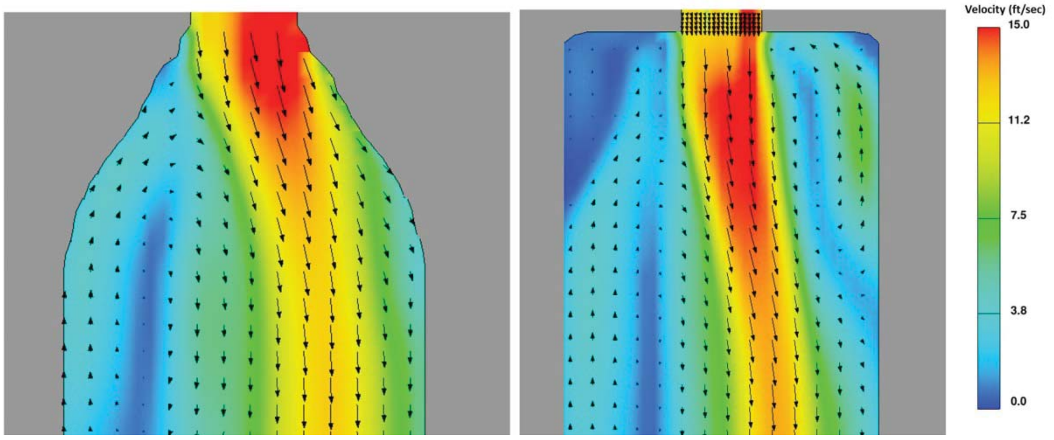


Figure 1 illustrates recirculating flow conditions on both sides of the abrupt transition in Alternative 1, Version 2. The smooth transition in Alternative 1, Version 1 better aligns with the flow expansion out of the rectangular channel on the top of the figure. Dark blue regions in Figure 1 illustrate low-velocity fields that would likely result in deposition areas that would accumulate sediment. These low-velocity areas are essentially ineffective flow areas with little conveyance capacity.

It should be noted that ineffective flow areas are highly dynamic and change with varying diversion discharges. However, Figure 1 provides a good representation of the types of ineffective flow areas that would be present throughout various operational conditions. Deposition in ineffective flow areas should also have little impact on overall performance of the system because little to no conveyance is attributed to these areas.

Also of interest in Figure 1 is that there are more concentrated high-velocity fields in Alternative 1, Version 2. This illustrates that the abrupt transition does not reduce the sediment-carrying capacity of the main flow paths in the diversion channel downstream of the transition. These results indicate that while there are more ineffective areas associated with the abrupt transition, the main channel velocities capable of conveying sediment are still maintained.

There are additional hydraulic losses associated with the abrupt transition and rapid expansion of flows as illustrated by larger ineffective flow areas in Alternative 1, Version 2. However, the additional hydraulic losses in Alternative 1, Version 2 did not result in large differences in overall peak diversion discharges, as shown in Table 2. Based on this, it is reasonable to conclude that the use of abrupt transitions would not have large impacts on overall conveyance or sediment capacity of the diversion facilities.

2.2 VE Concept 2 – Pressure Conduit

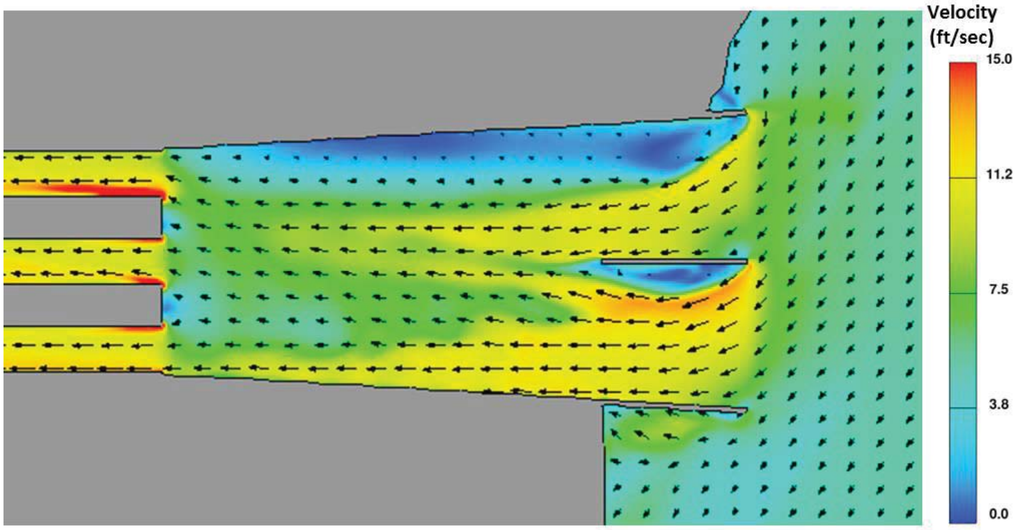
Three-dimensional numerical models were developed to evaluate the performance of two alternative pressure conduit designs: Alternative 4, Version 2 and Alternative 5, Version 2. These designs had immersed flared inlet sections with inverts set to –60 feet North American Vertical Datum 1998 (NAVD 88) in the Mississippi River. Table 2 provides the flow rates for these alternatives as follows:

- Alternative 4, Version 2 – 38,000 cfs
- Alternative 5, Version 2 – 32,000 cfs

Alternatives 4 and 5 share a general immersed inlet design consisting of a flared section that narrows slightly while the soffit rises, maintaining a constant invert elevation. Additionally, an interior wall was added for structural support. Figure 2 shows an instantaneous velocity field of the immersed inlet for Alternative 5 at –50 feet NAVD 88. As the flows turn into the diversion, turbulent wakes are observed on the downstream side of the inlet walls, creating ineffective flow areas.

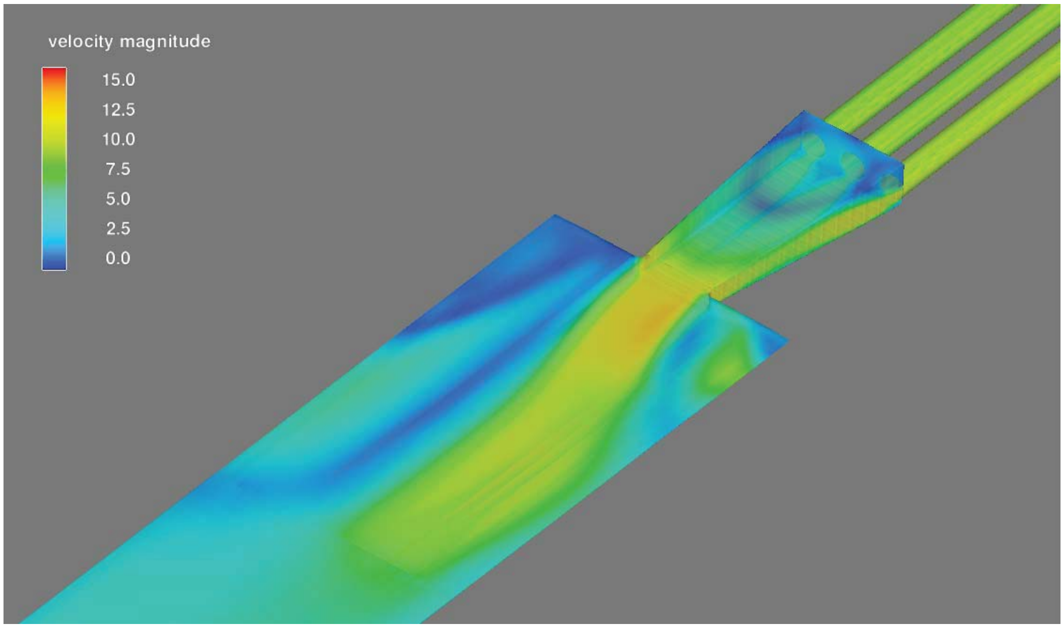
Design revisions should consider angling the inlet in the upstream direction. Another inlet design revision would be to stagger the inlet channel wall length that extends into the Mississippi River. If you were to extend the downstream inlet wall further into the Mississippi River you would effectively create a skewed inlet opening with a larger cross section perpendicular to flow rather than parallel to flow. Additional investigations into varying the elevation of the diversion walls in the Mississippi River should be completed as well, wherein staggered wall elevations could promote increased diversion efficiencies.

Figure 2. Velocity field in the immersed tube inlet



Alternatives 4 and 5 exhibited the same patterns of ineffective flow areas in the transition from rectangular channel sections to trapezoidal channel sections, as seen in the open channel inlet alternatives discussed previously. The transition for Alternative 5 is shown below in Figure 3 with three 25-foot-diameter immersed tube tunnels in the upper right flowing into the open channel trapezoidal section in the lower left. After the horizontal narrowing and vertical rise of the invert, the channel section expands abruptly to the trapezoidal section. This creates large ineffective areas including zones of strong recirculation on either side. These areas are highly dynamic and will change with varying diversion discharges.

Figure 3. Velocity in the transition for Alternative 5, Version 2



Based on results from the VE Concept 2 and VE Concept 4 analyses, it can be concluded that the abrupt expansion from rectangular to trapezoidal channel geometries may result in some additional head losses and some localized sediment deposition. However, these impacts should not affect the overall performance or sizing of the diversion channel.

2.3 VE Concept 5 – Improved Inlet Efficiency

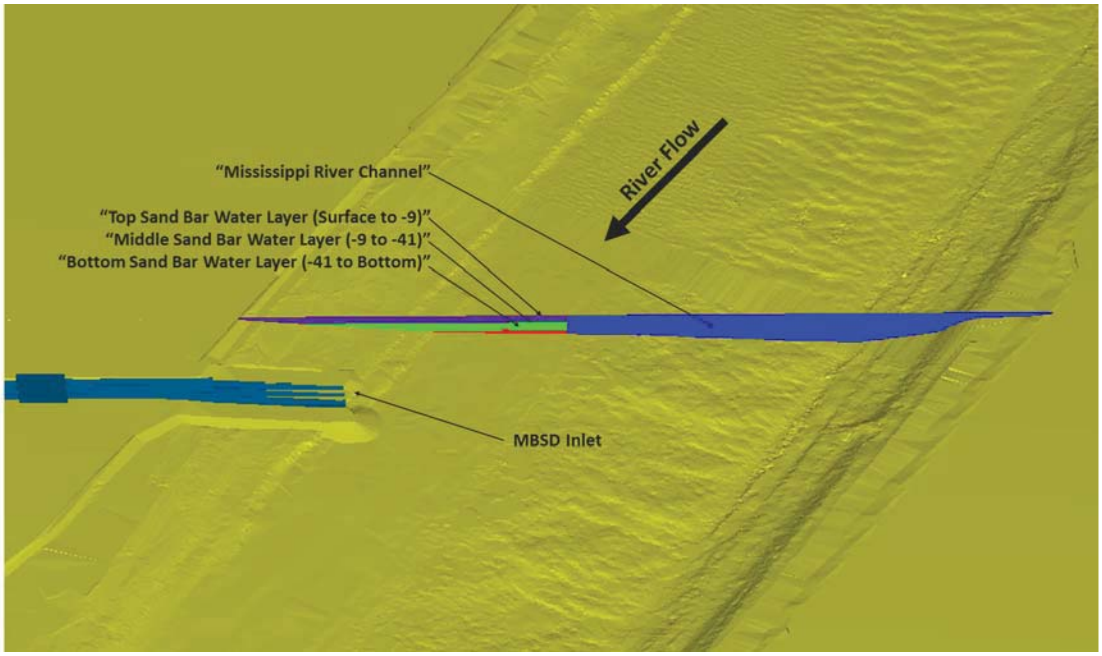
HDR completed three-dimensional models to define where diverted flows originated to determine relative capture zones in the Mississippi River. The analysis was conducted for:

- Alternative 1, Version 1
- Alternative 1, Version 2
- Alternative 2, Version 2
- Alternative 4, Version 2
- Alternative 5, Version 2

FLOW-3D has the ability to visualize flow fields with neutrally buoyant tracers. This tracer acts like dye in a physical model. By continuously releasing the tracer from different locations upstream of the intake, tracking its movement, and quantifying the rate of tracer capture by the diversion, it is possible to discover where diverted flows originated and what proportion of the diverted flows came from that location.

For the study conducted by HDR, tracers were released from four sections of the Mississippi River. These numerical planes broke the river above the sand bar into three sections over the depth, while the fourth section represented the main channel of the diversion opposite the sand bar. These planes are shown in Figure 4.

Figure 4. Numerical planes used to seed tracers



Tracer concentrations were then measured in the diversion channel for the five VE alternatives previously listed. Percentages of tracer concentrations are shown in Table 3. Tracer percentages directly identify the percentage of diversion channel discharge from each of the source locations in the Mississippi River. For example, Alternative 5, Version 2 diversion discharges are composed of 60 percent flow diverted from the middle sand bar water layer and 40 percent flow diverted from the bottom sand bar water layer.

Table 3. MBSD channel flow source summary

Alternative	FLOW-3D discharge[a] (cfs)	Top sand bar water layer (surface to –9 feet NAVD 88)	Middle sand bar water layer (–9 to –41 feet NAVD 88)	Bottom sand bar water layer (–41 feet NAVD 88 to bottom)	Mississippi River channel
Alternative 1, Version 1	82,000	51%	44%	5%	0%
Alternative 1, Version 2	78,000	54%	41%	5%	0%
Alternative 2, Version 2	56,000	58%	40%	2%	0%
Alternative 4, Version 2	38,000	0%	63%	36%	0%
Alternative 5, Version 2	32,000	0%	60%	40%	0%

[a] This discharge was calculated in FLOW-3D using the tailwater assumptions determined by HEC-RAS two-dimensional modeling at a value engineering level. It is subject to change based on refinements to tailwater, modeling geometries, and modeling methods. Assumes initial Barataria Basin conditions without land building (0 to 5 years).

The results of the tracer analysis indicate that the open channel, –40 feet NAVD 88 invert alternatives mainly convey flow originating from the top and middle water layers over the sand bar, with minimal flows from the bottom sand bar water layer. However, the tunnel alternatives diverted discharges are composed solely of the middle layer and bottom layers from over the top of the sand bar. Based on this, it is expected that sand-water ratios associated with the tunnel alternatives will be significantly higher than those of the open channel alternatives. A recent study by Meselhe (The Water Institute of the Gulf [The Water Institute] 2014) also indicated that sediment-water ratios with diverted inlets were proportionally greater than open channel alternatives. Significant increases in tracer concentrations from the bottom sand bar water layer in the tunnel alternatives may allow the MBSD to divert lower flows while maintaining similar sediment loads. The ability to divert lower discharges could end up being beneficial to reducing impacts in the Basin.

Additionally, the specific inlet configurations of both the open and submerged designs will affect the amount of tracer diverted. During the next phase of design for MBSD, it will be beneficial to build a better understanding of how the shape and orientation of the inlet improves diversion performance. Additionally, it will be important to complete a large-scale physical model of the diversion inlet to better understand the complex hydraulics and sediment behavior as flows are diverted out of the Mississippi River.

Tracer studies indicate that little to no flows are pulled from the top layers of the water column in the Mississippi River for the submerged inlet alternatives, which would limit the amount of floating debris captured by the diversion. There is still potential for submerged debris to be captured by these alternatives, but some reduction in debris could be expected when compared with the open channel alternatives.

2.4 VE Concept 3 – Set Levee Back and Eliminate ACBM

Hydraulic models of the levee setback associated with VE Concept 3 indicate that water surface elevations increase by less than 0.1 foot. Velocities along the overbank area for the 180-foot levee setback were within 2 percent of those computed for the 80-foot levee setback. However, velocities in the setback area are less than 2 feet per second in both setback distances. Based on these velocity values, it is reasonable to assume that ACBM along the levee face and a large portion of the 180-foot setback area would not be needed to maintain levee stability. A reduction in overbank and levee scour countermeasures for the increased levee setback can be attributed to moving the levee farther from the erosive velocities in the main channel.

VE Concept 3 allows for consideration of the removal of the ACBM as the levee is set back a significant distance from the higher velocities in the main channel. Scour countermeasures would still be recommended along the interface between the main channel bank and the overbank area. These scour mitigation alternatives could be achieved with a key in of riprap at the top of bank. The smaller 80-foot levee setback could also explore scour countermeasures that were stable for lower velocities in future design phases, depending on additional refinements of the overbank flow characteristics.

Additional multidimensional analysis should be explored for levee setback scour mitigation, specifically around the bridge and around transitions. Flow paths and turbulence can create higher erosive velocities around structures and transitions that can exist in overbank areas. Without scour mitigation measures in these areas, there is an increased risk for erosion and failure of critical components.

It is likely that deposition of sediment could occur during certain operational conditions in the overbank areas. Deposition in these areas should not have a large impact on overall performance of the diversion. If sediment were to be removed from the overbank areas, access and maintenance methods would have to be carefully considered depending on the type of overbank scour mitigation measures.

3 Other Hydraulic Items Investigated

Several additional hydraulic analyses were completed to help further inform VE alternative design considerations. Additional hydraulic analyses were completed with the following objectives:

- Review of launching toe design – evaluation of long-term sediment transport for VE alternatives to define potential long-term scour and effectiveness of VE alternative launching toe.

- Evaluation of Basin-wide fixed bed tailwater – review of two-dimensional Barataria Basin models to develop additional understanding of Basin hydrodynamics related to VE alternative diversion rates.
- Evaluation of inlet influence on Mississippi River near field velocity vectors – review of three-dimensional models of VE alternative inlet performance during operation and nonoperational conditions.

3.1 Review of Launching Toe Design

Sediment transport analysis of VE alternatives was completed with HEC-RAS to identify approximate long-term channel evolution trends. Alternatives were analyzed with all bridge and gate structures with no channel bottom protection. Table 4 summarizes the 50-year sediment transport trends.

Table 4. General 50-year sediment transport trends

Trapezoidal channel bottom width	Approximate channel erosion or deposition
100 feet	15 feet erosion
200 feet	5 feet erosion
300 feet	2 feet deposition

Sediment transport analyses completed for the various alternatives indicated that as the trapezoidal channel bottom width was reduced, additional erosion was induced. These trends are based on the assumption that as discharge is reduced the sediment-water ratio is also reduced. This reduction in sediment-water ratio creates flows that are more erosive and pull sediment from the channel bottom. Further refinements are needed to the sediment transport analysis and sediment-water ratio to provide more accurate erosion or deposition depths.

Proposed VE alternatives mitigate channel erosion with the installation of a riprap launching toe that protects to a scour depth of 22 feet. VE sediment transport analysis indicates that the self-launching riprap toe would be adequate to mitigate the long-term scour for all of the alternatives defined in this report. However, this will need to be confirmed as channel geometry is refined, geotechnical understandings are further developed, and sediment-water ratios are better understood.

Additionally, design evaluation indicated that in the 100-foot trapezoidal bottom width alternatives a fully lined riprap channel results in less riprap quantities than a launching toe. Based on this, a sediment analysis was completed for a fully armored channel to determine erosion and deposition trends. Model results indicate that less than 1 foot of deposition occurs during short periods of higher sediment concentrations. These results indicate that for trapezoidal channel bottom widths on the order of 100 feet, the recommended erosion mitigation measure will consist of a full riprap channel lining.

Sediment transport results also indicate a higher erosion potential near the transitions downstream of the gate structure rectangular channel and the transition upstream of the back structure rectangular channel. These model results validate the need for ACBM through the transition areas for all VE alternatives, as shown in the current plans. Additional evaluations of the selected channel alternative will be needed to further refine the extents of the ACBM installations

3.2 Evaluation of Basin-wide Fixed Bed Tailwater and Hydrodynamics

HEC-RAS (Version 5.0. Beta, June 2014) two-dimensional models were created to analyze stages associated with the proposed MBSD in Barataria Basin. The modeling effort had two primary goals: (1) to establish a rating curve for determining the downstream water surface elevation (WSE) boundary conditions for use in FLOW-3D and HEC-RAS one-dimensional models and (2) to analyze general trends in stage throughout Barataria Basin during diversion operation and Basin response after the diversion is closed.

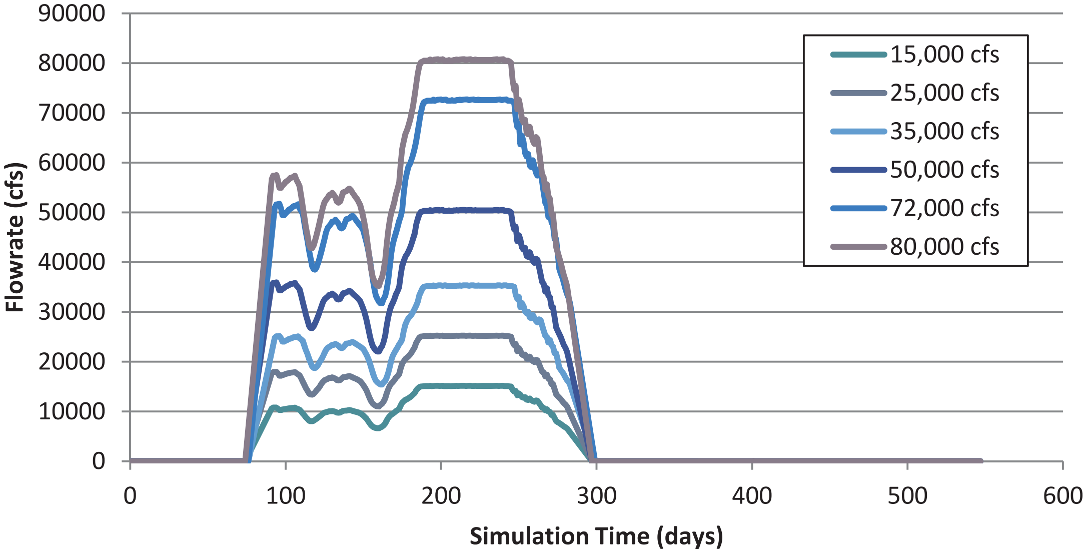
Previous hydrodynamic models of the Basin were developed using RMA2. While RMA2 is in adequate model for performing this task, it also has some disadvantages for meeting the immediate needs of this project. The previous RMA2 models were developed using a relatively coarse version of the terrain for the Barataria Basin that does not capture many of the channels and other finer terrain features in the Basin that are important to the hydrodynamics and morphological response. Using RMA2 with a much more refined terrain dataset would have been required but would have resulted in significantly longer run times than were possible with HEC-RAS 5.0. This decision to use HEC-RAS 5.0 for this purpose was based on the following factors:

- Computational Efficiency – The HEC-RAS 5.0 two-dimensional model uses a grid that incorporates the full terrain dataset within the grid cell and cross sections on the grid faces that are extracted from the refined terrain surface. This allows the use of a larger grid size to represent the terrain detail without requiring a very small mesh that would be required with RMA2 to represent the same terrain detail. This allowed a more detailed simulation of the hydrodynamics of the Basin than previous models, using a more detailed terrain dataset with substantially shorter run times. This allowed HDR to perform the full range of simulations within the defined project schedule.
- Increased Model Detail – As described above, the computational methods employed in HEC-RAS 5.0 allow the model to perform the simulation with as much terrain detail as is available with substantially reduced run times.
- Maximum Diversion Flow Rate Analyses – HEC-RAS 5.0 does not yet incorporate the ability to simulate wind. This feature will be added with the public release version or later versions. However, for the analysis of maximum diversion rates a no-wind condition was what was desired for this simulation since the maximum diversion rate from the various alternatives was the desired outcome. With wind conditions, the tailwater will be higher than these simulations. This refinement of the operational conditions with wind will be included in future efforts after the preferred alternative is selected and the design refined.
- Full Dynamic Solution – Like RMA2, the HEC-RAS 5.0 two-dimensional model includes the option of solving the Saint Venant equations, which is required with a dynamic tidal boundary condition. This option was employed in these simulations.

Models were developed using diversion hydrographs that were based on the 2011 year condition with the assumption that the gates would remain open whenever the river was above 600,000 cfs. This produced a diversion period of approximately 7 months with the diversion operating at peak flow for approximately 2 months, using the following peak flow conditions (as shown below in Figure 5:

- tide-only (without project)
- 15,000 cfs peak diversion
- 25,000 cfs peak diversion
- 35,000 cfs peak diversion
- 50,000 cfs peak diversion
- 72,000 cfs peak diversion
- 80,000 cfs peak diversion

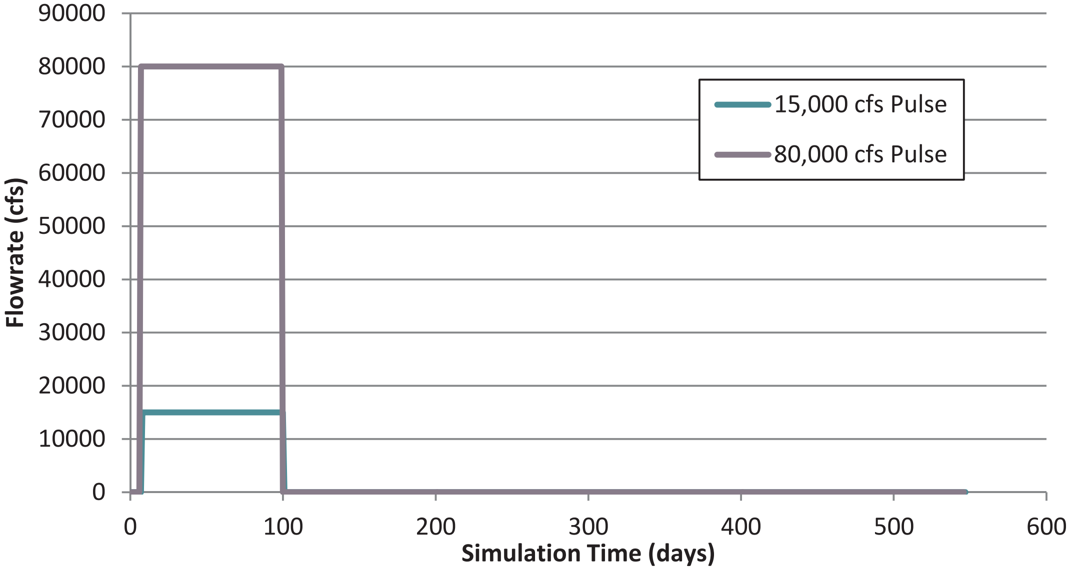
Figure 5. Flow hydrographs for peak diversion HEC-RAS boundary conditions



Additional HEC-RAS two-dimensional models were run to investigate the behavior of the Basin in response to opening and closing the diversion gates. These “pulse” diversion runs used constant MBSD flow rates over a 100-day period with instantaneous peak flow initiation and deactivation. The “pulse” diversion hydrographs are shown below (Figure 6):

- a constant 100-day, 15,000 cfs pulse
- a constant 100-day, 80,000 cfs pulse

Figure 6. Flow hydrographs for pulse diversion HEC-RAS boundary conditions



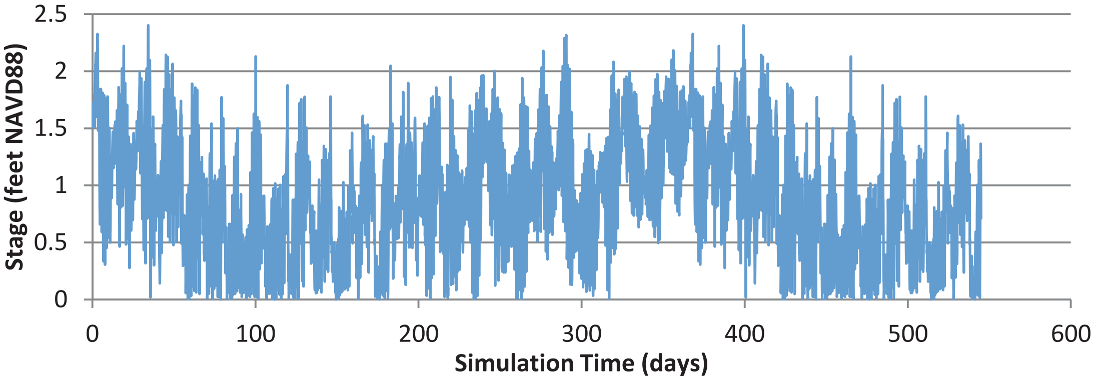
Sensitivity runs were completed to investigate the sensitivity of the Basin to varied Manning's roughness coefficients. Identical boundary conditions and model geometries were run for the 80,000 cfs peak diversion model with varied roughness in Barataria Basin.

Two boundary conditions were applied in each model:

- a stage boundary to represent the tidal action of the Gulf of Mexico
- a flow hydrograph to simulate the MBSD discharge

The tidal boundary condition with the Gulf of Mexico was based on stage data obtained from the National Oceanic and Atmospheric Administration (NOAA) station at Grand Isle, Louisiana, for 2013 (Station ID: 8761724). This period was selected because it was a recent period where there were no extreme storm surge events in Barataria Basin. To create a 545-day hydrograph from this period, a portion of the data was copied and appended to either end of the hydrograph to extend the record by several months. The Grand Isle station is located on the northern side of Grand Isle near Barataria Pass; however, the boundary condition was applied at the edge of the modeled extents along the boundary with the Gulf of Mexico, located approximate 4 to 6 miles from the barrier islands. This is consistent with assumptions previously used during FTN RMA2 modeling of Barataria Basin completed for CPRA. Figure 7 illustrates the extended tidal boundary used in HEC-RAS two-dimensional modeling. However, it should be noted that the datum for this gage needs to verified with the recent Fugro study. The values appear to be high relative to other reported values in this region of the Basin.

Figure 7. Stage hydrographs used for tidal boundary conditions for all simulations



3.2.1 Terrain Development for Barataria Basin

To support the hydrodynamic simulations of diverted flows into the Barataria Basin using HEC-RAS 5.0 and simulations of morphological changes in the immediate outfall area performed by The Water Institute, a terrain surface for the Barataria Basin was needed. The terrain surfaces used in previous land building and Basin hydrodynamic models were determined to be too coarse for the analyses needed to support this design effort. The previous models used a less refined terrain for the feasibility studies in order for those models to be computationally efficient. A more refined terrain was deemed necessary for this effort to account for the various channels throughout the Basin that influence flow distribution.

To facilitate these analyses, a more refined terrain surface was developed using various datasets that were merged into a composite terrain surface for these efforts. In the area near the outfall, field surveyed transects were prepared by Fugro in 2013. These transects, combined with aerial imagery, were used to construct breaklines around marsh areas and within the channels in this region. Outside of the near field area, LiDAR data acquired in 2010 and 2011 were used. The terrain surface used to create the topography for the model had two main components: the two NOAA digital elevation models (DEMs) shown in Figure 8, which were used as the primary sources for topographic information for the large-scale Barataria Basin surface outside of the 8-mile radius (a full list of the data used in this effort is contained in the References section of this report):

- Southern Louisiana ⅓ arc-second (~10 m) NAVD 88 DEM
- New Orleans (LA/MS) ⅓ arc-second (~10 m) NAVD 88 DEM

The NOAA DEMs used in the modeling effort had a resolution of approximately 32 feet and were based on a wide range of topographic and bathymetric data. NOAA created the DEMs as, essentially, a grid of 32 feet wide by 32 feet wide grid cells with a single elevation based on the averaging all of the data within that grid cell.

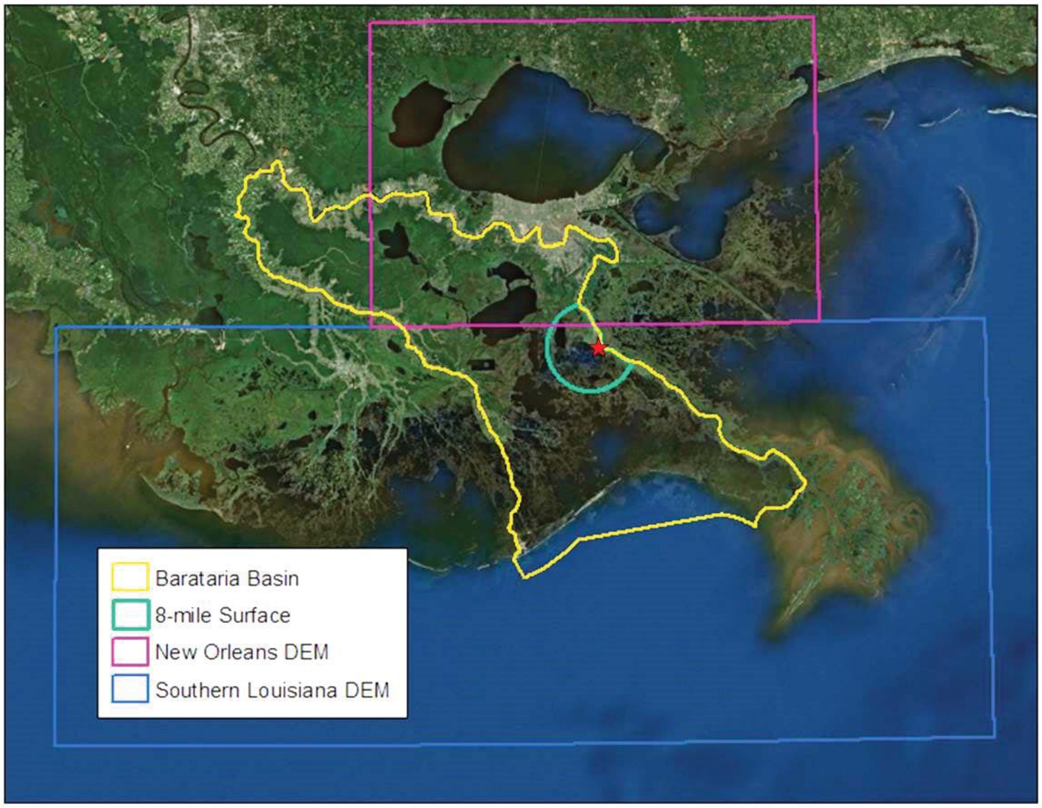
These DEM data are a common way of presenting large areas of elevation data, but do not capture smaller details. Additionally, many of the dredged canals and smaller bayous in Mid-

Barataria do not have bathymetry data. For areas with no bathymetry, the NOAA DEM shows the WSE at the time of survey.

An 8-mile radius was selected for detailed refinement, after discussions regarding modeling focus with the modeling team and CPRA. The goal of these efforts was to capture the smaller canals and flow paths that would convey diversion discharges through the Basin. Additional survey data and transect data collected by the MBSD team in 2013 surveys were used to help supplement and guide refinements to the NOAA DEM base data in the 8-mile radius.

Figure 8 illustrates the extents of the Barataria Basin topography information and the boundary of the 8-mile radius data. It should be noted that the northwestern quadrant of the Basin is not included in these datasets. In this region, a much coarser 5 m Ifsar dataset is available but was not used. Based on previous RMA2 models, it was originally believed that water surface changes in this region would be relatively minimal and refinements in the modeling of this region would occur once the more recently acquired U.S. Geological Survey (USGS) LiDAR dataset became available.

Figure 8. NOAA Barataria Basin DEM information and 8-mile radius



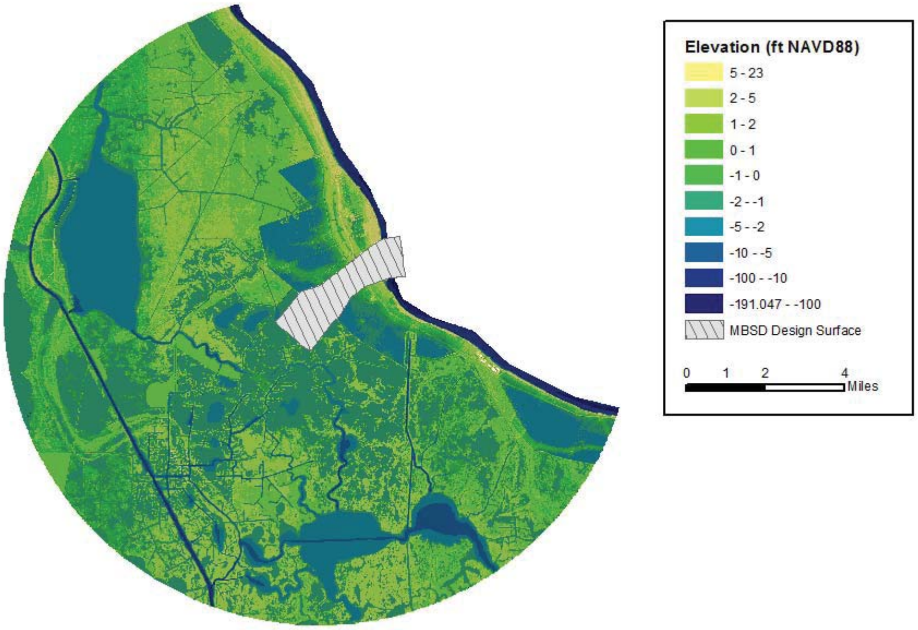
In the 8-mile radius around the MBSD outfall, the NOAA DEMs contained only bathymetric information for Barataria Waterway; all other open water areas were represented as the WSE at the time of the data acquisition. A review of transect data in Barataria Basin was completed to help determine an average marsh bottom elevation for the open water areas. Survey transects for a wide range of open water areas, not including any defined channel or bayou, were investigated for any consistent trends. It was found that, generally, the open water marsh areas had an average elevation of –1 foot NAVD 88. Based on this understanding, an assumption was made to set all submerged areas without readily available survey information to an elevation of –1 foot NAVD 88. Special deeper areas at the Pen and Round Lake were accounted for with deeper representative depths.

Where survey data were available in open water areas, breaklines were built to connect selected survey points to give definition to channels and lakes. Additional definition of dredged canals and channels was completed for features that were identified as potential conveyance paths. If a feature was identified as a potential conveyance path and did not have transect data, transect data from a similarly sized adjacent canal were used to help define the breaklines. This process was completed for the entire 8-mile radius Barataria Basin surface.

The additional topographic information that was incorporated into the surface was the existing and future restoration projects constructed with pumped dredged material. Elevation assumptions for proposed restoration projects were provided by Moffat & Nichol (MN) with the agreement of CPRA.

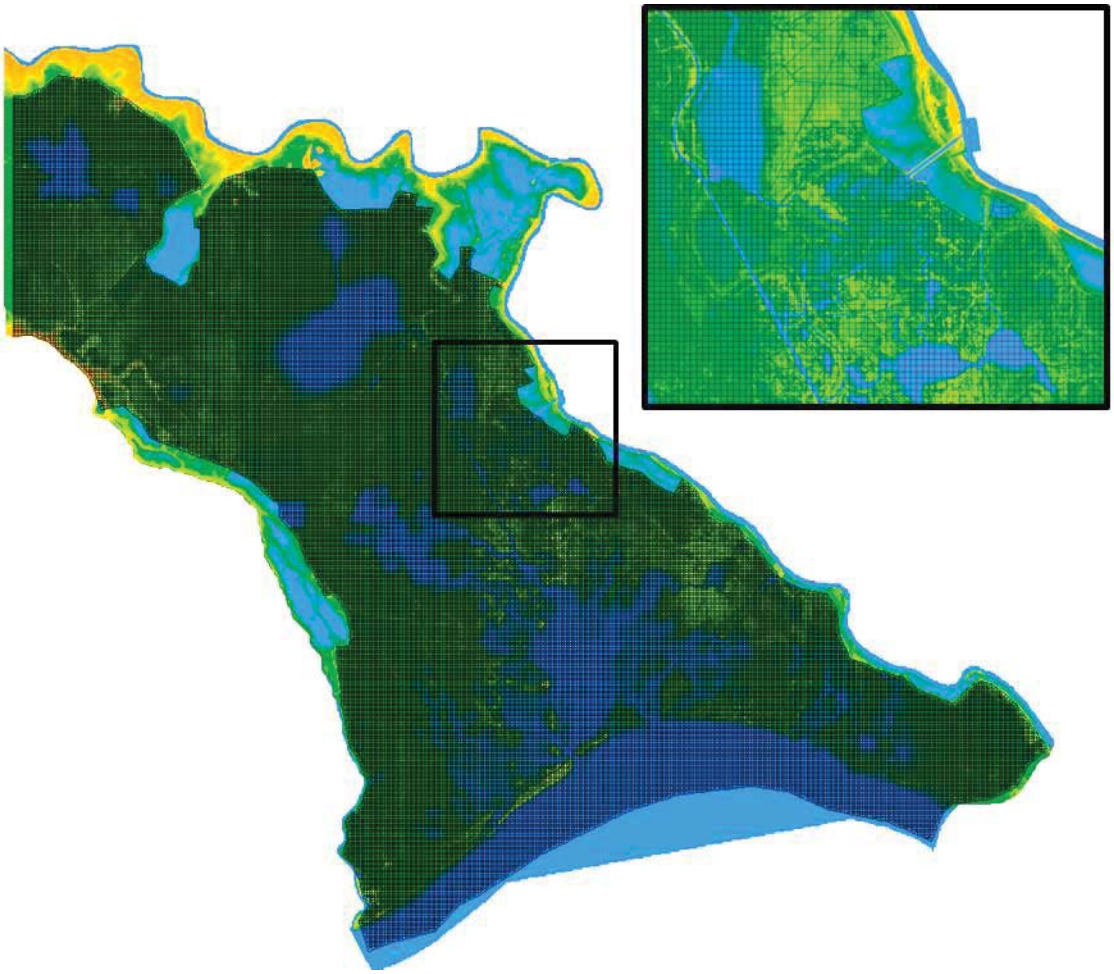
Figure 9 illustrates the Barataria Basin surface created for the 8-mile radius around the diversion channel outfall. This figure also shows an outline of the MBSD design surface used in FLOW-3D modeling. This surface includes the proposed diversion design and an approximate 1-square-mile outfall area that used 2013 surveys completed for MBSD by John Chance Land Surveyors, Inc. (JCLS).

Figure 9. Revised surface for 8-mile radius Barataria Basin



Finally, the 8-mile radius and large-scale Barataria Basin surfaces were merged with the adjoining unrefined topographic mapping for the majority of the remaining Basin area into one surface for import into HEC-RAS. Figure 10 presents the HEC-RAS model mesh (black lines) overlaid on the terrain surface. The deep blue areas represent lower elevations—these include leveed areas that were not modeled (outside the geometry) and lakes and bays that were modeled (inside the geometry).

Figure 10. Combined final Barataria Basin surface for HEC-RAS model grid



3.2.2 Model Results

The MBSD project is moving from a conceptual and planning phase to a design, environmental evaluation, and permitting phase. HDR believes it is important to establish, up front, the model performance metrics for these efforts. Previous Barataria Basin hydraulic analysis presented in a recent study by Meselhe (The Water Institute 2014) provides a good starting point for these discussions. These standards have not yet been established for design and permitting; therefore, we did not calibrate the models but instead looked at general trends.

The two-dimensional HEC-RAS hydraulic models were intended to provide insight into the general behavior of flows within Barataria Basin and the general impacts of diversion on Basin conditions. The other intended purpose of these analyses was to refine the tailwater conditions for a no-wind condition, which is the condition that would produce the lowest tailwater and define the maximum diversion channel discharge rate. Conditions with wind would produce higher tailwater conditions typically and would slightly increase tailwater and slightly reduce diversion rates. Under high wind conditions, the diversion would not likely be operated. Therefore, evaluation of the conditions with wind will be performed in future design and environmental documentation efforts.

The following provides commentary on the necessary data and process improvements required for design and environmental modeling:

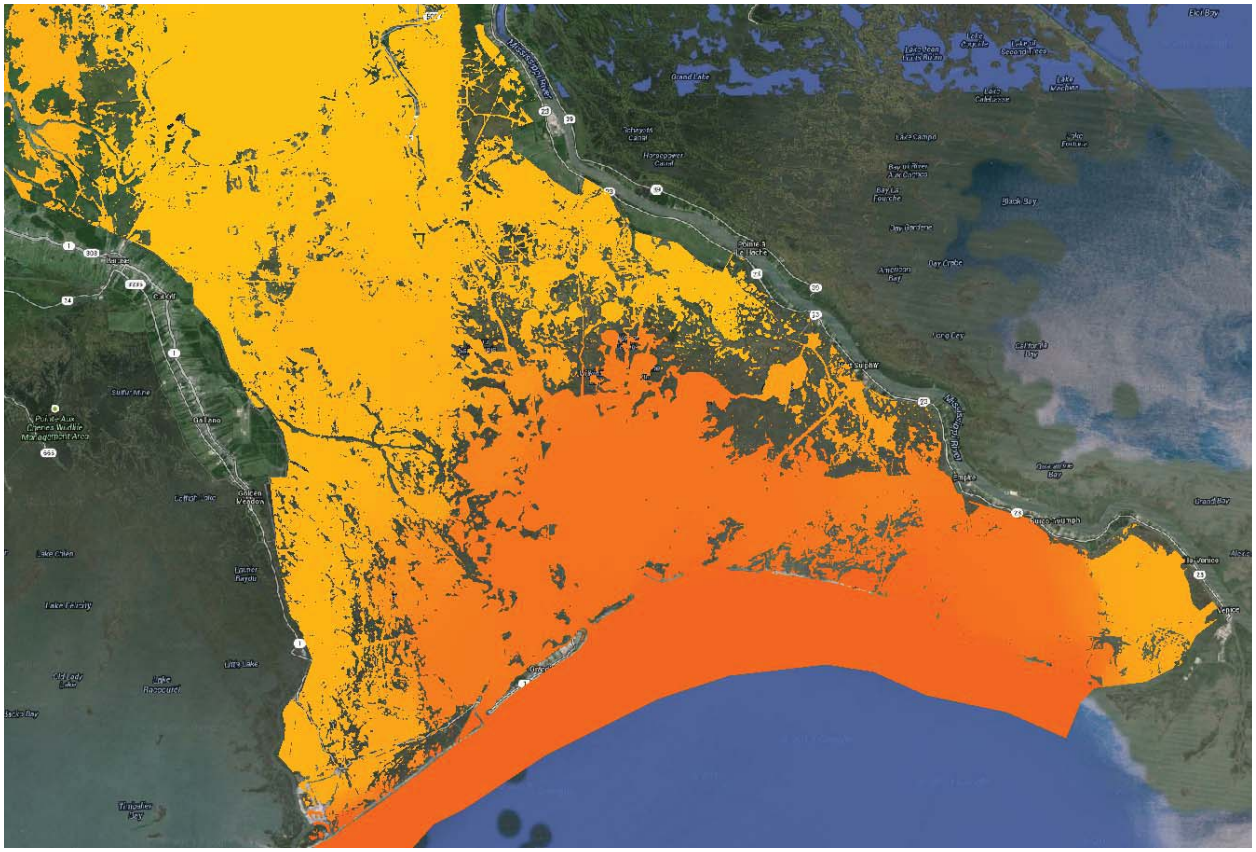
- Calibration Data Limitations – The Coastwide Reference Monitoring System, NOAA, and USGS datasets are related to an absolute elevation using a gage datum at each gage site. Many of the gage datums were either approximated or were established with a variety of vertical adjustments from known monuments established during different time frames, subsidence adjustments, and different geoid assumptions. This has resulted in significant variability between the basis of elevation used for each of the available gages, with the gage datum deviating from 0.3 to over 1.0 feet from a value that would be on a common vertical framework (personal communication, Ricardo Johnson, Fugro, July 2014). To resolve this problem, CPRA has contracted with Fugro to correlate all of the gage datums using a common vertical bench mark and specified geoid to make all of the data on a consistent vertical baseline. Without these adjustments, use of unadjusted data could lead to model adjustments that would be different when values are properly correlated to one another.
- Boundary Condition Elevation Limitations – The tidal dataset being used as the downstream boundary condition suffers from the same true elevation uncertainties described above. Prior to calibration, this datum for this dataset needs to be verified.
- Calibration Limited to No-Project Alternative – Once the datum adjustments are available, the Basin gage network can be used to calibrate the models for the no-project condition only.
- Improved Terrain Data Will Be Available – During the next phase of design, the newer and more accurate LiDAR terrain dataset for the entire Basin area will be available from USGS. At that point in time, the terrain dataset being used for this analysis will be substituted for the newer and more detailed terrain data. Additional bathymetric data in the channels will also be necessary to refine that terrain dataset. At that time, calibration would be more appropriate for the design effort. A design calibration needs to begin with model adjustments to better reflect the physical characteristics being modeled (improvement of the representation of the channels with accurate bathymetry and refining connectivity representation in the model, for example). Additional bathymetric surveys of the largest channels within the Basin will be important to the calibration process. Adjusting roughness coefficients can result in a better fit to observed data, however, a design level calibration capturing observed flow dynamics using other data available for flow velocities in the channels would provide a more defensible calibration for use in simulating design-level diversion flows. Sufficient level of bathymetry to capture this level of detail and calibration flow data currently does not exist.
- Upper Region of Basin Not Included – The model extents at the northwestern part of the model domain are based on the available more detailed terrain datasets. The topographic mapping for the upper region that is currently available is older and has a much lower resolution. The future model and terrain refinements will include this area using the recent LiDAR dataset by USGS.

- Highway 90 – The upper region of the Basin is not correctly reflected in the model since Highway 90 blocks much of the Basin in this region, which is not adequately captured with the current model. The flow interaction into this extreme northwestern region of the Basin must be conveyed through existing culverts and bridges. Incorporation of the roadway embankment, culverts, and bridges will be needed to correctly simulate inflows and outflows into this region of the domain.
- Other Linear Features – Other linear features that affect flow distributions in the Basin need to be adequately reflected in the model as a part of the calibration process. This would include roadway embankments, levees, and the existing floodwall along the western side of the Pen.
- Definition of All Inflows and Outflows – Barataria Basin inflows and outflows need to be better defined. Inflows would include the Intracoastal Waterway, groundwater, Naomi Syphon, Davis Pond, precipitation, etc. Outflows would include the Intracoastal Waterway and other potential overflow areas along the western edge of the model domain.
- Atmospheric Conditions – Wind influences in particular result in variability in recorded water levels in different parts of the Basin at any given time. HEC-RAS 5.0 Beta does not yet include the ability to simulate the impacts of wind. As mentioned previously, wind may be added to HEC-RAS 5.0 in future updates. It may be necessary to use Delft3D or RMA2 to incorporate wind. The benefit of HEC-RAS to is quickly run scenarios. Long-term influences of wind or unexpected storms may need to be evaluated using other models.
- Because the primary purpose of the analysis was to evaluate the general hydrodynamics of the Basin, potential differences in water surface relative to a no-project condition and tailwater elevations to the area within 1 mile of the diversion outfall, it was felt that the results from this modeling effort were sufficient for the purposes described in this report. Refinements to improve these results are appropriate during the next phase of the design effort using the better data that will also be available at that time. Model output comparison for the tide-only analysis with the available Coastwide Reference Monitoring System datasets does show that the model reasonably mimics tidal fluctuations in various parts of the Basin.

Results for Tide-only Simulation

Review of the results from the without project simulation (tidal influence only), some very important dynamics can be noted which are more apparent when an animation of the tidal flux is viewed. The predominant tidal fluctuation occurs in the region shown in Figure 11 which is the HEC-RAS 5.0 model output for a typical high tide condition. At the northern limit of this tidal flux region, significant marsh has formed along a half moon shaped area which appears to have been the dominant interface between the salt and fresh water regions of the Basin prior to the construction of channels through these marsh areas (which have allowed more interchange of salt water further north in recent decades). The terrain dataset along this northern limit of this darker orange zone associated with high tide elevations shows a relatively consistent elevation of this half moon shaped marsh area that is above an elevation of 3 feet where a denser marsh area has formed in this region. Therefore, flow from the north of this region can only pass through the openings in the marsh which are predominately navigation channels. These navigation channels have limited conveyance capacity, especially at high tide. The 2D simulation shows this feature as having a very significant influence on the flow dynamics during a diversion sequence also.

Figure 11. General extent of primary tidal flux



Results for Diversion Scenarios

For the purpose of discussion, WSE information was extracted from the model results at selected points. The location of these points is shown on Figure 12. At each of these selected points a modeled WSE hydrograph is presented in Figure 13. The reported WSE elevations should be considered approximate because of the factors described above.

Figure 12. HEC-RAS two-dimensional model data points

These results indicate WSE increases on the order of 1.5 to 2.0 feet throughout the northern part of the Basin at the 80,000 cfs discharge. This indicated that there were measurable WSE impacts that extended all the way to the northwestern boundary of the HEC-RAS model. However, WSE impacts in the southern portion of Barataria Basin near the Gulf were less pronounced due to factors described in Section 3.3.1. As reported in Section 3.3, the project influence at the northwestern boundary is likely to be overpredicted since the model does not account for the limited connectivity into this region of the Basin caused by Highway 90. Once the model is refined to account for the limited connectivity provided by Highway 90 culverts and bridges, project influences in this region will likely be significantly lessened.

Figure 13. HEC-RAS 2D model stage hydrographs with and without project

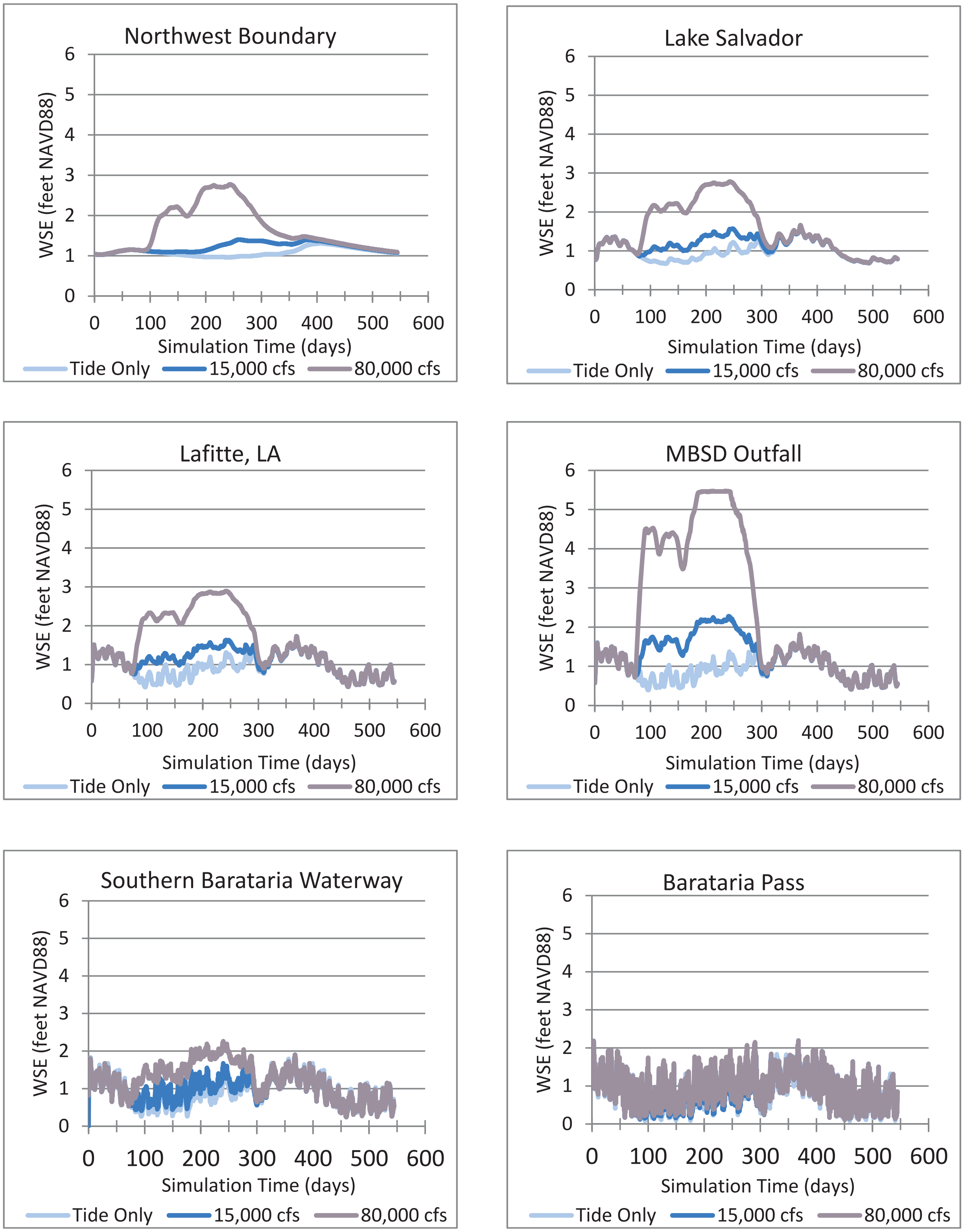


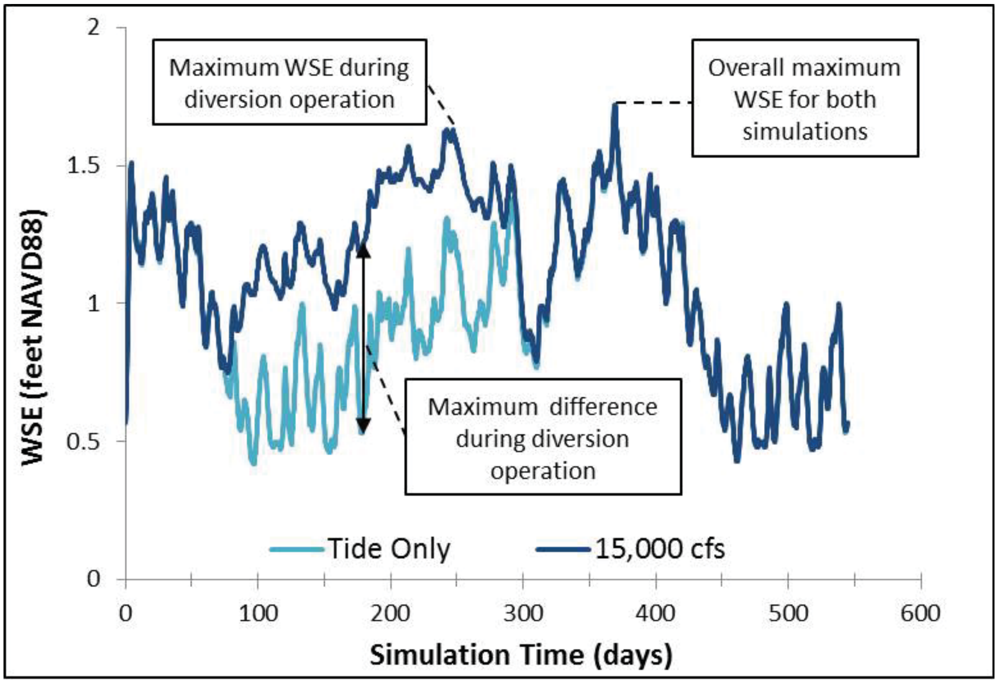
Table 5 gives the maximum differences between the WSEs experienced during diversion operation and those experienced in the tidal-only run at selected points around the tidal restart models. In the 15,000 cfs diversion, the increases in WSE during diversion operation compared to the tidal-only run were on the order of 0.5 to 1.5 feet. However, the overall range of WSEs experienced in the entire 15,000 cfs diversion simulation was approximately the same as that of the tidal only run. This is attributable to the background fluctuations in the tidal stage experienced over the entire simulation. This can be seen in the hydrographs in Figure 14, where in the latter portion of the simulation the tidal levels become relatively high, producing WSEs slightly above those experienced during the operation of the 15,000 cfs diversion for some areas of the model. Figure 20 is an example set of hydrographs from a location approximately 7 miles from the diversion, which illustrates this complexity. In this figure, the value depicted as “the maximum difference during diversion operation” corresponds to the values provided in Table 5.

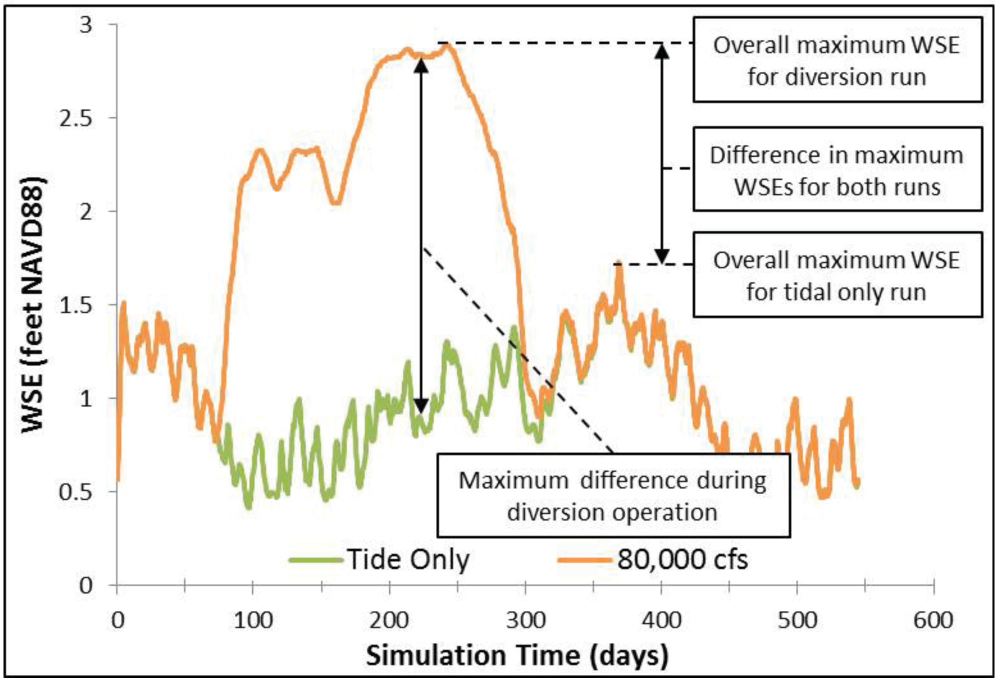
Table 5. Maximum difference in WSEs during diversion operation for selected areas

Location	15,000 cfs diversion (feet)	80,000 cfs diversion (feet)
Northwestern boundary	0.4	1.8
Lake Salvador	0.5	1.8
Lafitte, Louisiana	0.7	2
MBSD outfall	1.4	4.7
Southern Barataria Waterway	0.3	1.2
Barataria Pass	0.5	0.6

Notes: cfs = cubic feet per second, MBSD = Mid-Barataria Sediment Diversion

Figure 14. Example WSE hydrographs for diversion operation and tidal only runs showing various local and overall maximum





Plots were created illustrating approximate overall maximum WSEs found across the whole Barataria Basin from the entire simulation (including before and after diversion operation). The approximate maximum WSEs can be attributed directly to diversion flows in some areas and to tidal fluctuations before or after diversion operation in others. Actual WSEs during diversion operation will vary from those shown based on wind, tidal variation, and other hydrologic factors. Figures 15 to 17 illustrate the approximate Barataria Basin maximum WSEs for the tidal influence only, 15,000 cfs peak diversion run, and 80,000 cfs peak diversion run, respectively.

Figure 15. Approximate maximum Barataria Basin WSE – tidal influence only

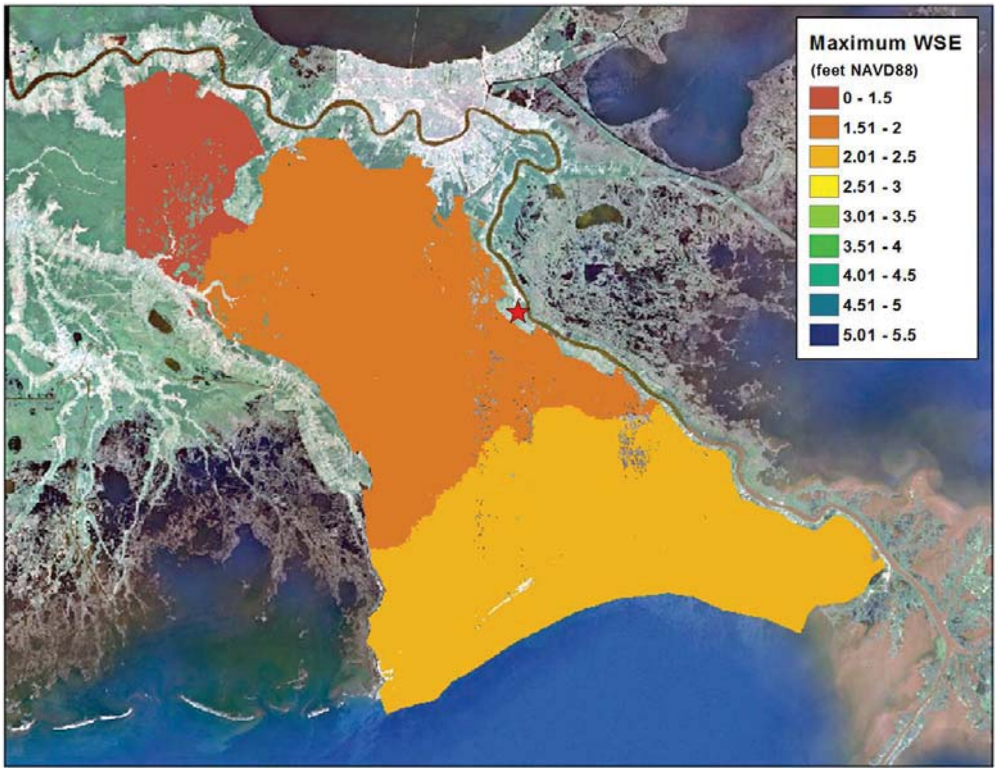


Figure 16. Approximate maximum Barataria Basin WSE – 15,000 cfs peak diversion

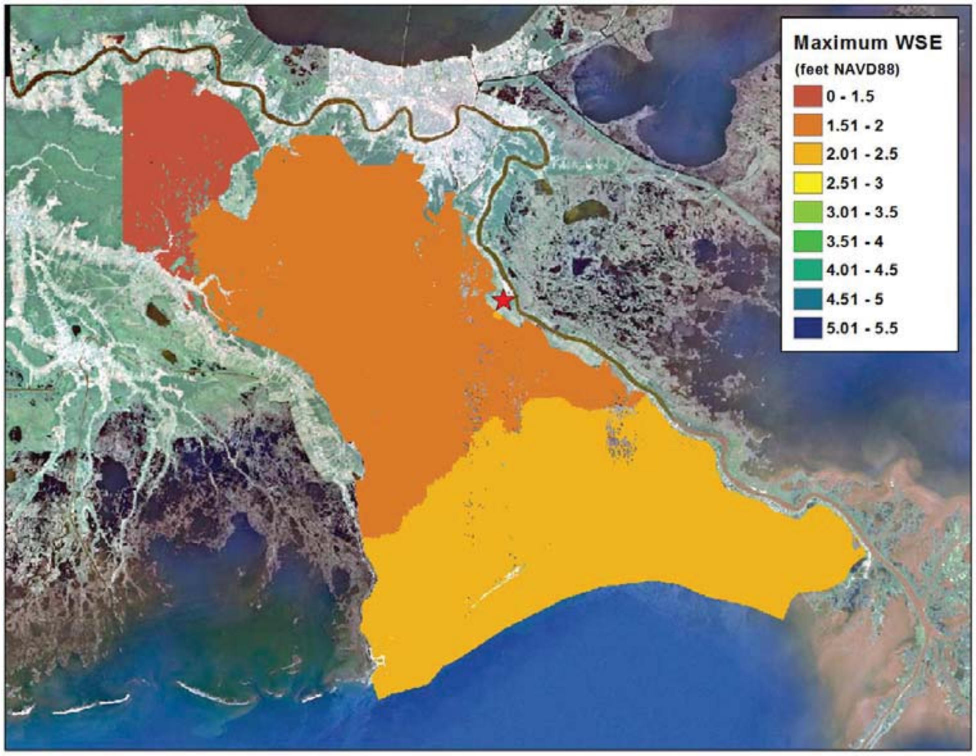
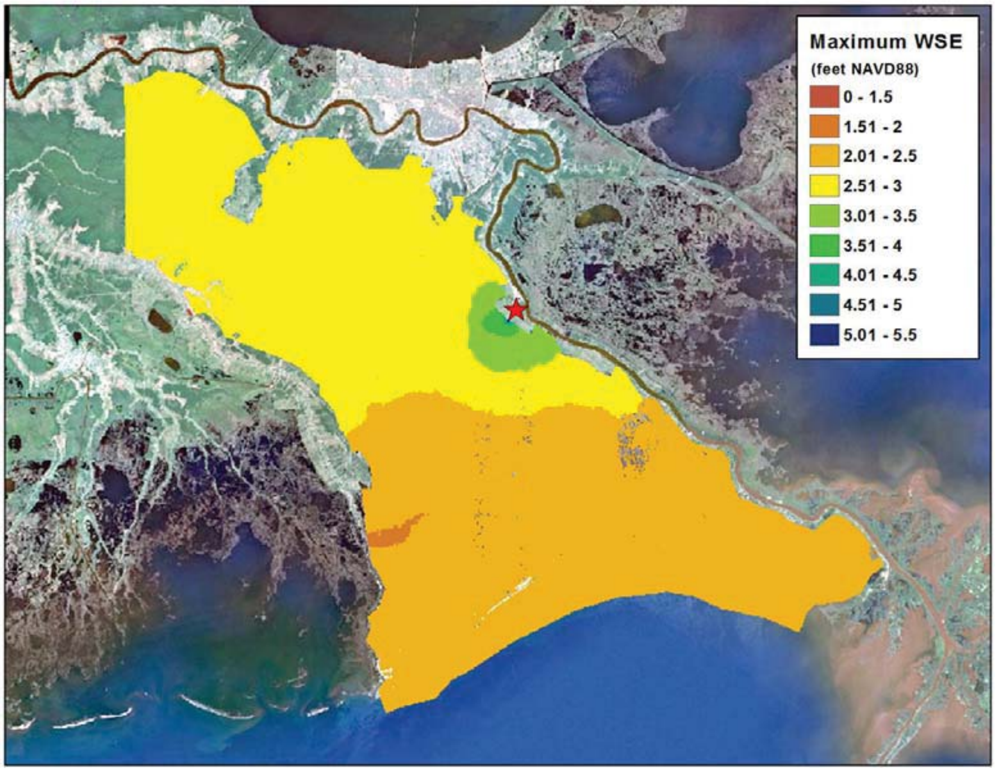


Figure 17. Approximate maximum Barataria Basin WSE – 80,000 cfs peak diversion



To illustrate the differences between the 80,000 cfs and tidal-only runs, the approximate overall maximum WSEs from the tidal-only run was subtracted from that of the 80,000 cfs peak simulated diversion run. This value corresponds to the difference in maximum WSEs for both runs depicted in the example hydrographs in Figure 14. The results of these analyses are shown in Figure 18. This figure demonstrates that the areas with the greatest WSE change are located to the north in Barataria Basin, away from the Gulf. Nearer to the Gulf, the tide, combined with the high terrain feature noted in Section 3.3.1, significantly influences the distribution of diverted flow volume in the Basin.

In the 80,000 cfs peak diversion model, the highest WSEs from the diversion are observed in the direct vicinity of the outfall. The 80,000 cfs peak diversion hydrograph produces maximum WSE differences of approximately 4 feet in the immediate outfall area, as compared to the maximum in the tidal-only model. Differences in maximum WSEs in the areas northwest of the diversion are approximately 1.0 to 1.5 feet. This modeling indicates a propensity for diverted flow to accumulate in the Basin northwest of the diversion.

Figure 18. Approximate maximum change in Barataria Basin WSE – 80,000 cfs peak diversion

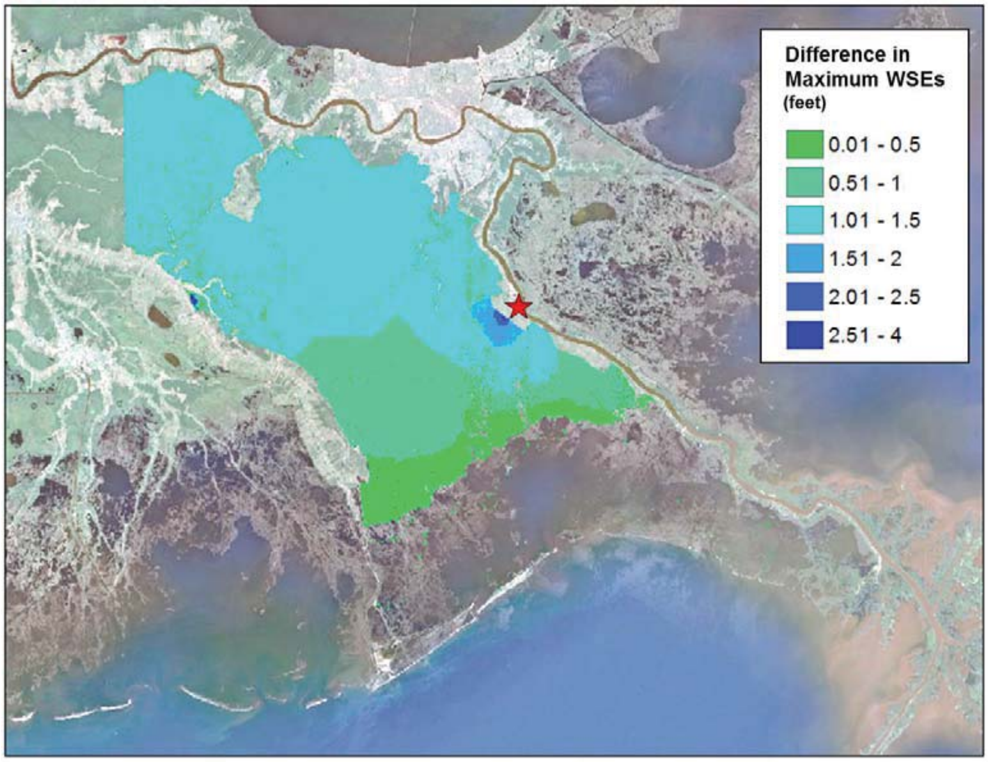


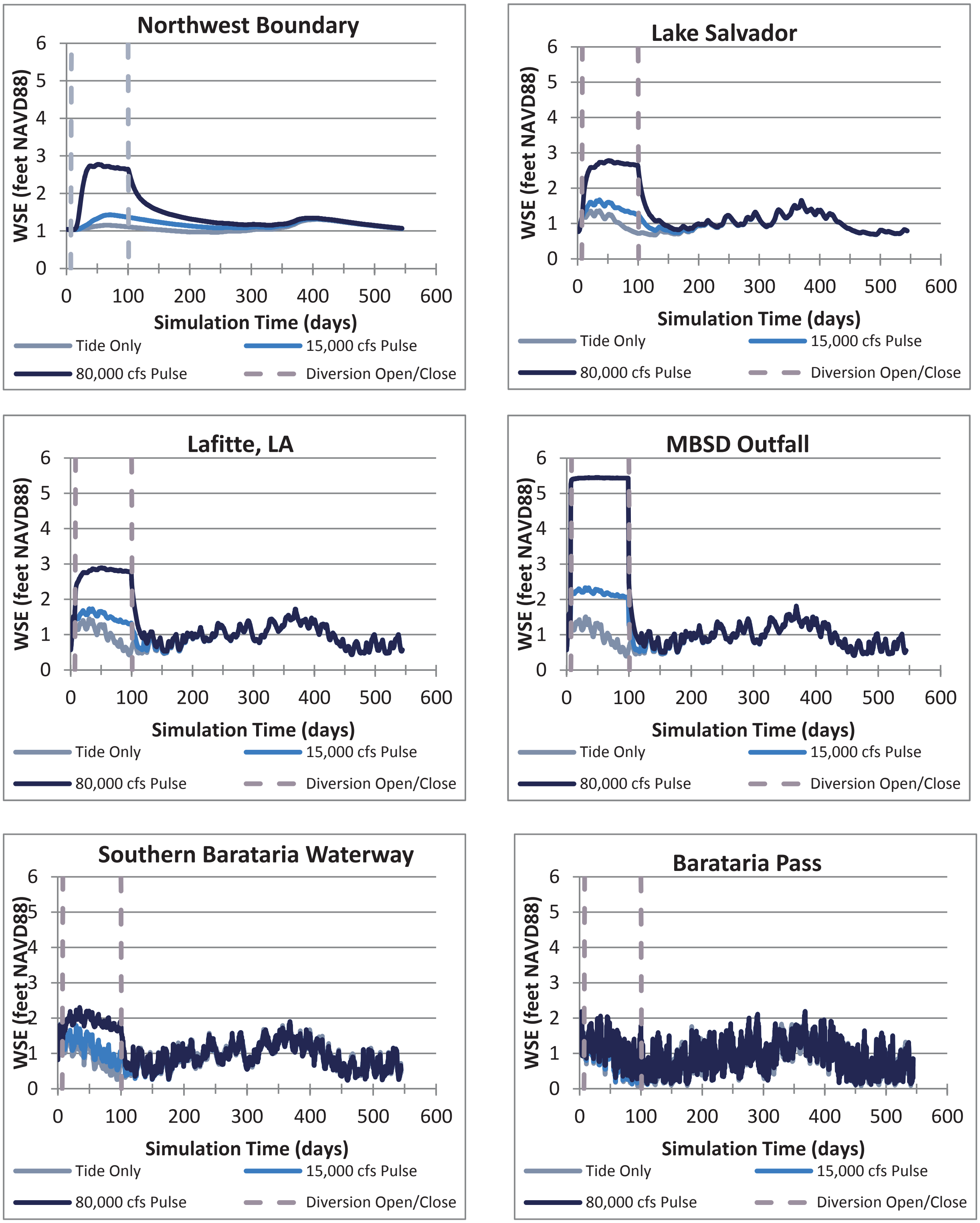
Figure 14 illustrates that during 15,000 cfs operational runs, the maximum difference with tide-only runs was approximately 0.5 feet to 1 foot. However, due to seasonal variation in the tides, the fall tide cycle results in WSEs greater than those observed during diversion operation in the spring and summer. Due to the seasonal variations, comparison of the maximum water surface elevations for the 15,000 cfs diversion was not capable of providing good spatial plots. Further refinements to the model would allow for results to be limited to diversion only periods to better understand the spatial maximum WSE differences for lower flow diversions.

Pulse Diversion Models

To investigate the duration of WSE recession after diversion shutdown, pulsed diversion models were completed. These models had an instantaneous opening of the diversion at 8 days into the simulation and an instantaneous closing of the diversion 100 days into the simulation, with a constant diversion discharge during operation. Figure 19 presents stage hydrographs with the time of opening and closing marked by dashed lines. Also depicted are the tide-only runs, which demonstrate the background WSEs that would be expected without the diversion in operation.

The results demonstrate that the lag between diversion opening or closing and the associated change in the WSE is longer in areas farthest away from the diversion. In general, it also takes longer for stages to recede than it does for stages to reach peak levels after opening. The lag is most pronounced in the northwest area of the model. For example, in the 80,000 cfs pulse model, at the northwest boundary, it takes over 200 days for the stage to recede to background levels, which is defined here as the WSE found in the tide-only run. Whereas in Lake Salvador, the recession takes around 75 days, and in The Pen near Lafitte, only around 30 days. At the northwest boundary, it takes approximately 12 days for WSE increases above existing conditions to drop below 1 foot, while at the MBSD outfall, WSE increases above existing conditions drop below 1 foot within 1 day. Impacts from pulsed operation models, once refined in future efforts, can help define operational considerations for the diversion.

Figure 19. HEC-RAS two-dimensional tidal restart model WSE pulse hydrographs



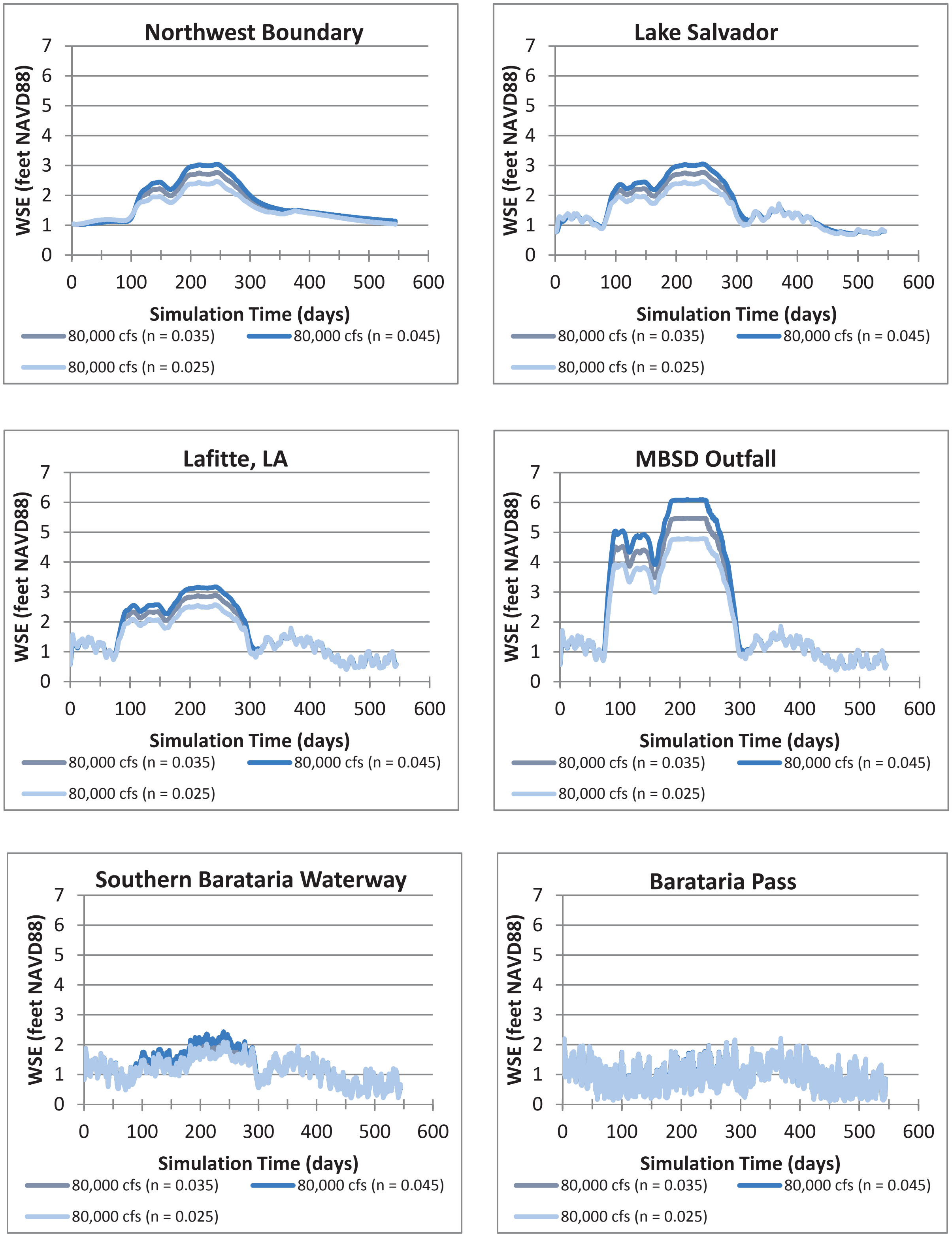
Roughness Sensitivity Models

Additional model runs of the 80,000 cfs peak diversion simulation were completed to determine the effect of varying the roughness of the Basin terrain. The Manning's n values used were 0.025 and 0.045, to compare with the assumed 0.035 used throughout the HEC-RAS two-dimensional modeling effort. Figure 20 presents stage hydrographs from these models as well as those of the original 80,000 cfs run with n equal to 0.035.

As expected, higher roughness generates higher WSEs during greater periods of inundation, when velocities are higher. Generally, increasing the Manning's value by 0.01 increased the Basin-wide peak WSEs by roughly 10 to 12 percent. Maximum impacts from roughness variations were observed in the vicinity of the diversion channel outfall and to the northwest of the outfall. The effects of roughness were less pronounced nearer to the Gulf, where stages were not greatly increased by the diversion.

Care should be taken in drawing any premature conclusions from this result. Roughness is not the only factor impacting model results and should not be used as the only calibration adjustment. During the future phase of work, these models will be calibrated using terrain refinements for proper evaluation of Basin connectivity within the Barataria Basin and with adjoining areas, consideration of groundwater influences, additional surface water inflows and outflows and other factors. Roughness in the Basin should also be treated as variable rather than as a constant value. These results were only developed for the purpose of demonstrating general sensitivity to this parameter.

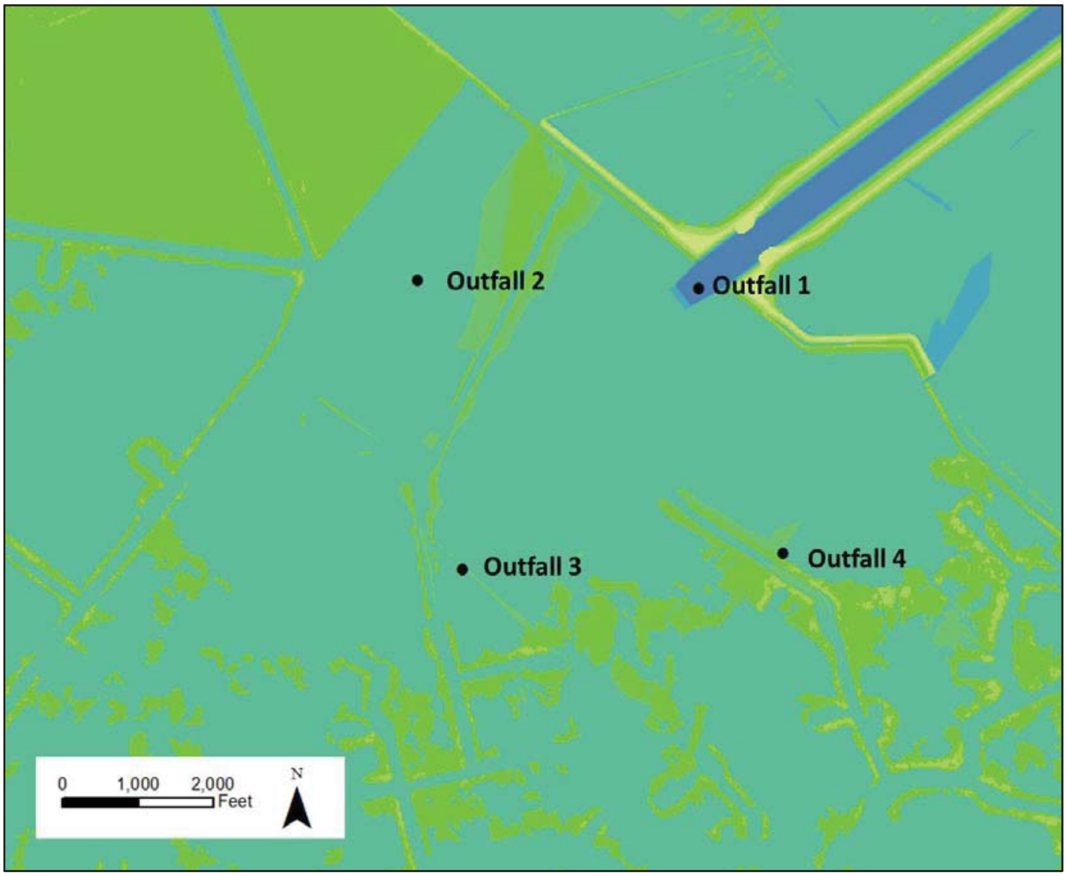
Figure 20. HEC-RAS two-dimensional tidal restart model WSE roughness sensitivity hydrographs



MBSD Outfall Rating Curve

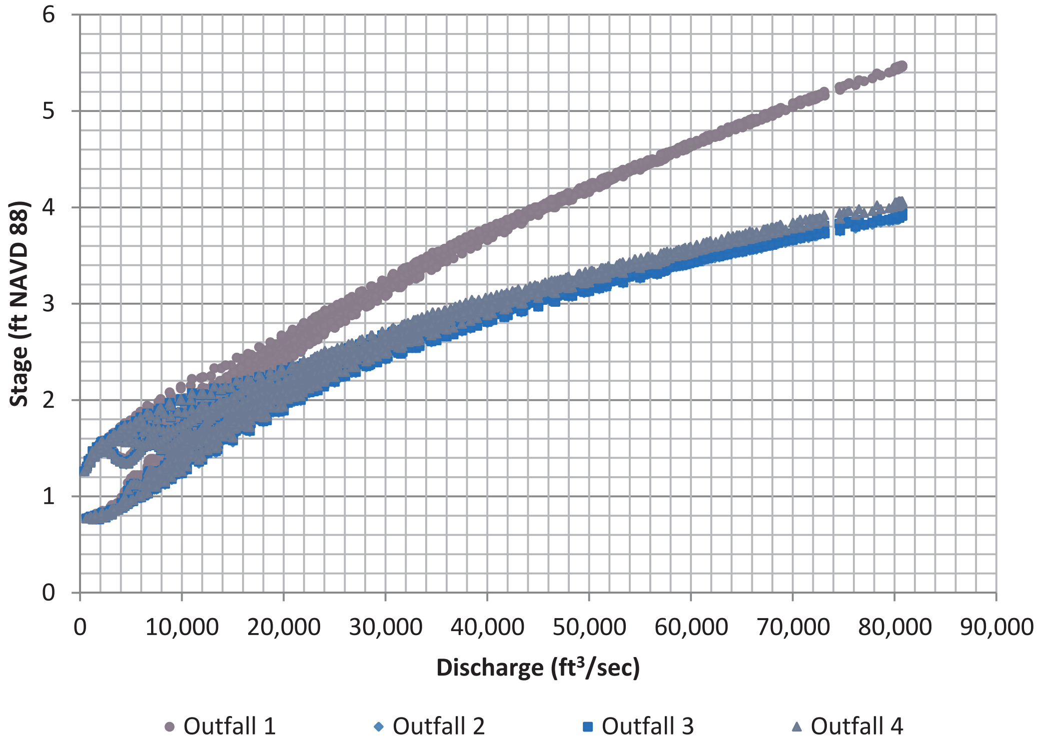
A rating curve was developed to relate diversion discharge and WSEs within 1 mile of the outfall. The rating curve was used to define the Basin WSE boundary condition in the FLOW-3D and HEC-RAS one-dimensional models. Hydrographs were taken from points along the approximate edge of the FLOW-3D surface in Barataria Basin, as shown in Figure 21. This information was then plotted with stage as a function of discharge in a rating curve, shown in Figure 22.

Figure 21. MBSD outfall rating curve hydrograph locations



The point referred to as Outfall 1 is located in the HEC-RAS cell where the MBSD diversion hydrograph was applied. Its associated results are shown in Figure 22 for discussion purposes. The points labeled Outfall 2, 3, and 4 are located on the edges of the FLOW-3D surface in Barataria Basin. The associated hydrographs from these points were used to determine tailwater elevations for each alternative. Outfall points 2, 3, and 4 were also representative of the farthest downstream cross section in the HEC-RAS one-dimensional hydraulic models.

Figure 22. MBSD outfall rating curve



The Basin WSEs derived from this plot are shown in Table 6. To identify the Basin WSEs for MBSD tailwater in subsequent FLOW-3D modeling, an estimate of diversion discharge was needed. These diversion rates were based on previous basis of design FLOW-3D modeling, HEC-RAS one-dimensional VE modeling, and professional judgment. For all alternatives, a 1,250,000 cfs flow rate in the Mississippi River was assumed.

Table 6. MBSD Basin boundary conditions

Alternative	Predicted discharge (cubic feet per second)	Basin water surface elevation (feet NAVD 88)
Alternative 1, Version 1	82,000	4.0
Alternative 1, Version 2	82,000	4.0
Alternative 2, Version 2	58,000	3.3
Alternative 4, Version 2	38,000	3.0
Alternative 5, Version 2	35,000	2.9

3.2.3 Design Considerations

The results of this modeling effort can inform design in several ways:

- An estimate of the hydrodynamic influence of Barataria Basin topographic features and tidal boundary influences;
- An estimate of the hydrodynamic influences of various diversion flow rates;
- An estimate of near field WSEs at the outfall area near the NOV/NFL levee without wind impacts;
- An estimate of the tailwater under a no-wind condition for use in evaluation of maximum diversion performance; and
- An estimate of the response time in the Basin to cessation of flows from diversion operation.

3.3 Evaluation of Inlet Influence on Mississippi River Near Field Velocity Vectors

Two three-dimensional models were run to simulate the hydraulics around the inlet when the diversion is not operating. This was done for Alternative 1 Version 1, an open channel configuration, and Alternative 4 Version 2, a tunnel configuration. Analysis of impacts was limited to the near field area around the inlet.

Figures 23 and 24 depict an instantaneous velocity field in the direct vicinity of the inlet for both alternatives at several depths. The models showed areas of increased velocity localized upstream and directly around the inlet as flow accelerates into the diversion during operation. Additionally, it can be seen that flow accelerates around the inlet channel walls and cofferdam where they protrude into the river on the downstream side of the inlet.

Figure 23. Velocity contours around the inlet for Alternative 1, Version 1 with the diversion not operating (top) and operating (bottom)

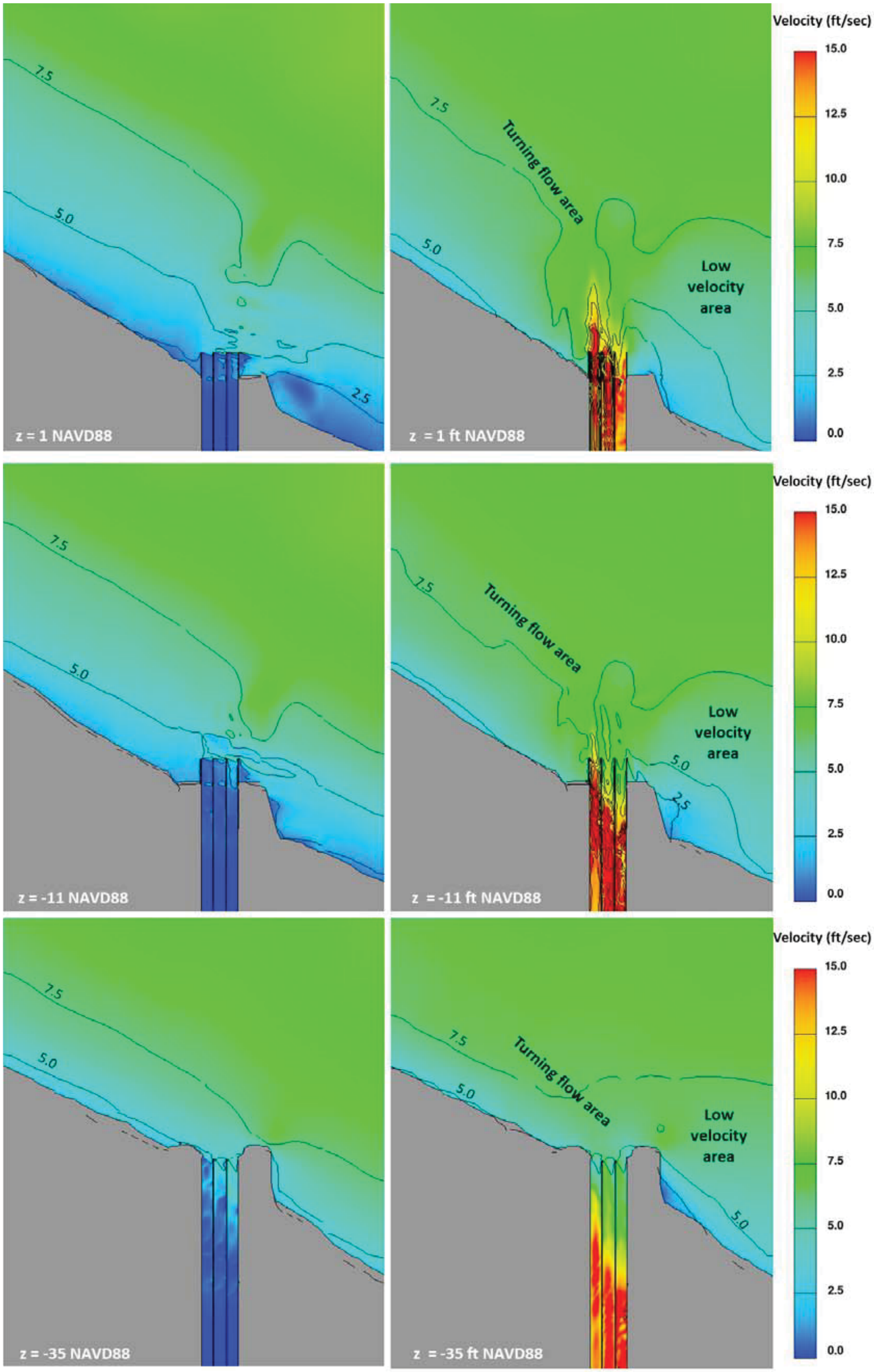
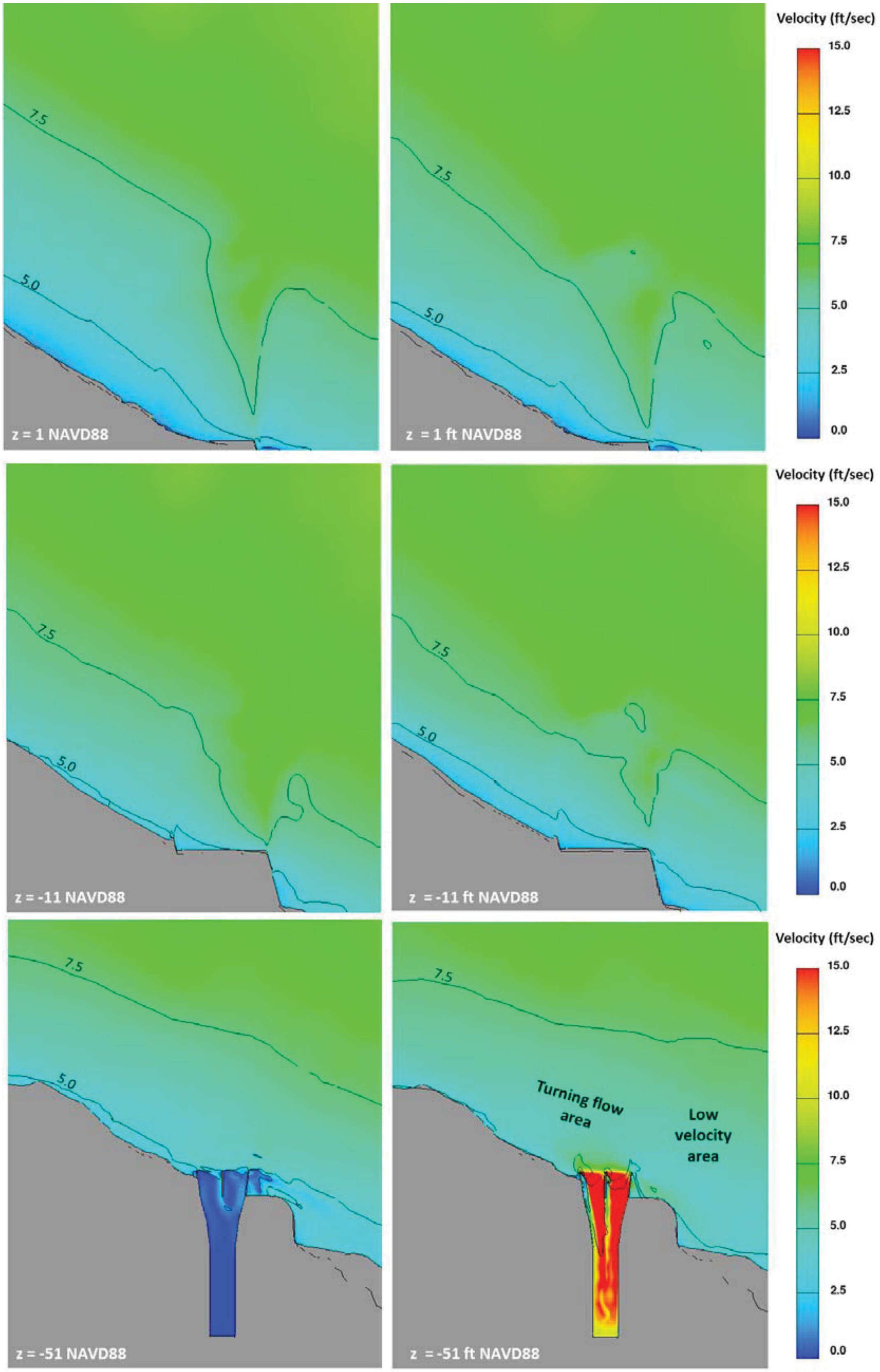


Figure 24. Velocity contours around the inlet for Alternative 4, Version 2 with the diversion not operating (top) and operating (bottom)



Results shown in Figure 23 and Figure 24 illustrate that diversion operation has impacts on the near field velocities. Generally, diversion operation creates lower velocities downstream of the inlet. These low velocity fields result from the hydraulic impacts of the turning of flow out of the Mississippi River into the diversion channel. The turning of flow out of the Mississippi River creates a shadow in the downstream direction that is not seen when the diversion is not in operation. Additionally, there is a larger recirculating flow component downstream of the diversion structures during operation, as flow is diverted out of the river and downstream flow is pulled upstream.

As expected, the lower velocities downstream observed during diversion operation were observed for the full flow depth in the open channel diversion. However, the submerged inlet design had minimal impacts on the velocity fields in the upper layers of the Mississippi River flow. These results further support the findings in Section 2.3 of this report, in that submerged inlets pull no flow from the top layers of the Mississippi River and thus, do not have any major impacts to the overall upper velocity fields.

Scour analysis previously completed for the 30% BOD report was based on empirical analysis of projecting structures into a flow field. These scour numbers correlate to a diversion system that is not operating. Results from this study indicate the potential for depositional areas downstream of the diversion in the low velocity shadow created by the turning of flows. This creates a condition where a scour hole would develop at the downstream end of the inlet during non-operational times that could fill in or shift during operational times. Caution should be taken in trying to predict specific location of scour holes without further refinements of the multi-dimensional models completed for a range of flow conditions.

4 Conclusions

Based on a wide range of hydraulic analyses, overall VE alternatives as defined in Section 1.1 of this report perform as expected. Analyses summarized in this report did not identify any critical items that would require substantial geometric or design changes to these alternatives.

Comparison of the open channel diversion and the submerged inlet produced interesting results. There is the potential for preferentially selecting flows from within the Mississippi River water column associated with submerged inlets that should be explored in future efforts.

Comparisons and evaluation of diversion alternatives is complex and is highly dependent on operational conditions. Operational conditions are directly tied to Mississippi River and Barataria Basin conditions. In order to more accurately compare and evaluate diversion for Mid-Barataria, advancement of the operational assumptions and interaction with the River and Basin will be required.

5 Recommendations

VE concept hydraulic analyses completed for this report were focused on identifying any critical issues that would require substantial re-design or geometric changes to the VE concepts. Analyses completed for this report were not intended to support final design efforts but do function to effectively progress the understanding of diversions at Myrtle Grove. In order to further develop the understanding of the MBSD hydraulic and sediment performance, the following additional work efforts are recommended:

- Refinement to the sediment water ratio analyses to support understanding of the submerged inlet. This would include a more comprehensive model of the inlet with a large portion of the Mississippi River.
- Investigations into the behavior of bed forms on the sand bar and in the main channel of the Mississippi River. This would include empirical analyses of the dunes for a range of conditions, as well as verification of impacts to hydraulics and performance with sediment transport models. These efforts would help understand the opportunities and constraints for inlet elevations.
- Refinements to the multi-dimensional models with focus on the inlet, overbank areas, gates, bridges, outfall, and transitions. Models with much greater detail should be created for scour-critical areas around structures to better understand the flow characteristics and help evaluate type and extents of scour mitigation alternatives.
- Further development of long term sediment models within the diversion channel based on improved sediment water ratio and geotechnical findings. Sediment water ratios and composition of the bed material throughout the channel will greatly impact the amount of erosion or deposition that occurs in the diversion channel and this understanding will be critical for designing channel lining.
- Definition of operational conditions or critical operational constraints. Currently models are run assuming operational triggers solely tied to Mississippi River discharges. It will be critical to better understand operational constraints from Barataria Basin, navigational interests, environmental interests, legal interests, and the Mississippi River.
- Implementation of ongoing Mississippi River hydraulic and sediment studies with model results. The Mississippi River is a highly dynamic system and current studies on the changing hydraulics and sediment behavior will help refine and inform the MBSD analyses.
- Creation of a connected Mississippi River, diversion channel, and Barataria Basin model with multi-dimensional capabilities. All system hydraulics are closely connected and models are becoming available that will have the ability to analyze a fully coupled system to more quickly evaluate the overall system behavior without the time consuming iterations between various models.
- Large scale physical modeling should be conducted at a minimum for the inlet to validate numerical modeling and to further develop the understanding of the complex inlet hydraulics and sediment diversion behavior. Large scale modeling should consider the interaction of submerged inlets and bed formations, as well as validate numerical tracer studies.

The Basin analyses described in this report and in the associated Water Institute report provide valuable insights into Basin hydrodynamics, morphological response during the initial diversion period, operational and sediment capture dynamics of various diversion configurations, areas of potential refinements in modeling efforts, and data collection needs. The primary purpose of these modeling efforts was to provide insight into the general Barataria Basin response to MBSD diversions, as well as provide near-field Basin WSEs for use in FLOW-3D and HEC-RAS 1D modeling. Modeling completed for Barataria Basin was completed for a day zero operation with no distributary channel formation. Additional terrain will need to be generated to represent future geomorphic Basin conditions or a Delft3D model will need to be created for the whole Basin, capable of representing the significant detail of the system. Pulse diversion operation should be conducted for various future conditions of the Basin to determine evolution of the hydrodynamic responses to diversion.

As described earlier in this report, Basin hydrodynamic modeling will need to be refined with the next phase of work to further refine the findings presented in this report. The next phase of work will need to consider the following:

- Use Newer LiDAR Terrain Data – The current terrain data needs to be substituted with the newer USGS LiDAR dataset that will also provide a dataset for the entire impacted domain.
- Collect Bathymetric Data – The results of these analyses demonstrate the importance of properly capturing the geometry of the various channel features within the Basin in the model. These channels are extremely significant to the flow movements within the Basin and between the upper region of the Basin and the southern region of the Basin, which is predominately tidally influenced. This will be very important to the water quality modeling as well.
- Breakline Data – Creation of a terrain surface requires the use of breaklines at the tops and toes of terrain features (roads, levees, marsh areas, channels, etc.). These breaklines must be manually created using available data from the LiDAR and bathymetric surveys.
- Compilation of New Terrain Surface – The USGS LiDAR dataset, bathymetric surveys, and breakline data will need to be used to create a defensible composite terrain surface representing the Barataria Basin.
- Compile Gage Datum Adjustment Data – The work being performed by Fugro for CPRA to adjust the reported gage datums for the region to a common geoid and common elevation reference will be critical to the validation and calibration of all modeling efforts.
- Collection of Highway 90 and Lafitte Floodwall Data – The incorporation of these linear features in the model are important to properly capture the hydrodynamics of the Basin.
- Intracoastal Waterway Influence – Inflows into the Basin as well as impacts to outflows from the Basin due to water level changes need to be captured in Basin simulations.
- Groundwater Influence – Recent studies have indicated that the volume contribution of groundwater into the Basin can be significant and seasonably variable. This influence should be explored further.
- Wind Data – Seasonal variability in wind direction and magnitude needs to be evaluated and incorporated into the models and operational decisions.
- Operational Meteorology – The range of potential conditions that would result in changes to operation of the diversion need to be identified. Once identified, the meteorological conditions that create wind speeds that would result in operational changes need to be evaluated with respect to several factors, such as season in which they occur and forecast lead time potential.

6 References

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Topographic Data Sources

A number of data sources were used to help define the refined Barataria Basin surface. Those data sources are as follows:

- Southern Louisiana ⅓ arc-second (~10 m) NAVD 88 DEM

Citation: Love, M. R., R. J. Caldwell, K. S. Carignan, B. W. Eakins, and L. A. Taylor. 2010. *Digital Elevation Models of Southern Louisiana: Procedures, Data Sources and Analysis, NOAA National Geophysical Data Center technical report*. Boulder, Colorado.

- New Orleans (LA/MS) ⅓ arc-second (~10 m) NAVD 88 DEM

Citation: Love, M. R., C. J. Amante, L. A. Taylor, and B. W. Eakins. 2011. *Digital Elevation Models of New Orleans, Louisiana: Procedures, Data Sources and Analysis, NOAA Technical Memorandum NESDIS NGDC-49*. U.S. Department of Commerce, Boulder, Colorado.

- Northern Gulf Coast (LA/AL/MS/FL) 1 arc-second (~30 m) NAVD 88 DEM

Citation: Love, M. R., C. J. Amante, B. W. Eakins, and L. A. Taylor. 2012. *Digital Elevation Models of the Northern Gulf Coast: Procedures, Data Sources and Analysis, NOAA Technical Memorandum NESDIS NGDC-59*. U.S. Department of Commerce, Boulder, Colorado.

Survey Transect Points

- MBSD 2013 Outfall Survey –JCLS
- MBSD 2013 Pump Station Outfall Survey –JCLS
- MBSD 2013 LIDAR –JCLS
- BA-39 Bayou Dupont As-built Survey Data 2011–2012 –JCLS
- BA-43EB LDSP 2011 Survey – provided by T. Baker Smith to HDR
- Myrtle Grove 2002 Survey – provided by MN to HDR (These surveys were supplied by the Louisiana Department of Natural Resources to MN and were surveyed by Pyburn & Odom in August 2002.)

Other

- National Hydrography Dataset (polygons of marsh mats)
- CPRA Restoration Projects (spatial data: SONRIS; elevations provided by MN to HDR)