Phase II Storm Surge Analysis

Post 45 Project, Charleston, SC

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Executive Summary

This report presents the methodology and results of a storm surge analysis for the Charleston Harbor Post 45 Deepening Project. The Post 45 Project will deepen and widen the federal navigation channel to accommodate larger vessels. In general, deepening river channels may affect water levels in the river during extreme hurricane events.

The objective of the study is to assist the South Carolina Ports Authority (SCPA) and the US Army Corps of Engineers (USACE) Charleston District in completing storm surge modeling in order to ensure compliance with EO 11988, Floodplain Management. This executive order requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In this case, modification of the federal channel constitutes a modification of floodplains. To comply with EO 11988, the project impacts must be identified. To this end, this analysis will: (1) estimate the potential impacts of the proposed project on storm surge water levels in the estuary; and (2) determine if the potential impacts are significant enough to affect the flood hazard zones designated by the FIRMs for the area.

To meet this objective, Water Environment Consultants (WEC) was contracted by the SCPA to use the ADvanced CIRCulation (ADCIRC) hydrodynamic model to estimate potential project impacts to storm surge levels. WEC modeled extreme storm surge water levels approaching from the ocean and the resulting extreme water levels inside the estuary both before and after the proposed project.

The ADCIRC model grid used for this analysis is based on the grid developed for the ongoing FEMA flood map revisions for South Carolina under a Cooperating Technical Partner agreement between the South Carolina Department of Natural Resources (SCDNR) and FEMA Region IV. The SCDNR grid was trimmed to focus on Charleston Harbor, and the grid was refined to adequately resolve the federal navigation channel. The ADCIRC model was then validated by comparing to observed surge heights at Customs House during Hurricane Hugo.

Representative input 50- and 100-yr return period storm conditions were developed for this analysis. Historical storm data from Hurricane Hugo was modified such that the modeled surge levels at Customs House are about equal to the 50- and 100-yr flood levels determined by FEMA.

For each storm surge condition, WEC modeled both the existing navigation channel and the Post 45 project channel with the recommended wideners from ship simulation results. WEC then calculated the differences in maximum water levels at eight locations throughout the harbor. These locations correspond to US Geological Survey water level gage locations (Figure ES-1).

The results of the modeling analysis indicate that the Post 45 project will cause insignificant increases in peak storm surge water levels in the estuary as compared to the total surge levels estimated by FEMA. The maximum increases to storm surge caused by the project are 0.1 feet or less.

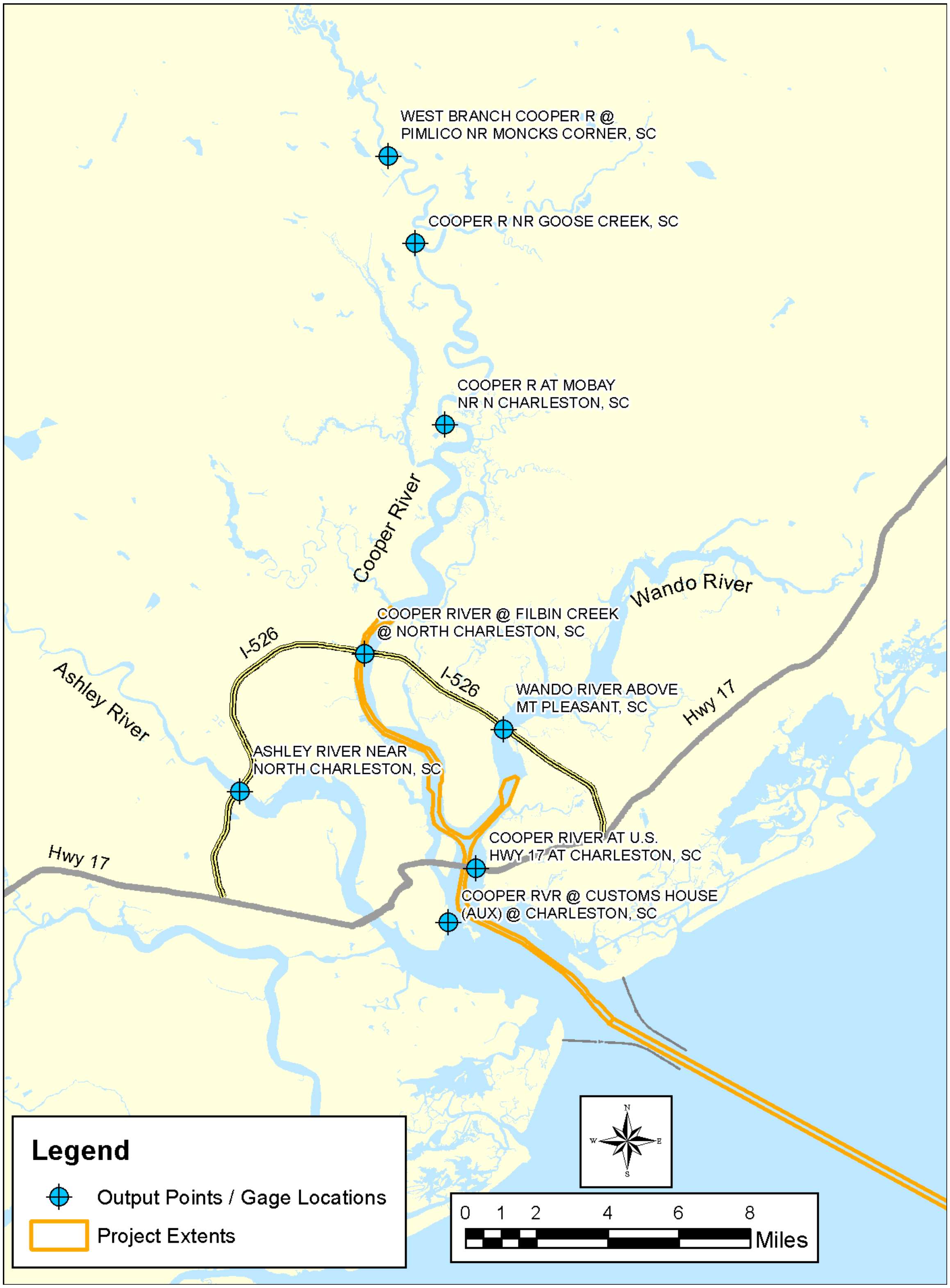

Figure ES-1. Output locations

As discussed above, in addition to quantifying the potential impacts to storm surge levels, the second goal of this study is to determine if the potential impacts are significant enough to affect the flood hazard zones designated by FEMA in the FIRMs for the area. This raises the question: how would the increased channel depths affect the SCDNR storm surge model results? A review of the SCDNR model indicates that the SCDNR model would be less sensitive to changes in navigation channel depth than the model used for this analysis. Therefore, if the deepened channel bathymetry were interpolated onto the SCDNR grid used for the new flood studies, then the SCNDR model would show even smaller impacts than those shown by the model analysis in this report. Furthermore, the potential impacts from the channel deepening are an order of magnitude smaller than the level of the uncertainty in the flood maps. Adjustment of the flood maps to incorporate the small effects from the channel deepening is unwarranted given the uncertainty in the SCDNR storm surge modeling and resulting stillwater estimates. Based on this analysis, the impacts from the project are sufficiently small that they would not affect the effective flood hazard zones designated in the FIRMs for the area.

Table ES-1 Modeled differences in maximum water levels

USGS Station ID	**Description**	**Difference in Max. Water Level (ft)**	
		50-yr	**100-yr**
2172020	West Branch Cooper River at Pimlico near Moncks Corner	0.0	0.0
2172050	Cooper River near Goose Creek	0.0	0.0
2172053	Cooper River at Mobay	0.1	0.1
2172067.7	Cooper River at I-526	0.1	0.1
2172069.8	Wando River above Mt. Pleasant (I-526)	0.1	0.1
2172070.9	Cooper River at Hwy 17	0.0	0.0
2172071.1	Cooper River at Custom House (AUX)	0.0	0.0
2172086.9	Ashley River near North Charleston (I-526)	0.0	0.0

1 Introduction

This report presents the methodology and results of a storm surge analysis for the Charleston Harbor Post 45 Deepening Project. The Post 45 Project will deepen and widen the federal navigation channel to accommodate larger vessels. The project includes:

- Deepening of the offshore entrance channel from a project depth of 47 feet to 54 feet mean lower low water (MLLW) and extension of the channel approximately three miles seaward to the 54 ft MLLW contour;
- Deepening of the inner harbor from an existing project depth of 45 feet to 52 feet from the entrance channel to the confluence of the Wando and Cooper Rivers, about two miles up the Wando River to the Wando Welch container facility and about three miles up to the Cooper River to the Hugh Leatherman Terminal, and to a project depth of 48 feet over the five mile reach leading from the Hugh Leatherman Terminal to the North Charleston container facility;
- Expansion of the existing turning basins at the Wando Welch and North Charleston Terminal and the permitting turning basin at the Hugh Leatherman Terminal; and
- Widening of selected channel reaches, as recommended by the ship simulation study.

In general, deepening a river channel may affect water levels in the river during extreme hurricane events. Deepening the channel increases the cross-sectional area and decreases the hydraulic friction, which allows a slightly greater volume of storm surge water to intrude into the river during an extreme hurricane event.

Earlier in 2016, Water Environment Consultants (WEC) completed a screening-level analysis of potential storm surge impacts using the EFDC hydrodynamic model. The EFDC model was developed for the project Environmental Impact Statement and Feasibility Study (EIS) and it was used to evaluate project impacts to water quality and sediment transport in the harbor. The EFDC model does not include floodplain areas above the normal high tide shoreline, and as a result, the results from that analysis are considered conservative (i.e., they over-estimate the project impacts). Based on the EFDC results, the screening-level analysis estimated that the Post 45 project would increase the maximum 100-year return period storm surge water levels by an average of 0.1 feet in the harbor area, and it would cause a maximum impact of up to 0.3 feet in certain areas. Because these estimates were large enough to potentially affect flood map elevations, if they were to be incorporated into the stillwater elevations used for the Federal Emergency Management Agency's (FEMA's) Flood Insurance Rate Maps (FIRMs), the US Army Corps of Engineers (USACE) decided to proceed with a more refined and more accurate analysis to quantify the potential project impacts. Subsequently, WEC was contracted to conduct a more detailed assessment of the potential storm surge impacts by using a hydrodynamic model that includes the floodplain areas surrounding the Charleston Harbor estuary.

The objective of the study is to assist the SCSPA/USACE Charleston District in completing storm surge modeling in order to ensure compliance with EO 11988, Floodplain Management. This executive order requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In this case, modification of the federal channel constitutes a modification of floodplains. To comply with EO 11988, the project impacts must be identified. To this end, this analysis will: (1) estimate the potential impacts of the proposed project on storm surge water levels in the estuary; and (2) determine if the potential impacts are significant enough to affect the flood hazard zones designated by the FIRMs for the area.

2 Methodology

The overall approach of the analysis is to model extreme storm surge water levels approaching from the ocean and determine the resulting extreme water levels inside the estuary both before and after the proposed project. To accomplish this, WEC used the ADvanced CIRCulation (ADCIRC) hydrodynamic model. The ADCIRC hydrodynamic model is a depth-integrated, time-dependent, long wave hydrodynamic circulation model (Luettich and Westerlink 2004; Luettich et al. 1992).

The first step in the analysis was development of an ADCIRC model grid that encompasses the western Atlantic Ocean basin and has high resolution in the project area. WEC developed this model grid by using the ADCIRC model grid developed for the ongoing FEMA flood map revisions for South Carolina under a Cooperating Technical Partner agreement between the South Carolina Department of Natural Resources (SCDNR) and FEMA Region IV. The Charleston Harbor area was extracted from this high resolution South Carolina grid and merged with a coarser Western Atlantic ADCIRC grid in order to reduce the total number of grid nodes and the model run time. The grid was then refined to adequately resolve the federal navigation channel. The ADCIRC model was then validated by comparing to observed surge heights at Customs House during Hurricane Hugo.

Representative input 50- and 100-yr return period storm conditions were developed for this analysis. In the effective FEMA Flood Insurance Study (FIS) for Charleston County (effective November 17, 2004), the 50- and 100-yr return period stillwater levels are 10.5 and 11 feet NAVD88, respectively. Stillwater levels listed in the FIS vary spatially throughout the harbor, and therefore the above values are based on a central location in the lower harbor listed in the FIS ("Along shoreline of Hog Island Channel" in Table 5 of the FIS).

The ADCIRC model can synthesize hurricane wind and pressure fields at every grid node on-the-fly using the dynamic Holland wind model. The required model input storm information includes storm track, central pressure, radius to maximum winds and maximum wind speed. Historical storm data from Hurricane Hugo was modified, through iterative scaling of the wind speed velocities, such that the modeled surge levels at Customs House are about equal to the above 50- and 100-yr flood levels at the Customs House gage.

Table 2-1 FIS stillwater elevations in Charleston Harbor

Return Period	Stillwater Elevation (ft NGVD29)	Stillwater Elevation (ft NAVD88)
50	11.5	10.5
100	12	11

The analysis includes modeling for two channel scenarios: existing conditions, and post-project conditions. The post-project conditions include the project channel with the recommended wideners from ship simulation results and the maximum deepening (including 2 feet of advance maintenance and 2 feet over-depth dredging, which is consistent with the EIS and Feasibility study EFDC analyses).

3 Model Grid

WEC developed the model grid by combining the ADCIRC model grid developed for the ongoing FEMA flood map revisions for South Carolina with a coarser Western Atlantic ADCIRC grid. This grid was then refined to adequately resolve the Charleston Harbor federal navigation channel.

The model grid for the ongoing remapping was provided by the SCDNR's contractor, AECOM, and hereafter it is referred to as the SCDNR grid. The SCDNR grid was developed by URS Corporation (which is now affiliated with AECOM) and the grid development process is described in detail in *South Carolina Storm Surge Project Deliverable 1: Grid Development Report* (URS 2009) and *South Carolina Storm Surge Project Deliverable 2: Validation Report* (URS 2012).

The SCDNR grid includes a coarse grid encompassing the Western Atlantic basin and Gulf of Mexico, and a high resolution grid along the South Carolina shoreline (Figure 3-1). The model grid elevations for the high resolution areas along Georgia, South Carolina and North Carolina are shown in Figure 3-2. The grid mesh is not shown in Figure 3-2 because the fine grid density would not be legible at this plot scale. This grid has 1,073,925 elements and 542,809 nodes. The high-resolution portion of the model consists of approximately 440,000 nodes with a minimum resolution of 100 meters (URS 2009). Within South Carolina, the SCDNR grid extends inland to about the 9-m elevation, which extends beyond the inundation level of the 0.2-percent annual-chance (i.e., 500-yr return period) stillwater elevation.

The SCDNR grid resolution in Charleston Harbor is shown in Figures 3-3 through 3-6. For reference, the federal navigation channel is shown by a red polyline in these figures. As shown by Figures 3-4 through 3-6, the grid is not aligned with the federal navigation channel. Therefore, grid refinement is required along the navigation channel in order to accurately assess the effects of the channel deepening. Also, as shown in Figure 3-4, the inlet jetties are not included in the SCDNR grid. This likely has minimal impact on predicted surge levels. URS (2009) did not specifically mention the harbor jetties, but URS did note that "resolution and inclusion of topographic features took precedence over bathymetric features since local bathymetric features (below MHW [Mean High Water]) tend to flood quickly in the simulation and thus have lesser impact on final still water levels."

The SCDNR grid was trimmed to retain only the high resolution grid surrounding Charleston Harbor and adjacent areas to the north and south. The high resolution areas in other parts of South Carolina are not necessary for evaluating storm surge in Charleston Harbor and were therefore removed in order to reduce the model run time. This grid was merged with a comparatively coarse grid of the Western North Atlantic and Gulf of Mexico created by Westerink and Luettich (1997) that includes 39,812 nodes. The grid was then refined to be aligned with and resolve the federal navigation channel in Charleston Harbor. The resulting grid includes 201,232 nodes. The model grid for the entire domain is shown in Figure 3-7. The grid elevations are shown in Figure 3-8 in the vicinity of Charleston Harbor. For reference, the harbor shorelines and the federal navigation channel area shown as black lines.

The model bathymetry was also updated in the Charleston Harbor estuary with the dataset used for the EFDC model. As described by the USACE (2015), this bathymetry data set includes new multi-beam and

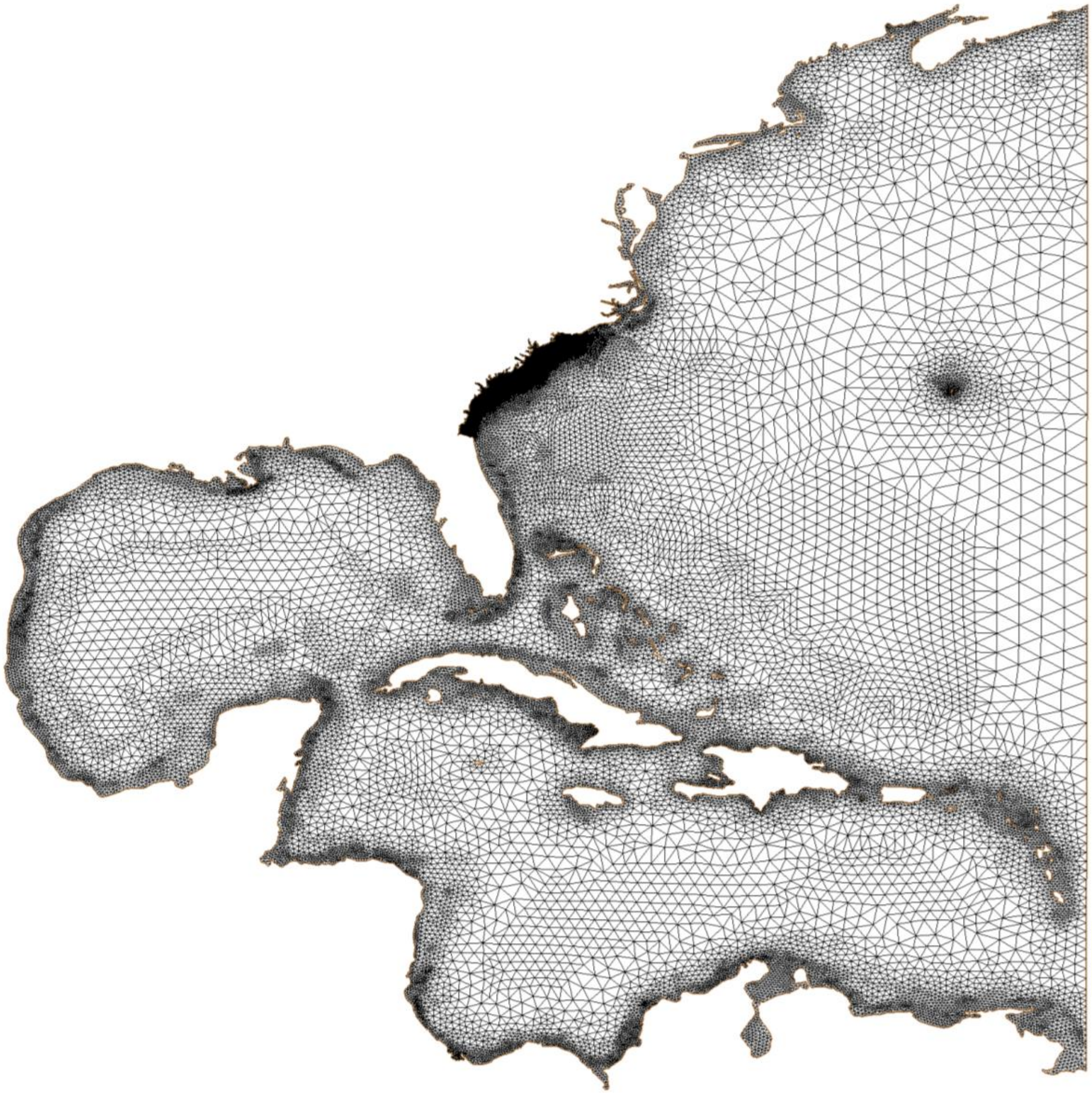

Figure 3-1. SCDNR model grid mesh

single beam survey data along the navigation channel collected by the USACE Charleston District. Data outside the federal channel was supplemented by NOAA survey data collected in 2009 and bathymetric data collected by Coastal Carolina University (CCU) in 2010 under contract with the USACE. The bathymetry in the upper Cooper River was updated with survey data collected by the USACE Charleston District in 2013 in areas upstream from the federal channel. For areas outside the coverage of these newer surveys, the National Oceanic and Atmospheric Administration's (NOAA) 30 meter resolution bathymetric digital elevation model for Charleston Harbor was used. The NOAA data set was published in 1998 and is derived from seventeen historic surveys of the estuary. The combined bathymetry data (i.e., the USACE, CCU and NOAA data) are shown in Figure 3-9. These data were merged with the SCDNR model grid elevations by deleting the SCDNR data in overlapping areas, and the combined data set was then interpolated onto the new grid mesh as shown in Figure 3-10 through Figure 3-13.

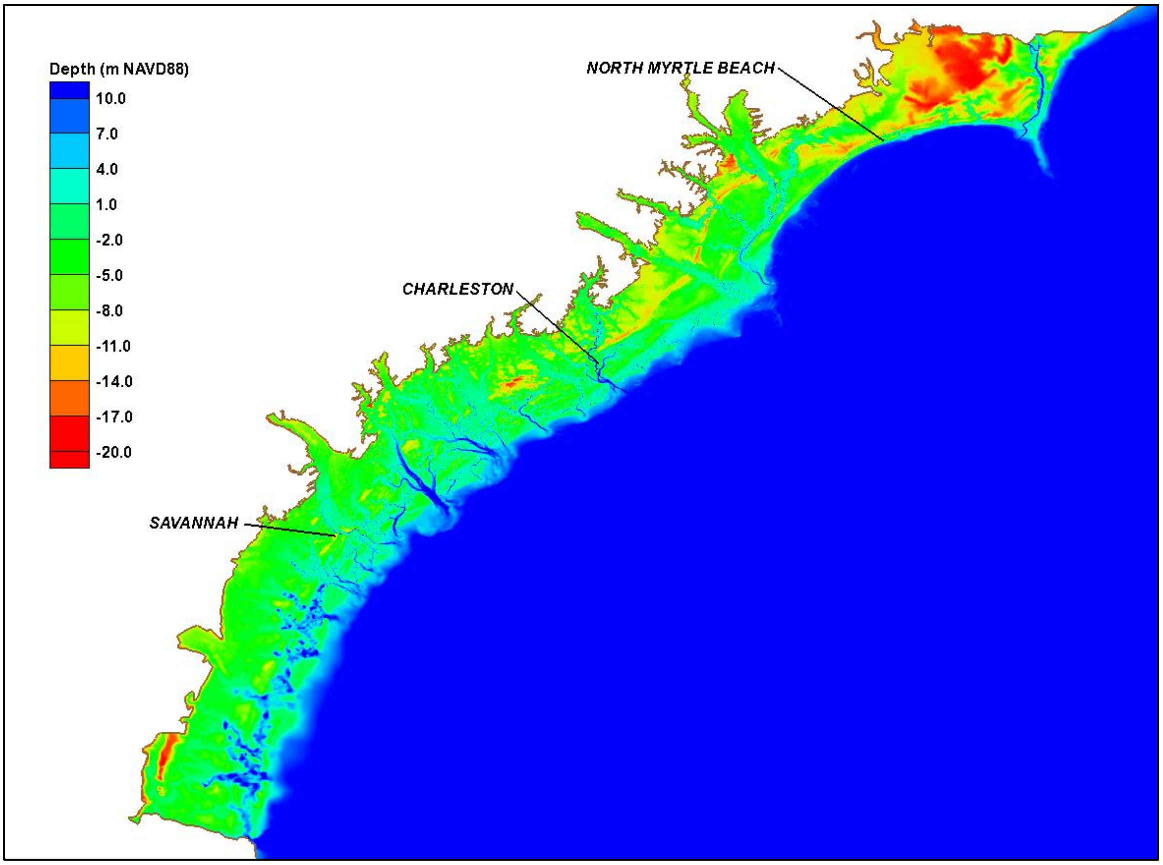

Figure 3-2. SCDNR model grid elevations along the Georgia, South Carolina and North Carolina coasts

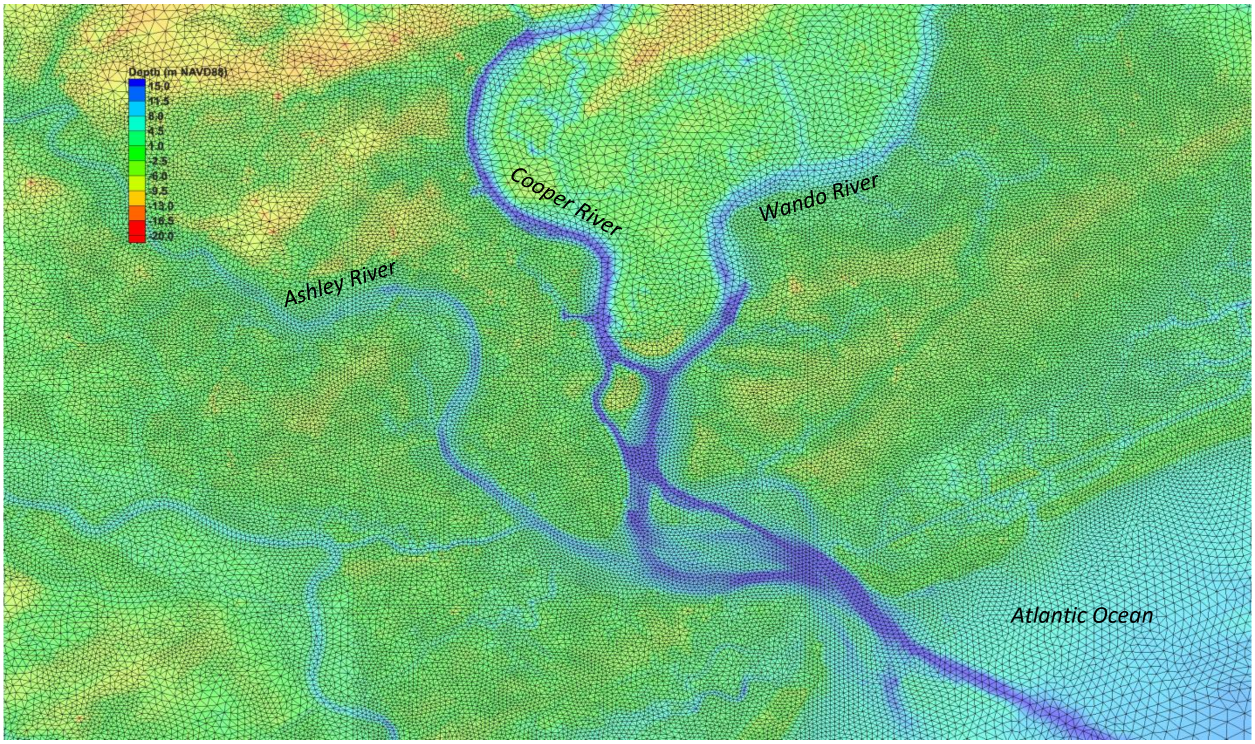

Figure 3-3. SCDNR model grid in the vicinity of Charleston Harbor

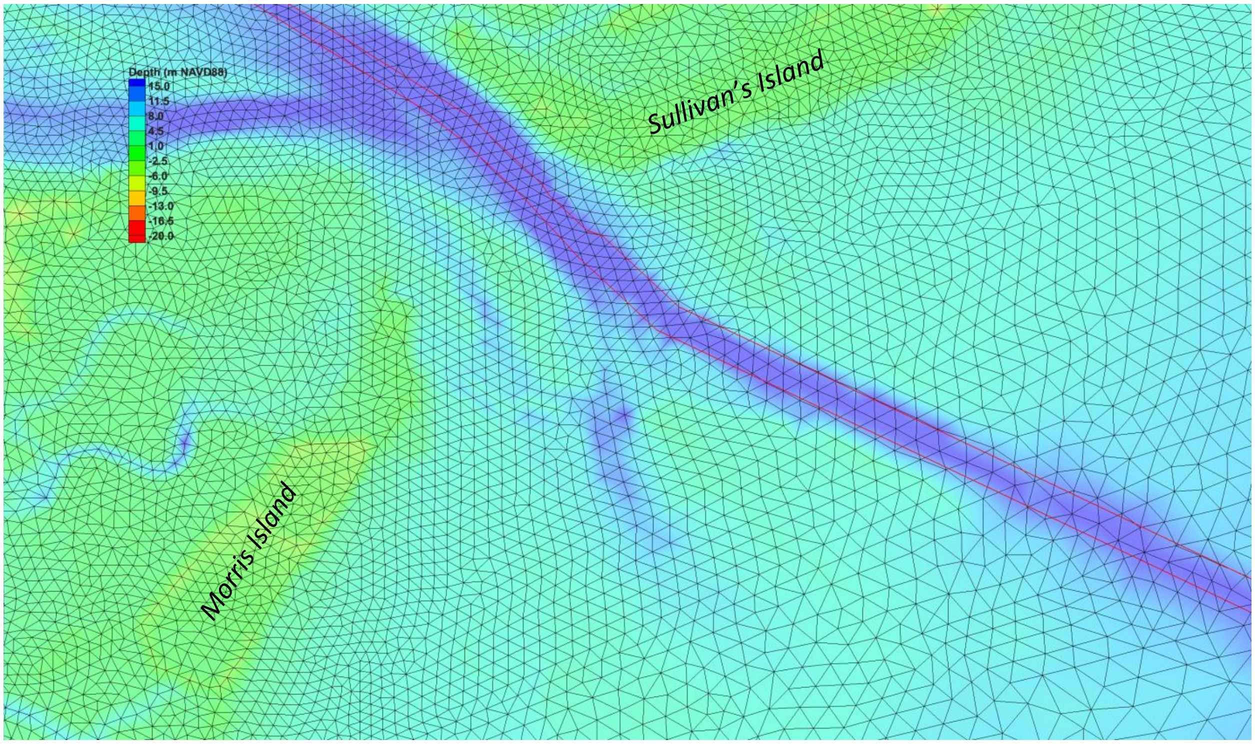

Figure 3-4. SCDNR model grid in the harbor entrance (navigation channel shown by red lines)

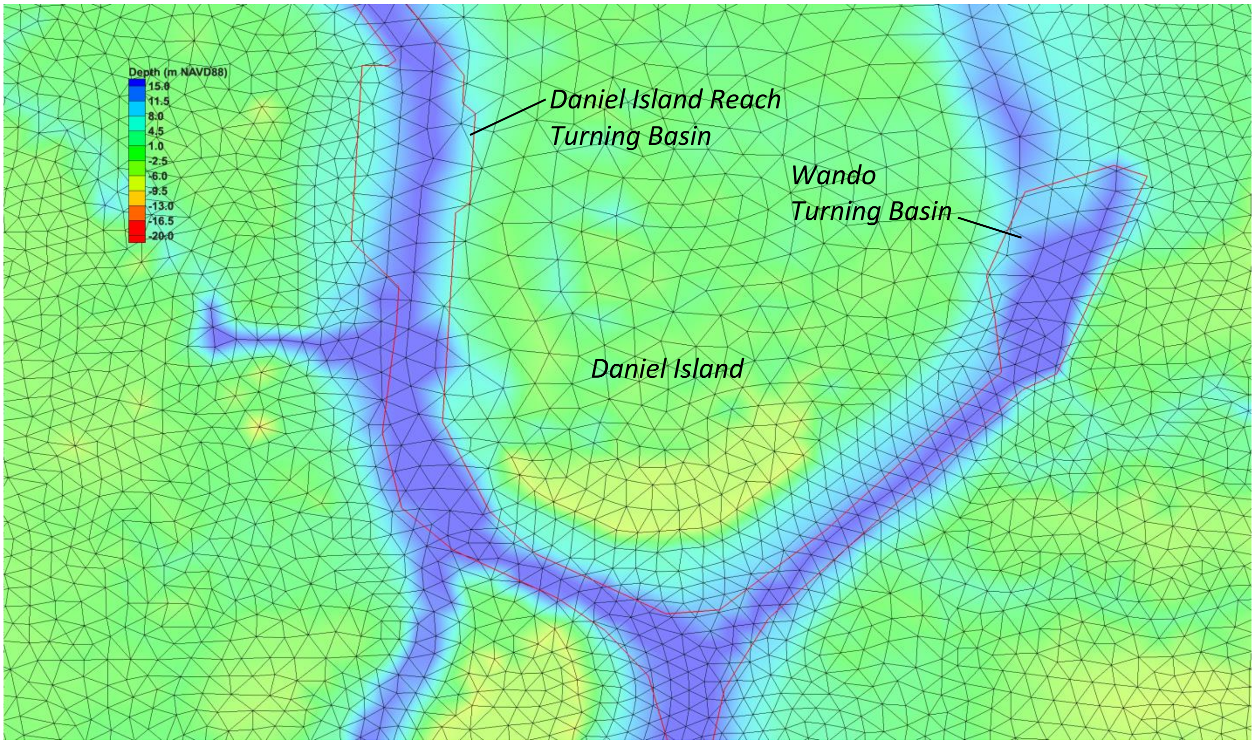

Figure 3-5. SCDNR model grid near Daniel Island (navigation channel shown by red lines)

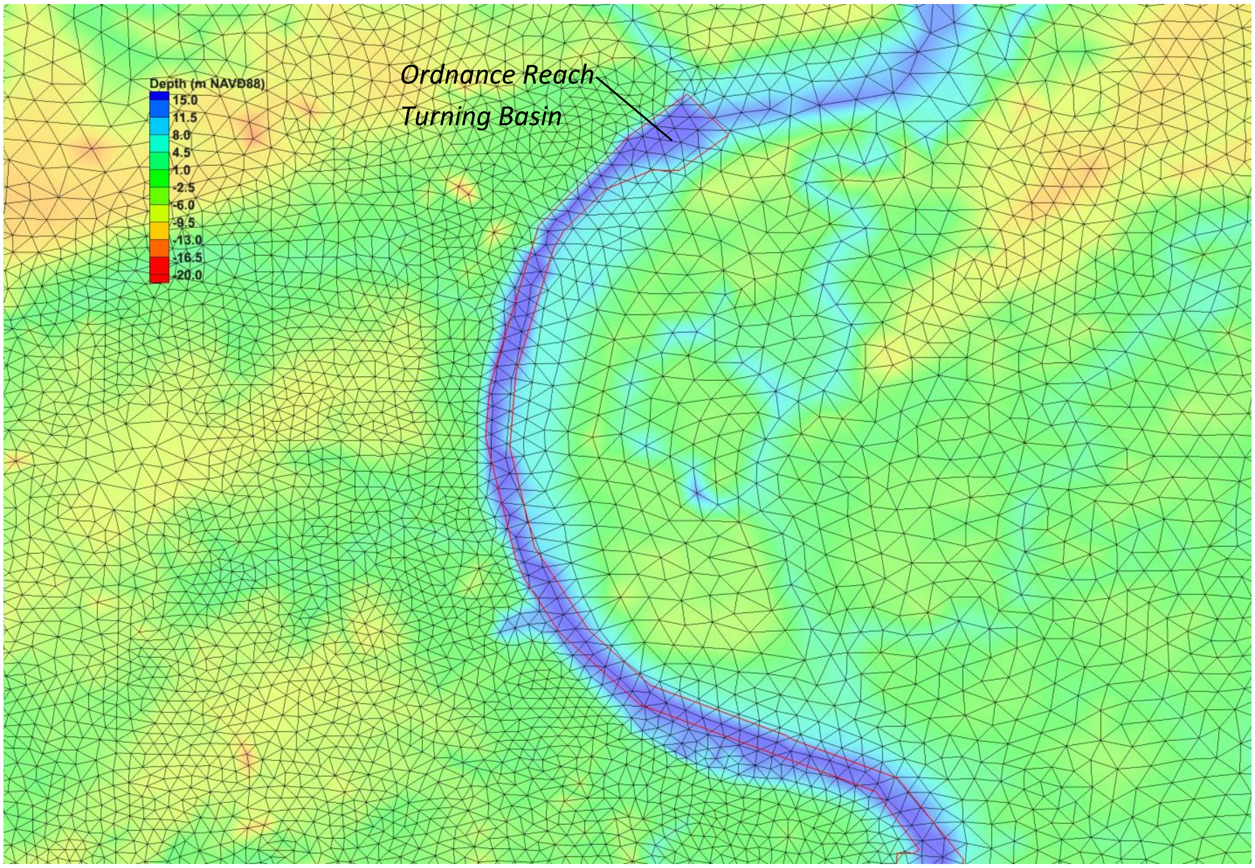

Figure 3-6. SCDNR model grid near North Charleston (navigation channel shown by red lines)

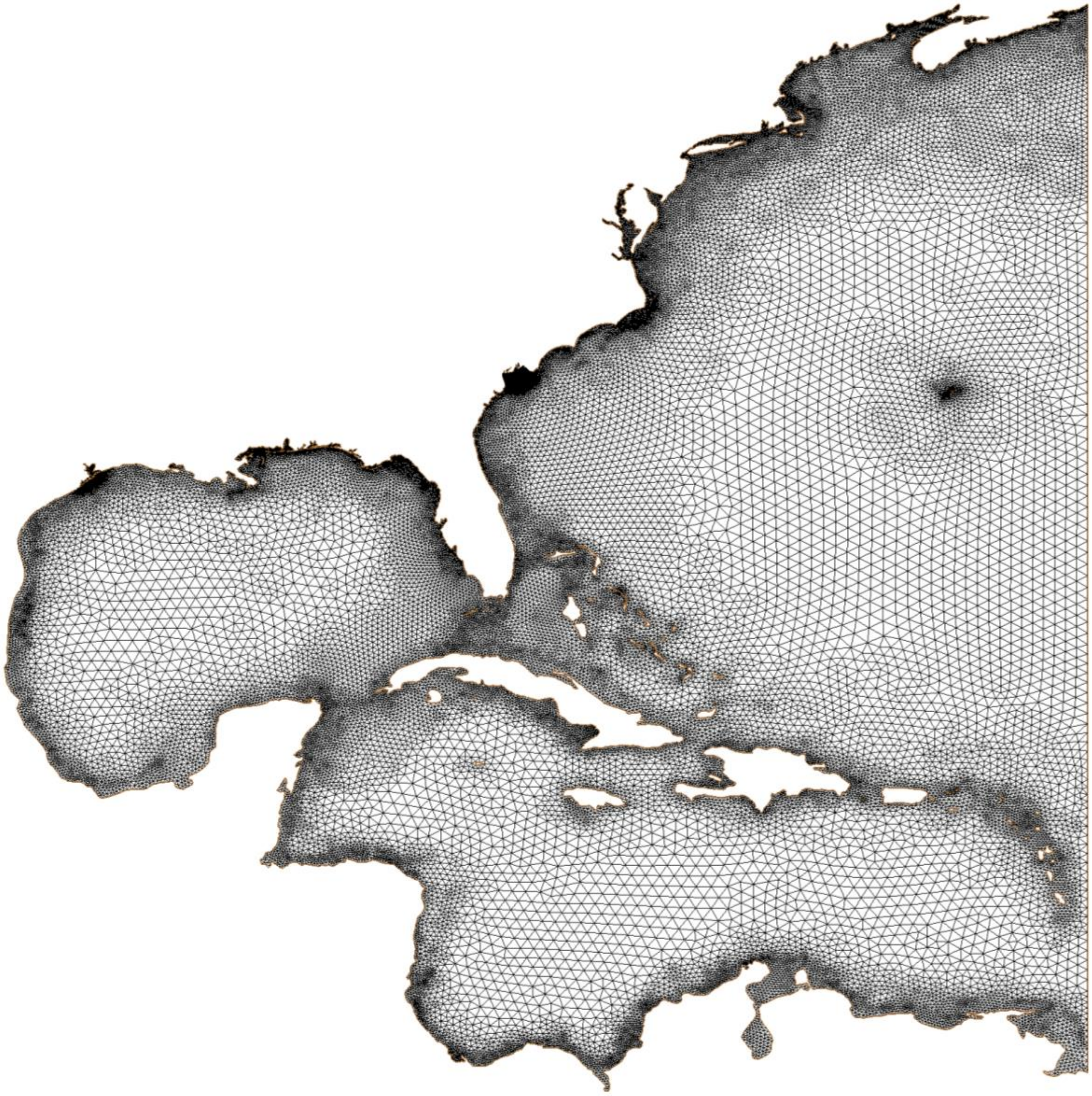

Figure 3-7. Model grid mesh

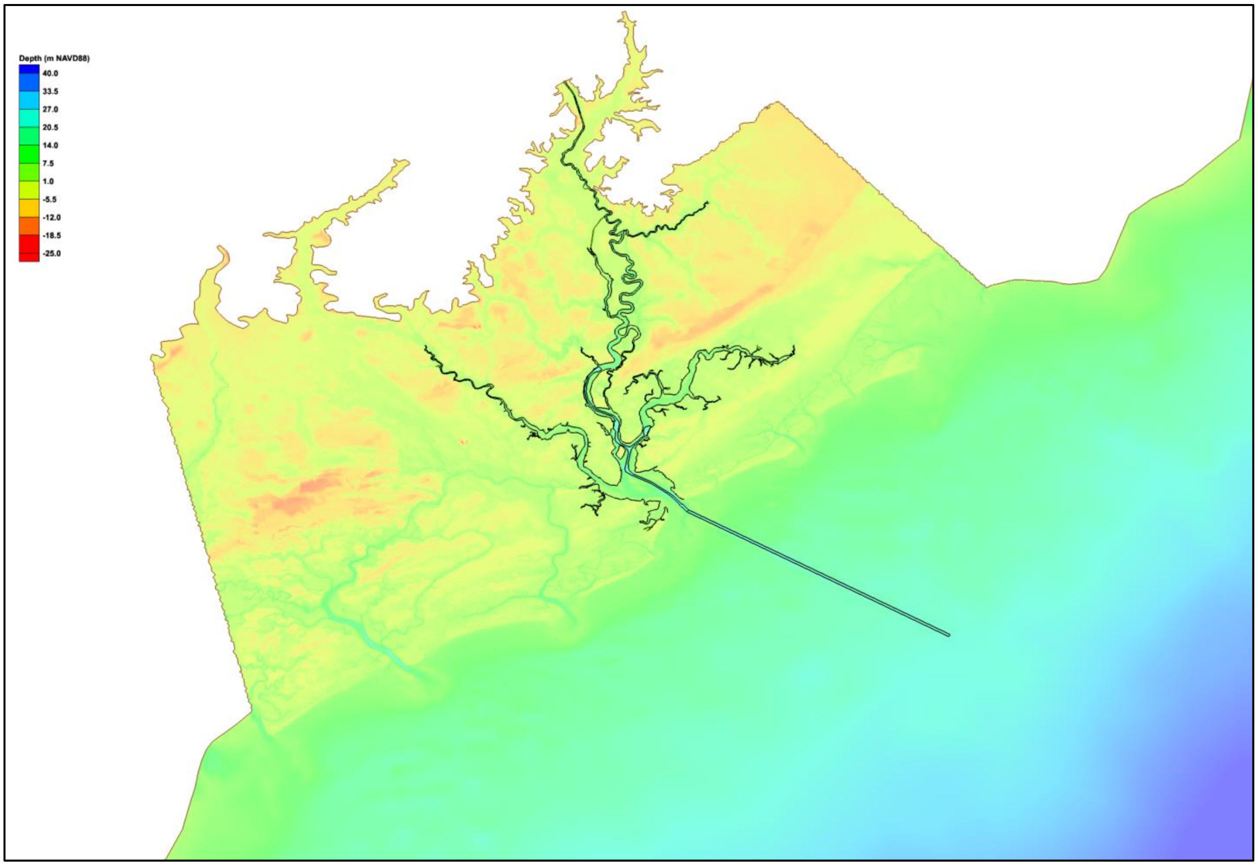

Figure 3-8. Model grid elevations surrounding the Charleston Harbor estuary

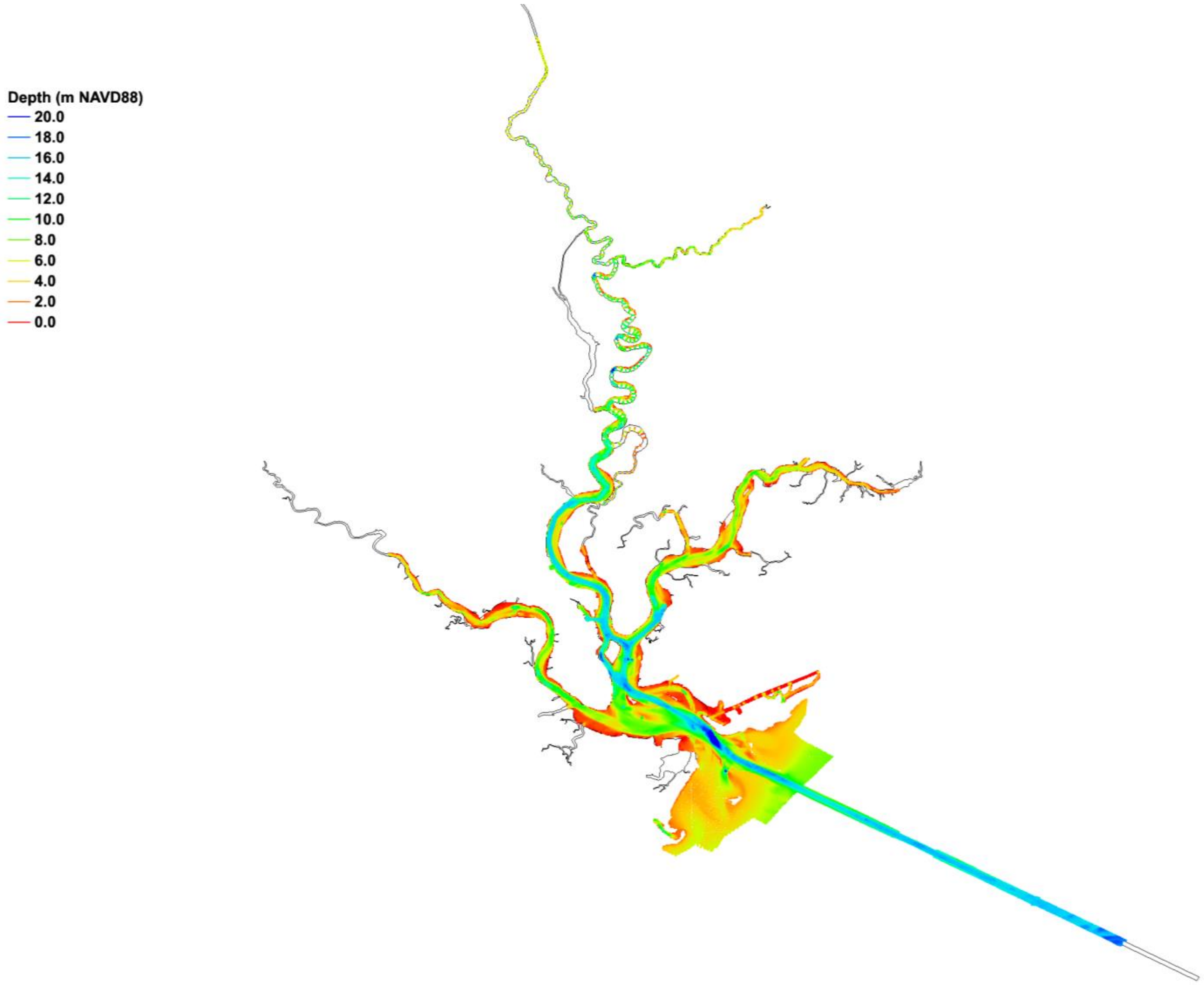

Figure 3-9. Charleston Harbor estuary bathymetry

As shown in Figure 3-11, the grid incorporates the entrance channel jetties. The jetties may have a lesser impact on flood levels than topographic features above MHW, but they were included for completeness. Black (1893) describes the construction of various South Atlantic Coast harbor improvements, including construction of the Charleston Harbor jetties and the approximate crest elevations of the structures. The jetties include a shoreward submerged weir and a seaward raised section. The submerged weir section was constructed only a few feet above the bottom. The outer raised section of the north jetty was constructed with an average crest elevation of +7 to +8 feet mean low water (MLW), and the outer raised section of the south jetty had an average crest elevation around +10 feet MLW. A 1966 inspection found general subsidence of 1.5 to 3.5 feet along the raised portions of the jetties (Sargent 1988). There has been no history of maintenance or repair to the jetties following their initial construction (Sargent 1988).

The jetties were implemented in the model by assuming the elevations of the submerged sections are 3 feet above the ambient grade. The outer section of the north jetty was assigned an elevation of 0.8 ft NAVD88, and the outer section of the south jetty was assigned an elevation of 2.8 ft NAVD88. This includes an offset of 1.2 feet of historic sea level rise, plus 2.5 feet of subsidence.

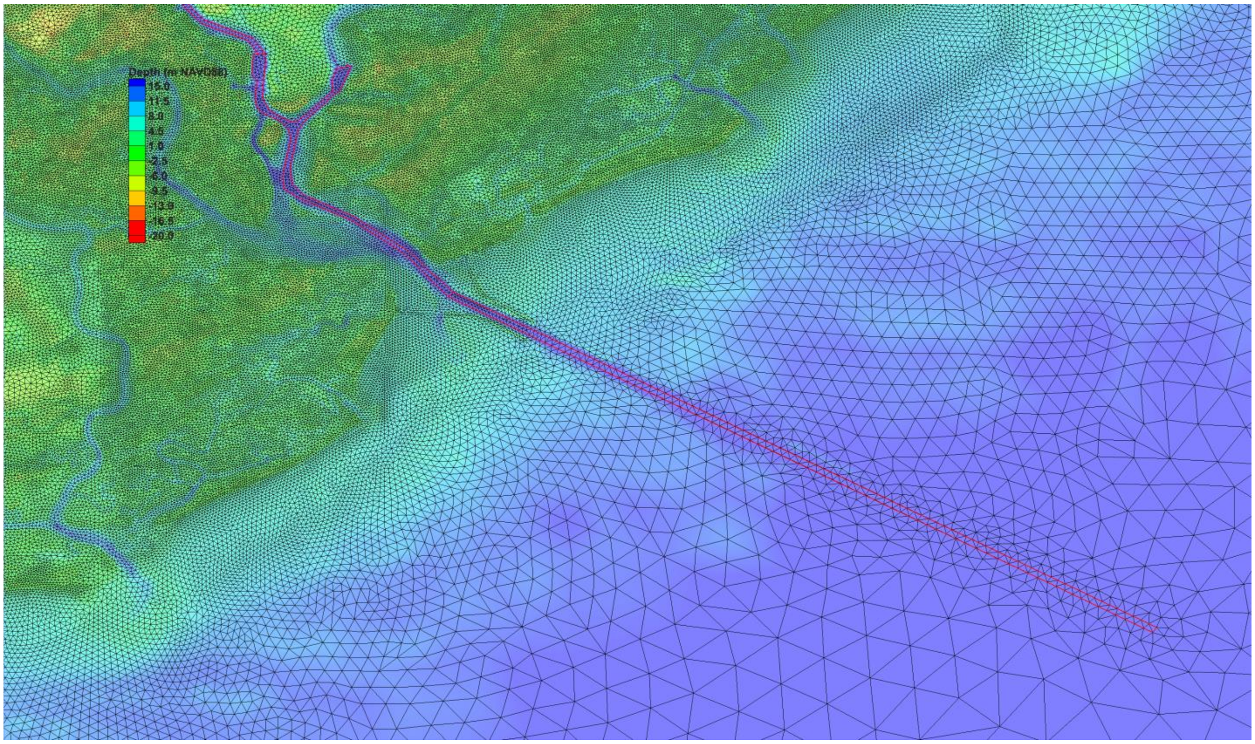

Figure 3-10. Refined model grid showing entrance channel and lower harbor (navigation channel shown by red lines)

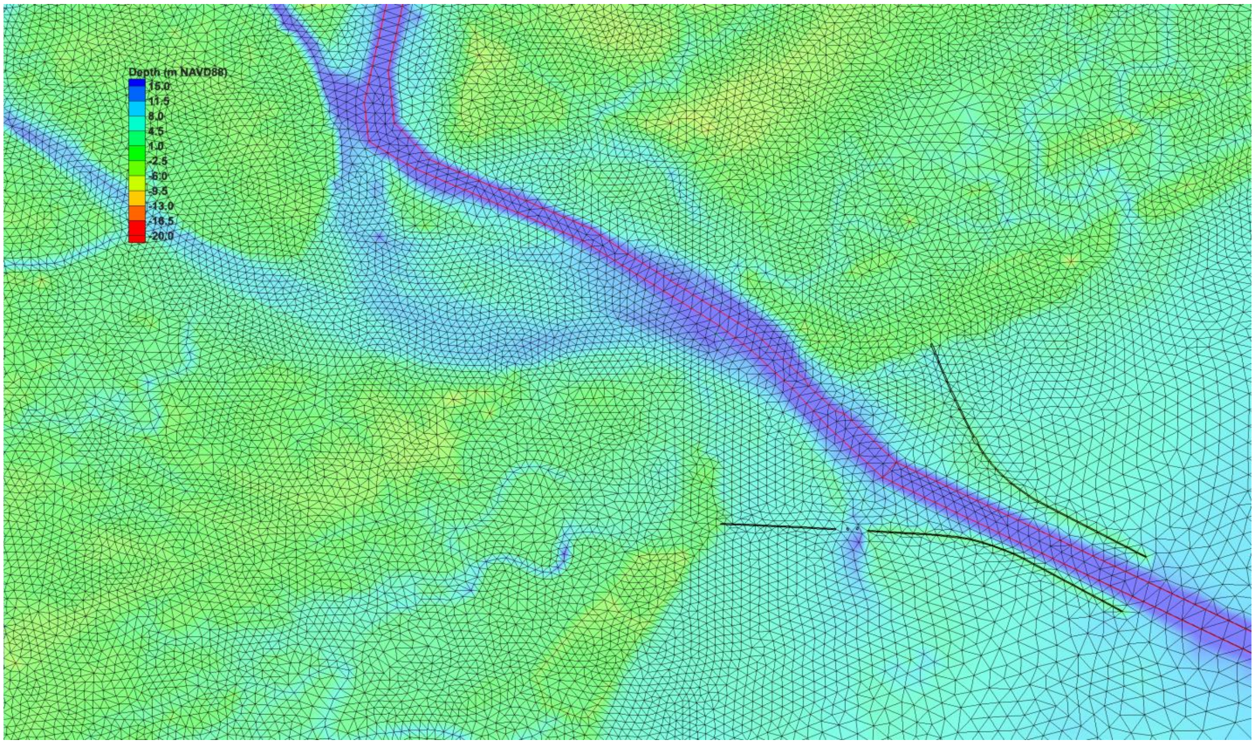

Figure 3-11. Refined model grid in the lower harbor and near the harbor entrance (navigation channel shown by red lines and jetties indicated by heavy black lines)

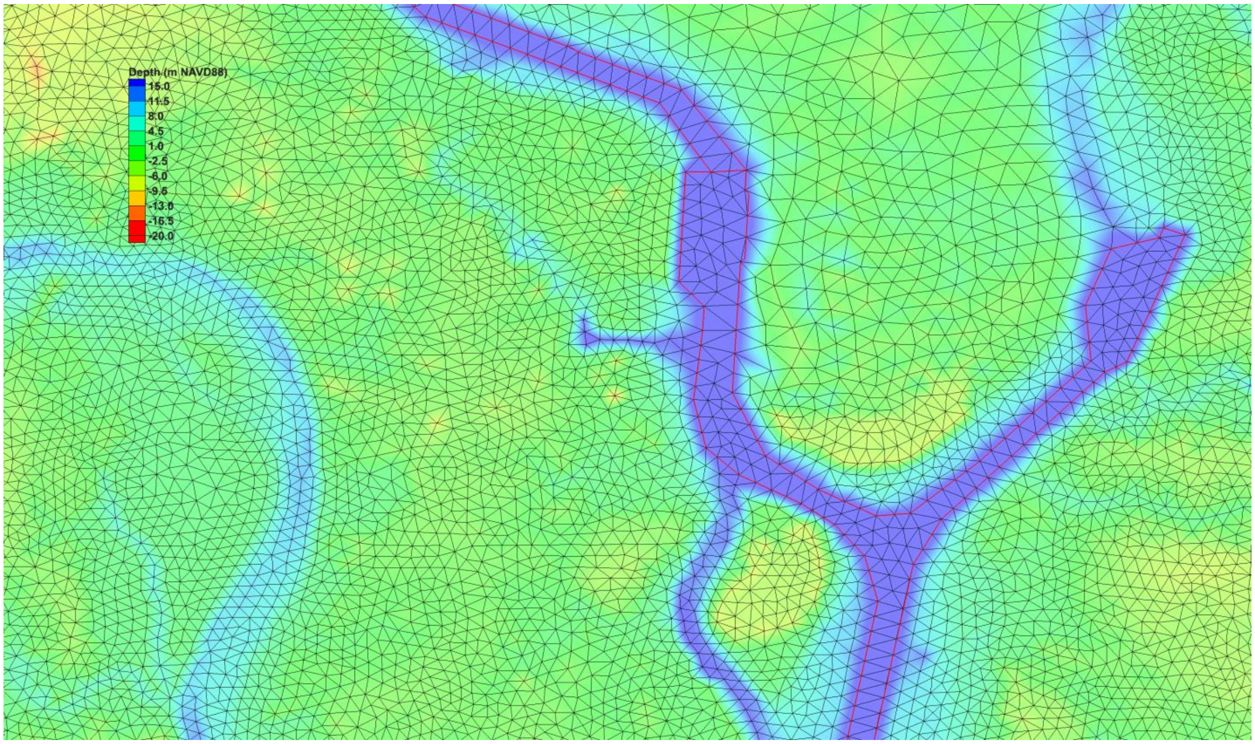

Figure 3-12. Refined model grid near Daniel Island (navigation channel shown by red lines)

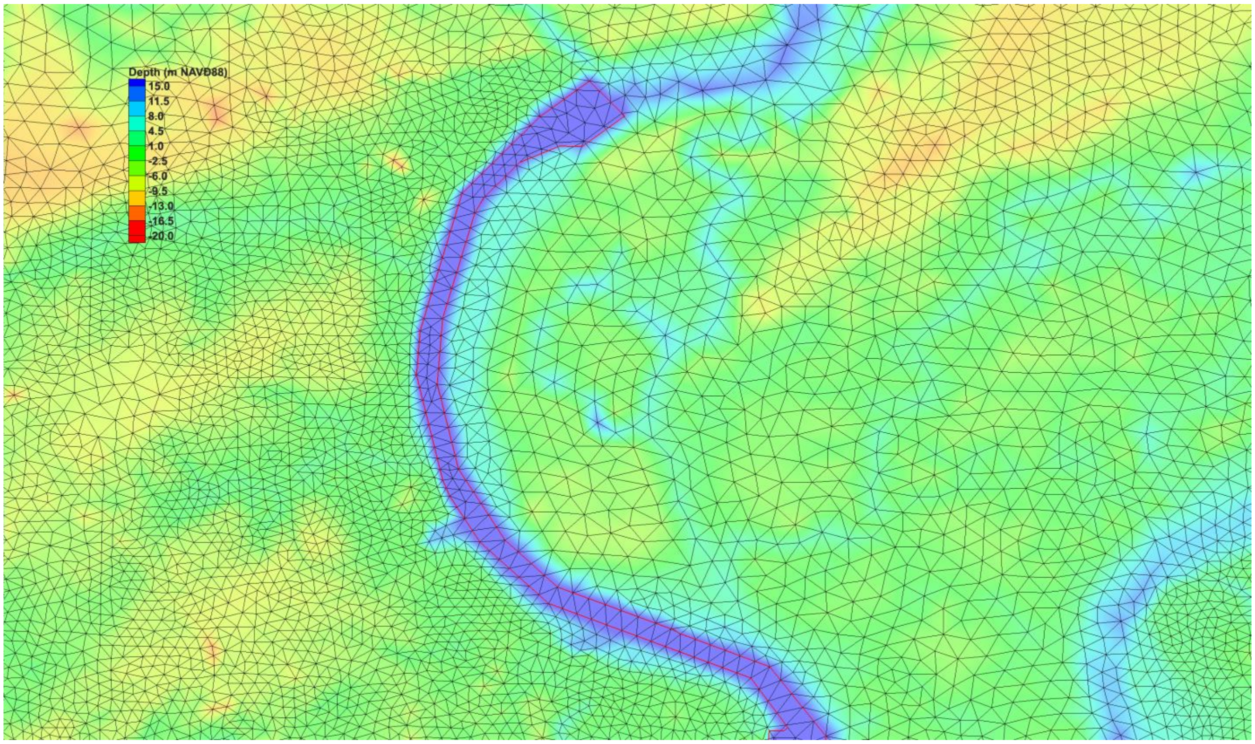

Figure 3-13. Refined model grid near North Charleston (navigation channel shown by red lines)

4 Nodal Attribute Files

The ADCIRC model can optionally include a nodal attribute file that provides spatially variable input data for the model. SCDNR's contractor, AECOM, provided the ADCIRC nodal attribute file used for the ongoing South Carolina remapping effort. The nodal attribute file (labeled a 'fort.13' file) includes several variables including:

- Primitive weighting in continuity equation;
- Manning's n at sea floor;
- Surface canopy coefficient;
- Surface directional effective roughness length; and
- Wave refraction in SWAN (Simulating WAves Nearshore).

This analysis essentially used the same nodal attributes as those developed for the SCDNR model. Each of the nodal attributes was interpolated from the SCDNR grid to the new grid, with the exception of the SWAN wave refraction attribute. Per the scope of work, this analysis does not include a coupled SWAN wave model, and therefore this nodal attribute was omitted. Inclusion of the SWAN wave model is not necessary for estimating the *relative* impact of the Post 45 project on surge levels in Charleston Harbor (i.e., the change in maximum flood levels). The Post 45 project will have a much greater effect on surge levels caused by wind and pressure effects (which are modeled by ADCIRC) than it will on surge levels from wave setup effects (which would require a coupled ADCIRC+SWAN model to quantify). Therefore, inclusion of the SWAN model was omitted from the scope of work.

The primitive weighting in the continuity equation is a coefficient (tau_0) that weights the relative contribution of the primitive and wave portions of the Generalized Wave Continuity Equation (GWCE) used to solve the ADCIRC governing equations. According to URS (2012), the nodal attributes file designates tau_0 as temporally variable for all nodes with average distances to neighboring nodes less than 1750 m distant (i.e., for nodes in upland areas and near the coast). For these nodes, ADCIRC calculates tau_0 based on local friction and a tau_0 "base" value of 0.03. For nodes with average distances to neighboring nodes greater than 1750 m distant (i.e., in the ocean), the nodal attributes file directly designates tau_0 values based on depth. In this case, tau_0 of 0.005 applies to depths greater than 10 m, and 0.02 to depths less than 10 m.

The manning's n is a friction coefficient that is converted to an equivalent quadratic friction coefficient before the bottom stress is calculated in the model. The surface canopy coefficient is set to either one or zero, with zero indicating areas where the surface wind stress is zero because of the shielding effect from the canopy in heavily vegetated areas. When this variable was interpolated from the SCDNR grid onto the new grid, the value was rounded to the nearest whole integer (i.e., one or zero). The surface directional effective roughness length is the level of impediment from ground cover on the wind flow from each of twelve compass directions. The development of these input variables for the SCDNR model is described in detail by Dhingra and Zhao (2009).

5 Model Validation

The model calibration was confirmed by modeling the storm surge associated with Hurricane Hugo, including the effects of wind, pressure and astronomical tides. The ADCIRC model was used to synthesize hurricane wind and pressure fields at every grid node on the fly using the dynamic Holland wind model option. This is a parametric model that calculates the wind field given inputs of hurricane track location, central pressure, maximum wind speed and radius to maximum wind speed. All of these variables, except for the last, are available from NOAA's HURDAT database. The radii to maximum wind speeds were approximated using a nomograph by Jelesnianski and Taylor (1973) that relates the radii to the maximum wind speed and central pressure deficit.

For the Hurricane Hugo model, ADCIRC was started approximately nine days prior to landfall of the storm, in order to allow spin-up of the tidal forcing for the model. Similar to the SCDNR model, the tidal boundary forcing was supplied by the LeProvost tidal harmonic database (LeProvost et al. 1994), which provided amplitudes and phases for eight tidal constituents at the open ocean boundary nodes. The eight tidal constituents included: M2, S2, N2, K1, O1, Q1, P1 and K2.

The modeled tides and surge at NOAA's Customs House gage (located on the southeast side of the Charleston Peninsula) are shown in Figure 5-1. To achieve good agreement between the maximum surge levels and the measured surge levels, the boundary layer adjustment factor for the Holland wind model was reduced from the default value of 0.9 to a value of 0.65.

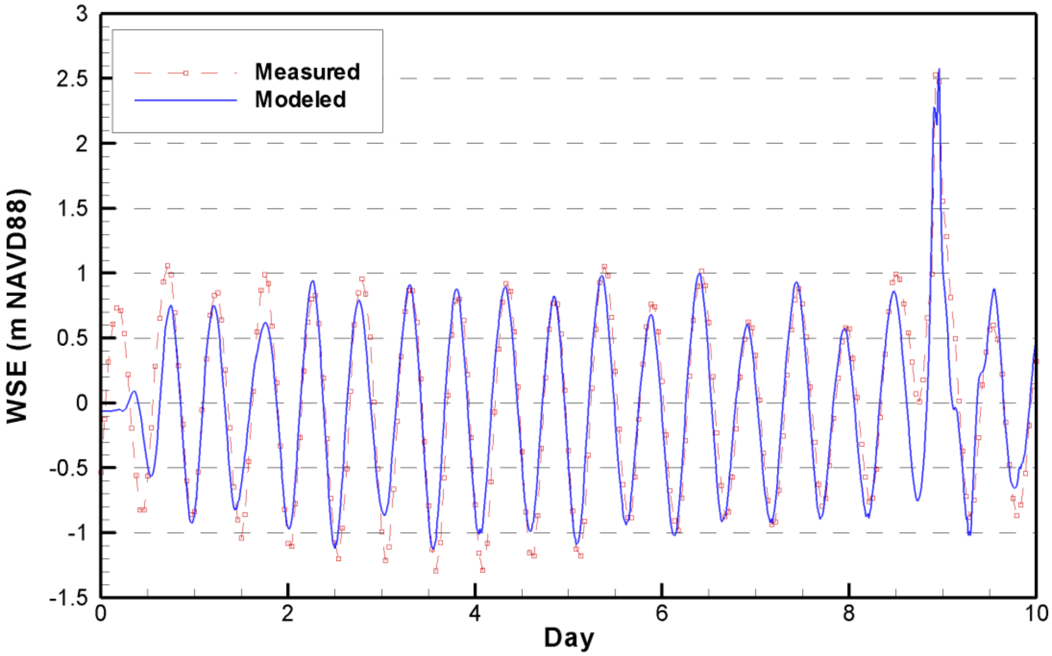

Figure 5-1. Observed and predicted water levels at the Customs House during Hurricane Hugo

6 Project Impacts Analysis

To assess the potential project impacts, synthetic storms were created to represent 50- and 100-year return period (i.e., 2% and 1% annual chance) storm events. These storms were created by increasing the Hurricane Hugo wind speed until the peak water levels in Charleston Harbor at the Customs House gage matched the water levels equal to the 50- and 100-yr flood levels determined by FEMA. As discussed in Section 2, 50- and 100-yr return period stillwater levels are 10.5 and 11 feet NAVD88, respectively, for the center of Charleston Harbor in the effective FIS for Charleston County (effective November 17, 2004). To reproduce these peak water levels for the different representative storm conditions, the Holland wind model speed was iteratively increased (using the boundary layer adjustment multiplier in the fort.15 input file) until the modeled water levels at the Customs House gage matched the target water level conditions.

The model grid was modified to represent the pre- and post-project bottom elevations in the federal navigation channel. The channel depths are summarized in Table 6-1. These channel depths include 2 feet of over-dredge allowance and 2 feet of advance maintenance, which is consistent with the EIS and Feasibility study analyses.

Table 6-1 Modeled channel depths

	Channel Depth		
Channel Reach	**ft MLLW**	**ft NAVD88**	**m NAVD88**
Pre-project			
Entrance channel	51	54.1	16.5
Inner harbor to Wando TB and Daniel Island TB	49	52.1	15.9
Daniel Island Bend to Ordnance Reach	49	52.1	15.9
Post-Project			
Entrance channel	58	61.1	18.6
Inner harbor to Wando TB and Daniel Island TB	56	59.1	18.0
Daniel Island Bend to Ordnance Reach	52	55.1	16.8

The modeled water levels were output at eight locations throughout the harbor that correspond to USGS gage locations, as shown in Figure 6-1.

The results of the analysis are summarized in Table 6-2, which lists the differences in maximum water levels at each location caused by the proposed project. For both the 50- and 100-year return period storms, the increases caused by the project are 0.1 feet or less. Plots of the water level time series are shown for the 50- and 100-year return period storms for three locations (Customs House, Cooper River at I-526 and at Wando River at I-526) in Figures 6-2 through 6-7.

Table 6-2 Modeled differences in maximum water levels

USGS Station ID	Description	Difference in Max. Water Level (ft) 50-yr	Difference in Max. Water Level (ft) 100-yr
2172020	West Branch Cooper River at Pimlico near Moncks Corner	0.0	0.0
2172050	Cooper River near Goose Creek	0.0	0.0
2172053	Cooper River at Mobay	0.1	0.1
2172067.7	Cooper River at I-526	0.1	0.1
2172069.8	Wando River above Mt. Pleasant (I-526)	0.1	0.1
2172070.9	Cooper River at Hwy 17	0.0	0.0
2172071.1	Cooper River at Custom House (AUX)	0.0	0.0
2172086.9	Ashley River near North Charleston (I-526)	0.0	0.0

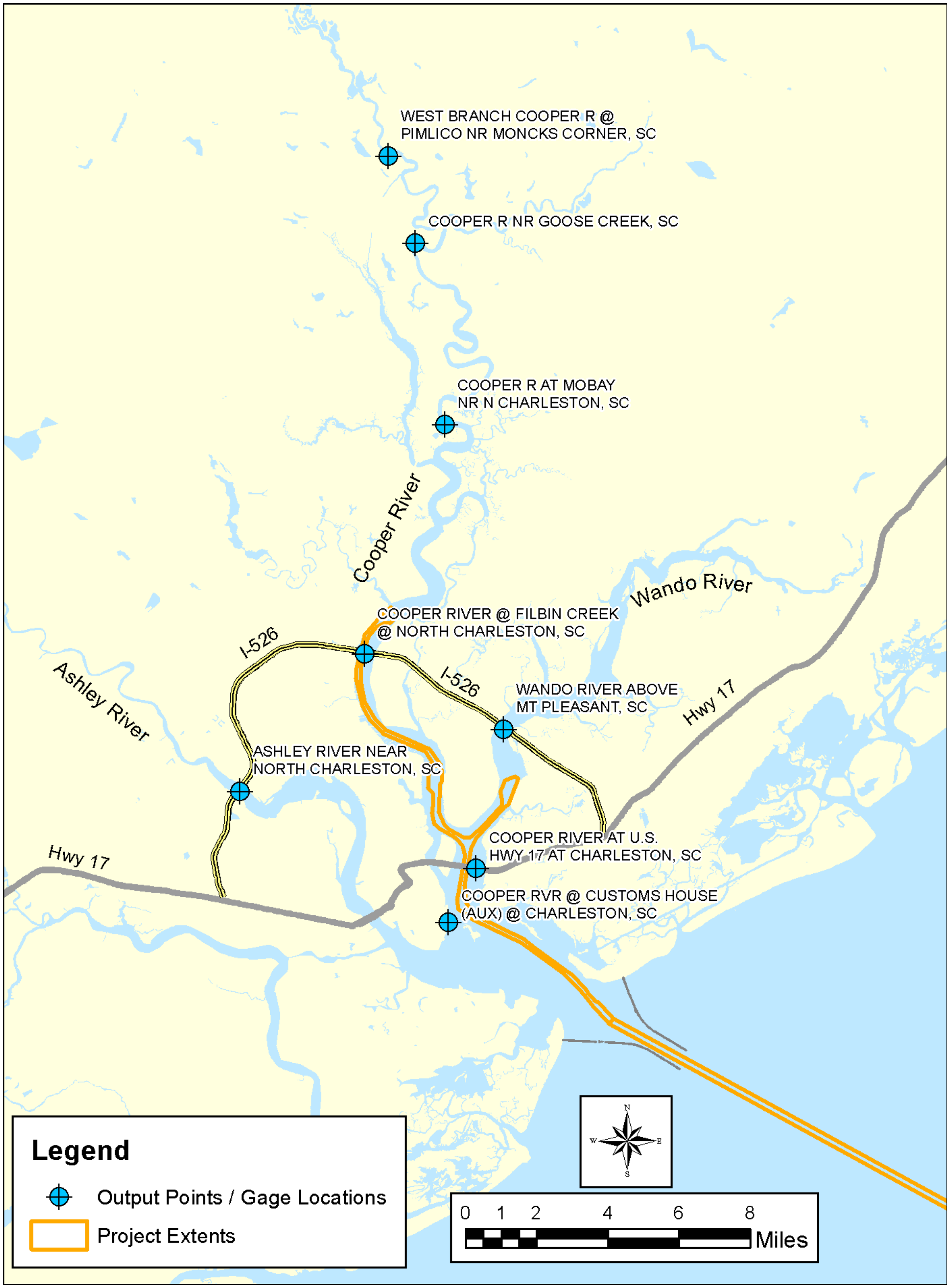

Figure 6-1. Output locations

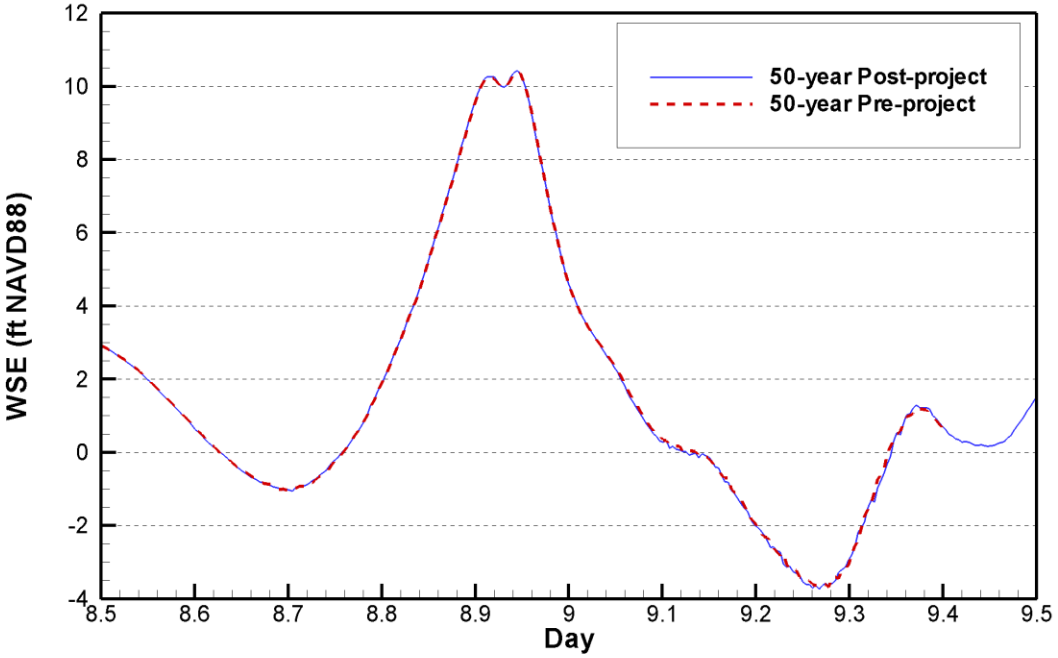

Figure 6-2. Modeled 50-yr return period event water levels at Customs House

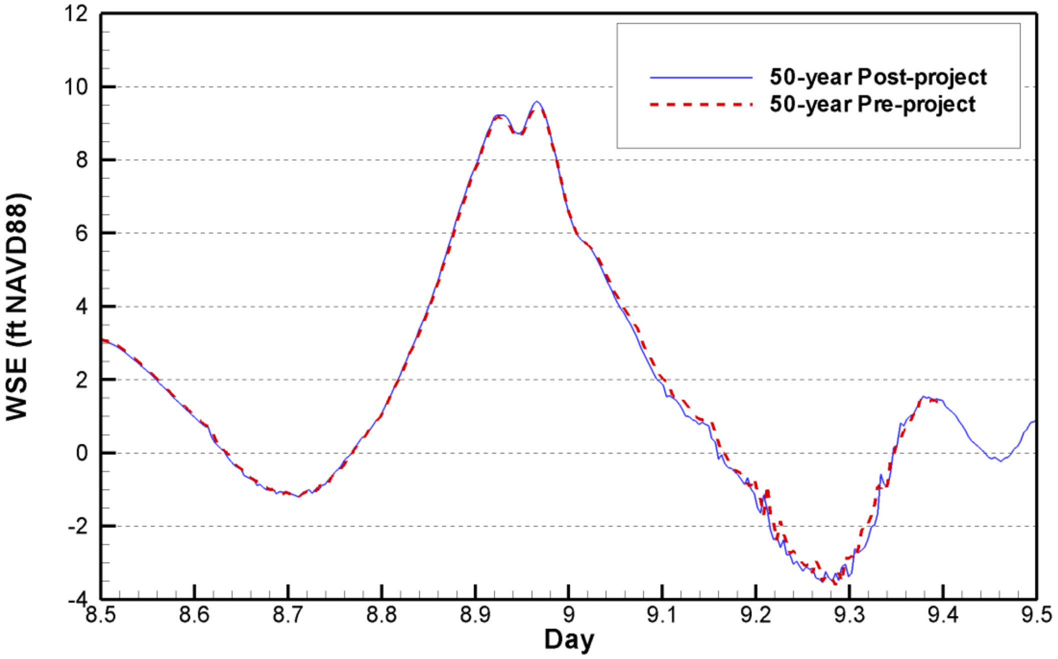

Figure 6-3. Modeled 50-yr return period event water levels on Cooper River at I-526

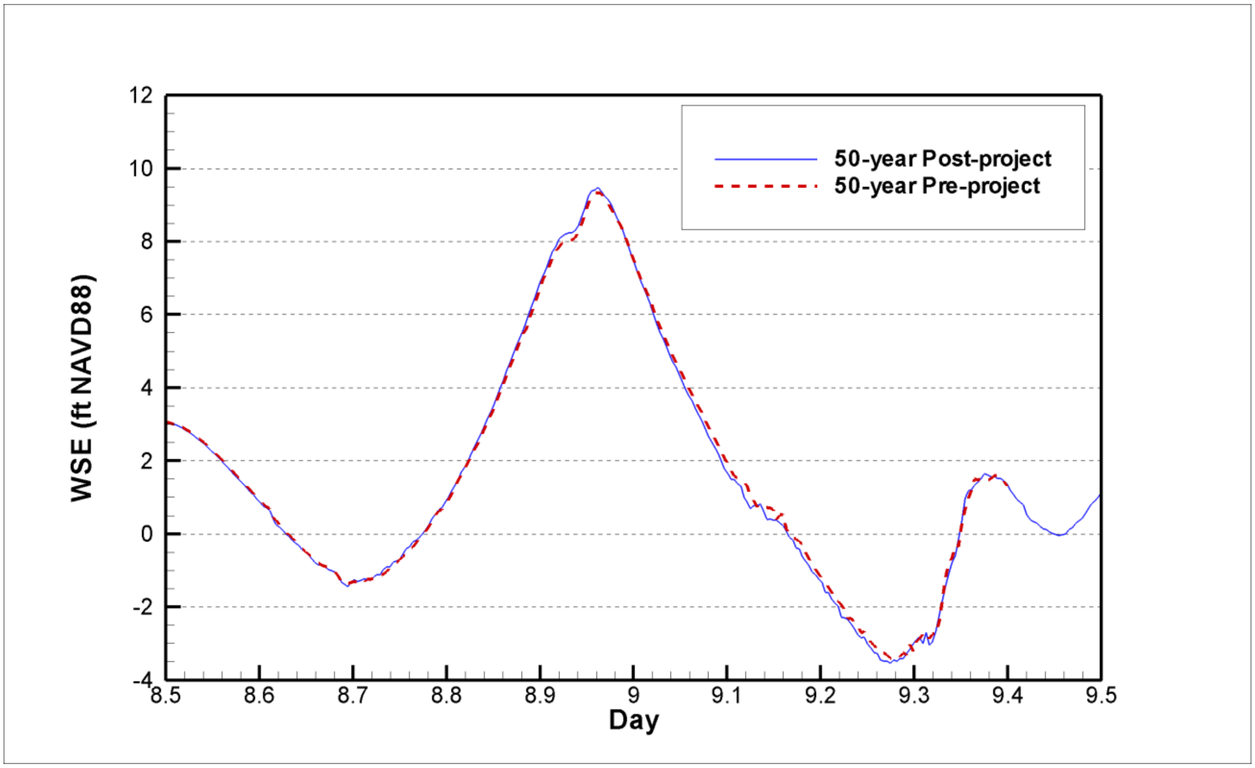

Figure 6-4. Modeled 50-yr return period event water levels on Wando River at I-526

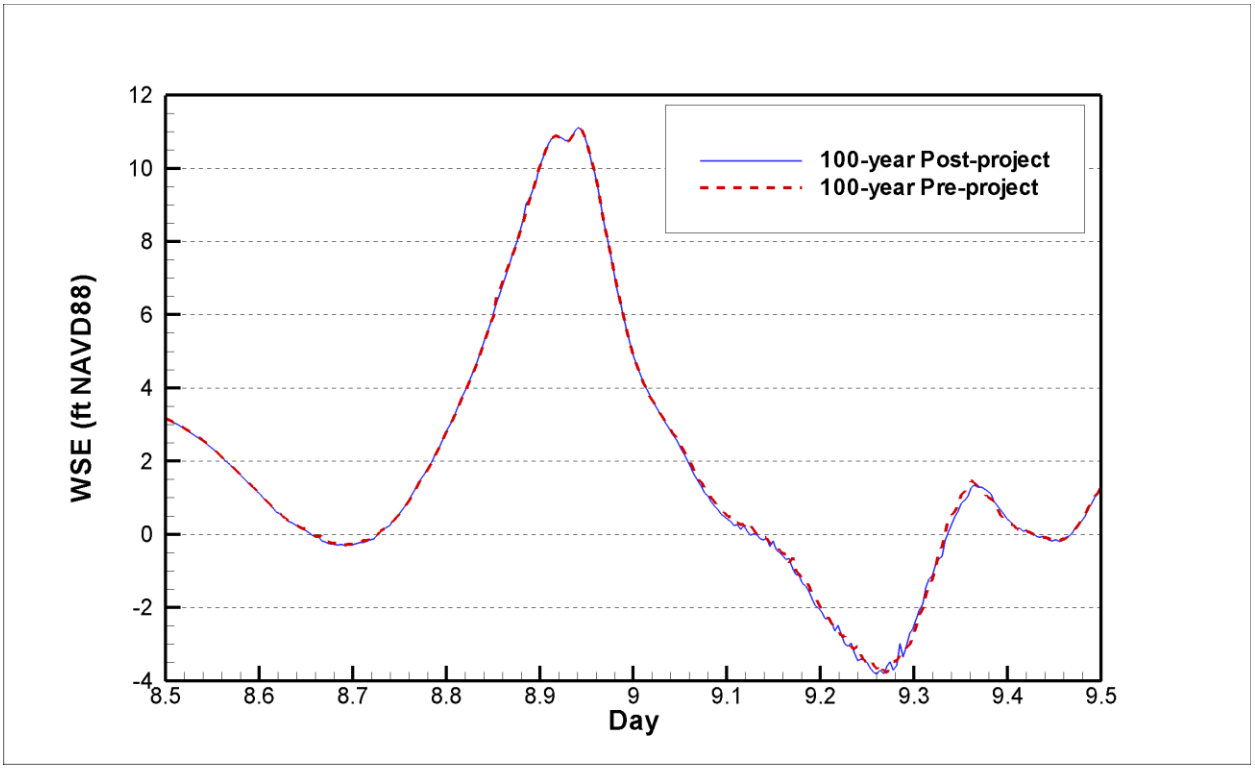

Figure 6-5. Modeled 100-yr return period event water levels at Customs House

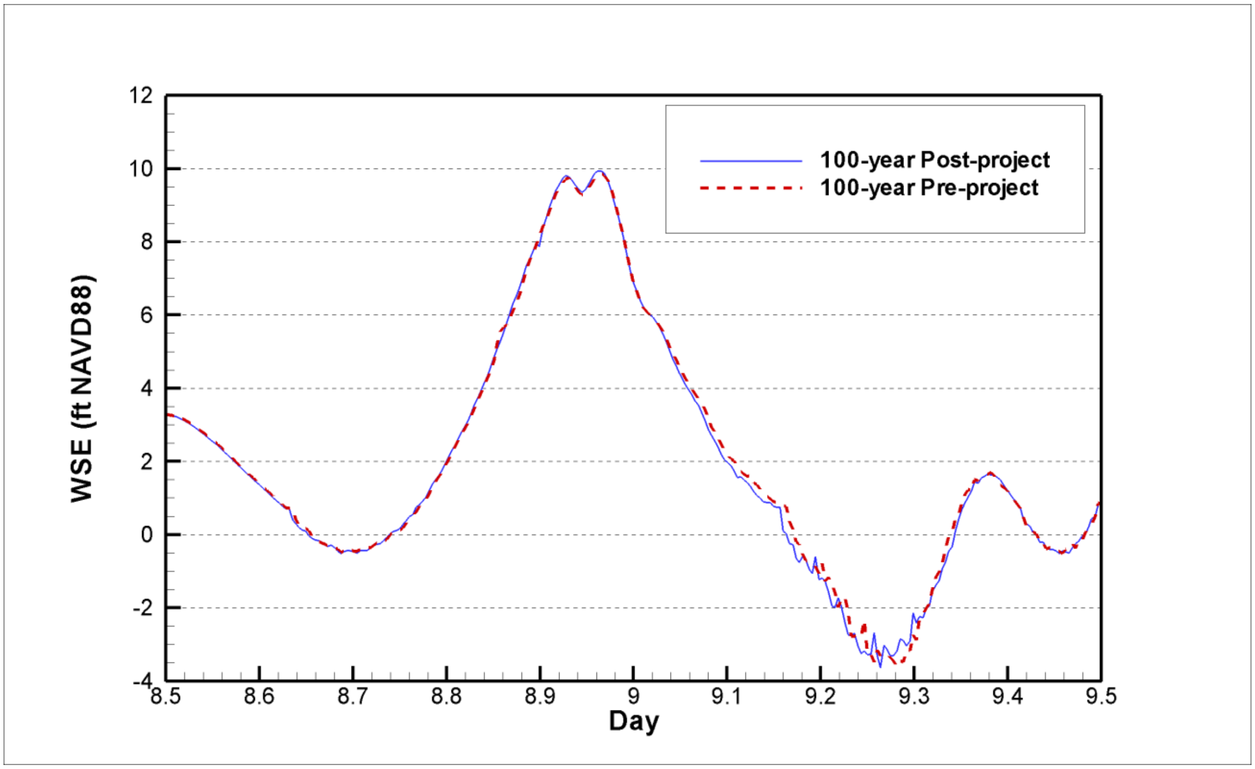

Figure 6-6. Modeled 100-yr return period event water levels on Cooper River at I-526

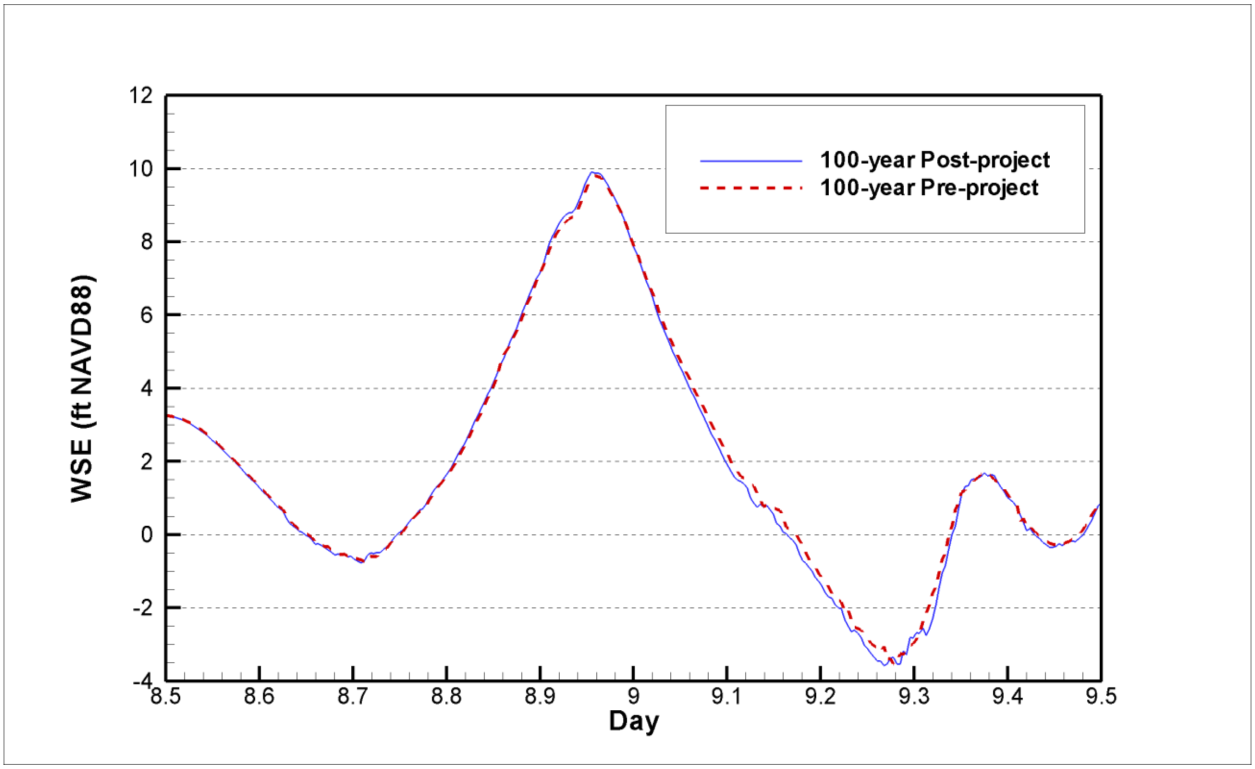

Figure 6-7. Modeled 100-yr return period event water levels on Wando River at I-526

7 Conclusions

The results of this modeling analysis indicate that the Post 45 project will cause very small increases in peak storm surge water levels in the estuary. The maximum increases to storm surge caused by the project are 0.1 feet or less.

As discussed in the introduction to this report, in addition to quantifying the potential impacts to storm surge levels, the second goal of this study is to determine if the potential impacts are significant enough to affect the flood hazard zones designated by FEMA in the FIRMs for the area. This raises the question: how would the increased channel depths affect the SCDNR storm surge model results? As shown by the Section 3 figures, the model grid used by SCDNR has many areas where only one grid node falls within the federal navigation channel part of the river cross-section. In contrast, the grid used in this analysis is aligned with the navigation channel. This makes the SCDNR model less sensitive to changes in navigation channel depth than the model used for this analysis. If the deepened channel bathymetry were interpolated onto the SCDNR grid used for the new flood studies, then the SCNDR model would show even smaller impacts than those shown by the model analysis in this report.

It is also noted that the potential impacts from the channel deepening are very small as compared to the uncertainty in the flood maps. According to URS (2012), the accuracy of the combined wind and wave models used for the ongoing remapping effort may be characterized by a standard deviation of 1 to 2 feet. This is based on analysis of high-water marks and other tests performed in a Mississippi storm surge study (Niedoroda et al. 2010 *in* URS 2012). Therefore, the effect of the project on stillwater levels is more than an order of magnitude smaller than the accuracy of the storm surge modeling used for the remapping studies. Adjustment of the flood maps to incorporate the small effects from the channel deepening is unwarranted given the uncertainty in the SCDNR storm surge modeling and resulting stillwater estimates.

Based on this analysis, the impacts from the project are sufficiently small that they would not affect the effective flood hazard zones designated in the FIRMs for the area.

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