

# **REGIONAL MODEL FOR SARASOTA BAY AND CASE STUDIES OF LONGBOAT PASS AND VENICE INLET**

## **Final Report**

**Prepared for:**

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&  
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**Submitted By:**

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## **1. INTRODUCTION**

This report summarizes the findings and recommendations for the inlet management studies for Longboat Pass and Venice Inlet. The study was conducted under a cooperative effort between the West Coast Inland Navigation District (WCIND) and the Florida Department of Environmental Protection (FDEP). The original purpose of this study was to evaluate alternatives for mitigating impacts to adjacent beaches from dredging the inlet for navigation, and from mining the ebb shoal to obtain sand to be used as beach fill. The study covers the evolution of Longboat Pass and Venice Inlet from 1880 to present. The analysis for each inlet begins with natural conditions that existed before dredging or inlet modifications and investigates how inlet evolution is influenced by natural and anthropogenic changes such as navigation improvements and mining ebb shoals for beach nourishment. Alternatives including strategic use of sand from flood shoals are considered to reduce deficiency in sand bypassing at both inlets.

### **1.1 Technical Approach**

The technical approach for Venice Inlet and Longboat Pass studies followed the approach which H&M has previously applied on numerous modeling studies for tidal inlets throughout the state of Florida. Examples of previous studies are discussed in (Dabees and Kraus 2004, 2005) and H&M (2007). The general approach is based on modeling and analysis of coastal processes on a large scale in time and space to develop boundary conditions that may then be used as input to local detailed modeling on a scale appropriate for evaluating specific project objectives.

The long timeframe of inlet evolution and morphology response to dredging may limit practical application of advanced coastal area models to investigation of short-term (order of seasons to a few years) morphology change. The response timeframe is a key factor because, in dealing with large sand shoals, adjustment in bypassing and morphology may require years or even decades before all of the effects become obvious. Dabees and Kraus (2004, 2005) presented a general methodology for examining the response of complex inlet systems to sediment mining at two inlets in southwest Florida. The methodology includes application of the Inlet Reservoir Model (IRM) (Kraus 2000a, 2000b) that simulates long-term evolution of inlet shoals.

The methodology is based on numerical modeling and data analysis for various spatial and time scales to evaluate the inlet evolution, existing condition, and alternatives for a proposed design. The analysis includes observed inlet evolution, and modeling of regional hydrodynamics, waves, and sediment transport at various times simulating main stages of the observed inlet system evolution. Process-based modeling results serve as input to the IRM to quantify

volumetric change and bypassing rates between the different morphologic features that comprise the inlet shoal system. The model is then applied to assess the long-term consequences of proposed dredging on the adjacent beaches as well as the recovery rate of the dredged area. This approach provides a comprehensive understanding of; regional processes, localized processes at subject inlets including long-term inlet evolution, as well as response to human-made alterations to natural systems where that has occurred. The goal is to provide quantitative tools for evaluating inlet management alternatives with respect to the effects of various alternatives on shoals, channels, and adjacent shorelines, in order to properly manage sand resources within inlet systems.

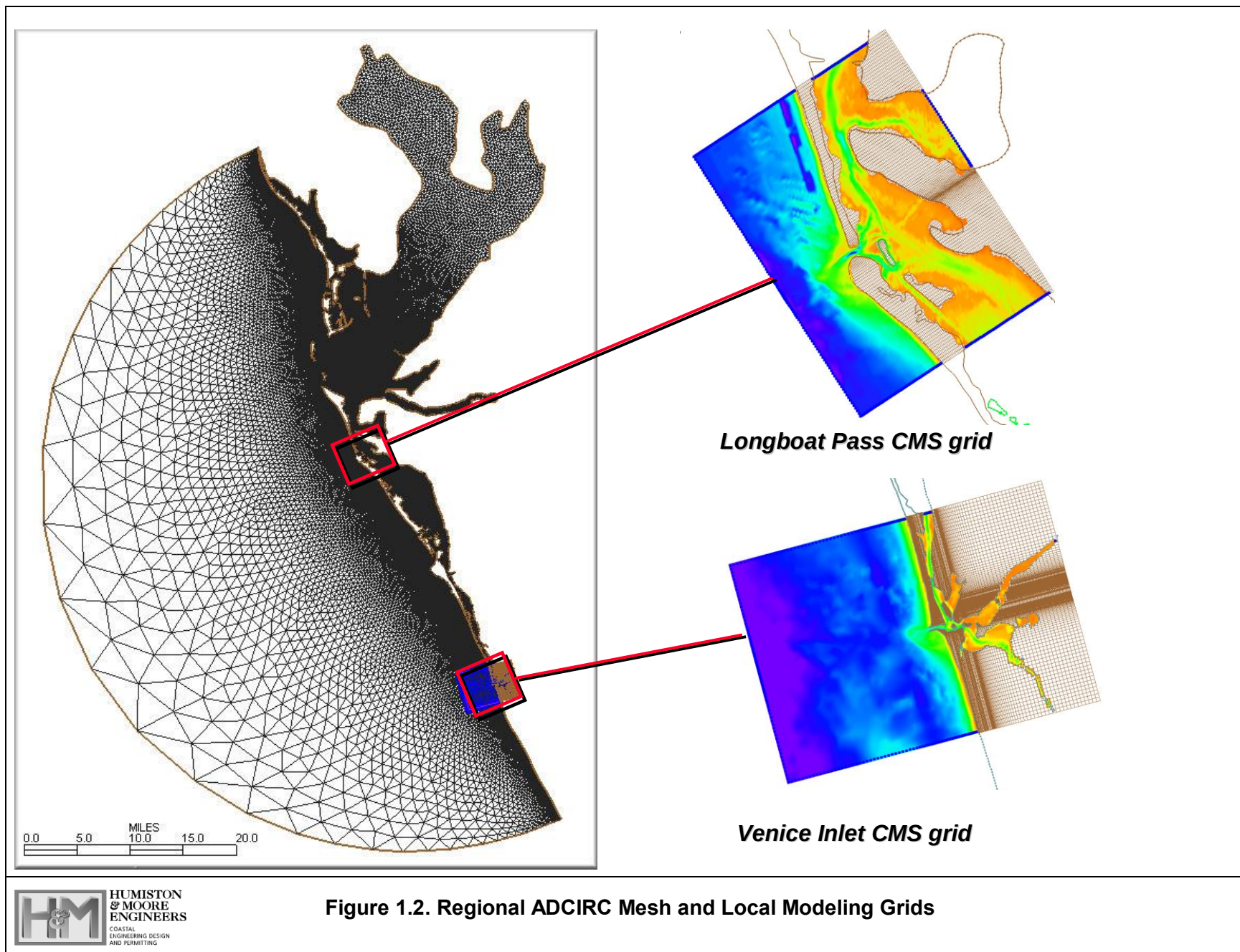
The study for Longboat Pass was initiated simultaneously with the study for Venice Inlet since both inlets are part of same bay system and one regional model would serve both studies. **Figure 1.1** shows the regional model extents which spanned over 4 counties from Pinellas County to Sarasota County. The regional model included 8 connected bays and the 9 inlets that connect them to the Gulf of Mexico. The regional hydrodynamics were simulated with the Advanced Circulation (ADCIRC) model (Luettich, et al. 1991). The regional model provides tidal driven current velocities and water level boundary conditions needed for input to local detailed models at any inlet within the regional model. **Figure 1.2** shows the regional model mesh and local modeling grids for Longboat Pass and Venice Inlet.

There are significant advantages to generating boundary conditions for the local models from a regional model, as opposed to generating those boundary conditions from detailed data collection at the individual local model boundaries. Data collection to establish boundary conditions for detailed local modeling requires long term monitoring in order to establish long-term averages. Data collection of long duration is necessary because data collection over short periods of time typically includes seasonal or weather specific variations that are not representative of normal long term average conditions that drive the hydrodynamic system. A local model forced by data collected at set boundaries will be limited to conditions similar to those which prevailed at the time of data collection and site specific conditions within local model domain which existed at that time. Furthermore, long term data collection is expensive because of instrumentation and labor requirements, and analytical tasks are delayed until data collection is completed. On the other hand, a local model driven by boundary conditions obtained from a regional model has the potential of simulating conditions at any point of time, past, present, and future. Additionally, the regional modeling approach provides flexibility to select any convenient boundary for the local, and will also address the effects of any modification to the system which may occur outside the local project area, such as dredging other inlets or bay areas that could influence hydrodynamics and processes within the local study area.



**Figure 1.1. Regional Coverage of Sarasota / Tampa Bays and Inlets System**





The detailed models for local inlets include wave and sediment transport modeling with the Coastal Modeling System (CMS) (Buttolph et al. 2006) and long-term morphology evolution modeling using the IRM . The combination of the CMS 2D flow/sediment transport model with the simple long-term morphology of the IRM provides a practical application tool to help identify morphologic features and sediment pathways for; conditions which existed before any dredging or inlet modifications, to describe how the system naturally evolved; for present conditions, to describe ongoing processes, and; for potential alternative inlet management strategies to provide a basis for management policy decisions.

## **1.2 Report Structure**

This report summarizes the methodology and findings of this study in three parts. Part one discusses the regional model and the dynamics of a multiple bay system that includes multiple inlets. The second part discusses the detailed modeling and analysis of Longboat Pass and the effects of previous ebb shoal dredging on inlet evolution. The third part discusses the detailed modeling and analysis of Venice Inlet.

## **2. REGIONAL MODEL**

This section discusses the regional hydrodynamic modeling for Tampa Bay, Palma Sola Bay, Sarasota Bay, and other connected embayments, plus the tidal inlets which connect the bay system to the Gulf of Mexico. The regional hydrodynamic modeling is an element of the analysis of coastal and inlet processes for sand management at Longboat Pass and Venice Inlet. This regional modeling analysis was necessary due to the complexity of the interconnected surface water system of the bays within the region and the multiple inlets that connect the bays to the Gulf of Mexico.

### **2.1 Background**

The regional hydrodynamic model was used to establish boundary conditions for the studies of Longboat Pass and Venice Inlet for various temporal conditions during the past century. The regional coverage and large time scale modeling was necessary to quantify changes in tidal prism due to natural and anthropogenic changes. Major anthropogenic changes during the past century included general infrastructure and bayside development, navigation improvements, and beach restoration projects. Navigation improvements included construction of the Inter Coastal Waterway (ICW) (1940's to 1960's), maintenance dredging, and jetty construction at some of the inlets in the regional study area. Inlet improvements included stabilization of Venice Inlet by two jetties in 1937, Longboat Pass jetty construction in 1957, and navigation improvements and maintenance dredging for Venice Inlet, New Pass, and Longboat Pass. Beach restoration projects affecting the inlets included mining sand from Longboat Pass and New Pass ebb shoals for beach nourishment.

Major natural changes during the past century included large morphologic changes and storm impacts affecting the central and southwest gulf coast of Florida. Among these storms were El Nino extra-tropical storms in 1983, Hurricane Elena in 1985, the storm of March 1993, Hurricane Mitch in 1998, and the highly active hurricane seasons of 2004 and 2005. Natural large morphologic changes include the migration and relocation of Longboat Pass (1880's to 1950's) and the closure of Midnight Pass in 1983. Midnight Pass was a natural inlet between Venice Inlet and Big Sarasota Pass separating Casey Key from Siesta Key. Natural and anthropogenic changes to the system which affected the distribution of tidal prism shares between Sarasota Bay inlets contributed to the closure of Midnight Pass. The natural changes which contributed to the closure would of course include the effects of storms. Modeling and analysis of the regional and long-term changes provide a means of determining how Longboat Pass and Venice Inlet in particular and Sarasota Bay in general, were influenced by these natural and anthropogenic changes.

## 2.2 Model Description

The regional hydrodynamics were simulated with the Advanced Circulation (ADCIRC) model (Luettich, et al. 1991). The regional model covered an area that spanned Sarasota, Manatee, Hillsborough and Pinellas counties, covering approximately 70 miles alongshore by 30 miles offshore. The model extended from the middle of Manasota Key in Sarasota County at the south end to the middle of Sand Key in Pinellas County at the north end. The modeled area included Little Sarasota Bay, Sarasota Bay, Anna Maria Sound, Palma Sola Bay, Tampa Bay and the inlets that connect the bays to the Gulf of Mexico. Those inlets include, from south to north, Venice Inlet, Big Sarasota Pass, New Pass, Longboat Pass, Tampa Bay entrance, Bunces Pass, Pass-a-Grille Pass, Blind Pass and John's Pass. **Figure 2.1** shows the ADCIRC regional model mesh, bathymetry and the NOAA station location that was used for model calibration.

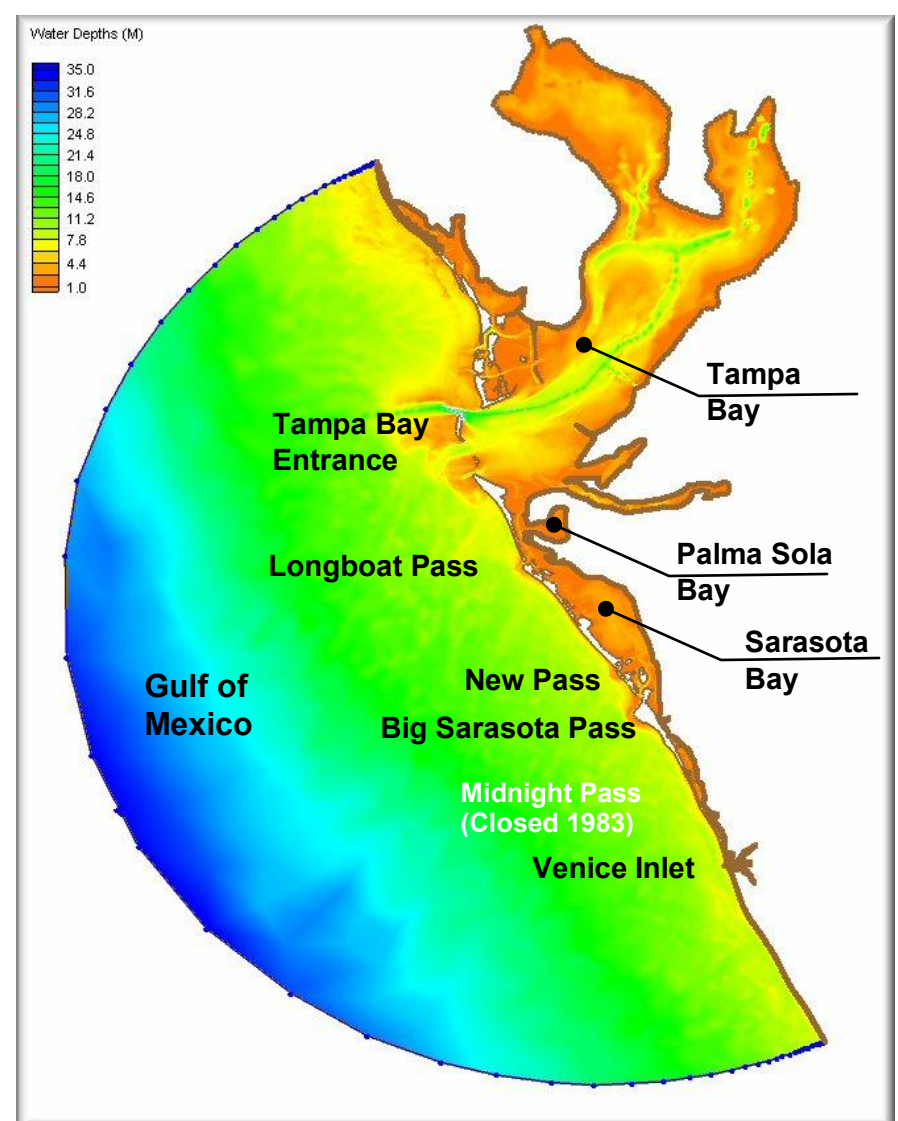
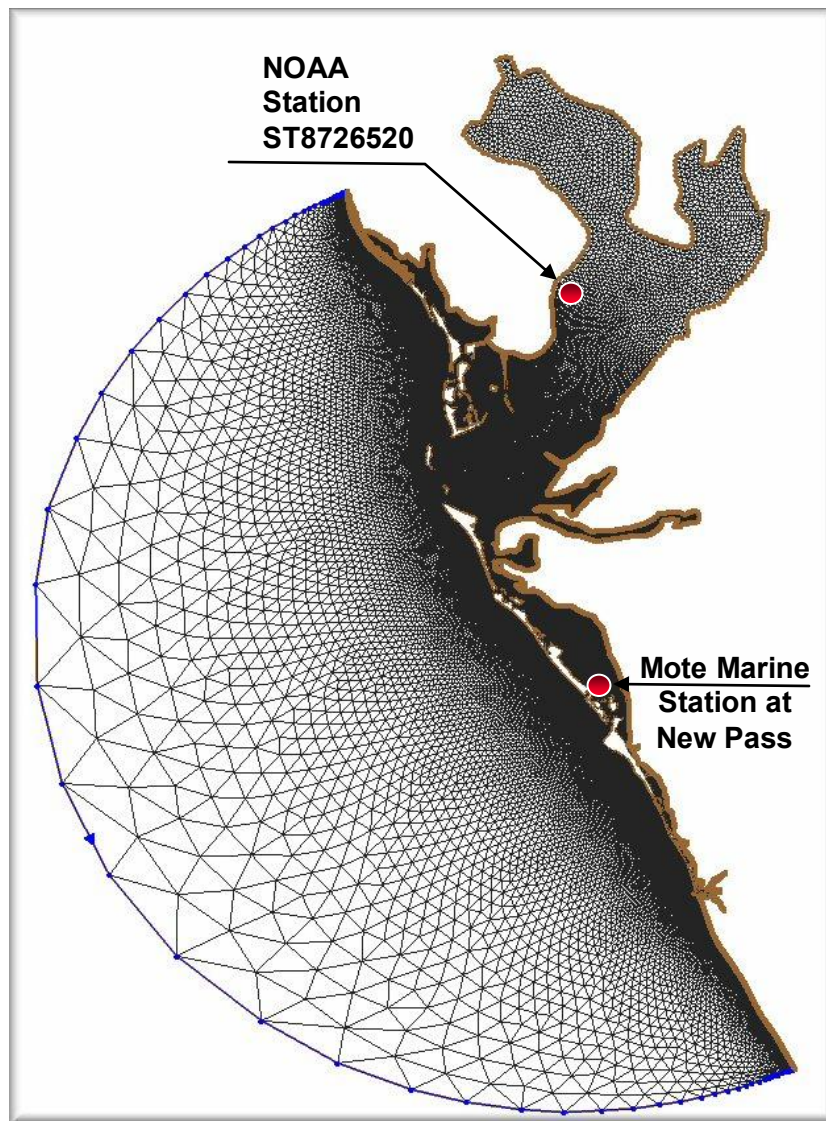
The ADCIRC grid varied from lower resolution at the gulf boundary where bathymetry changes gradually over broad areas, to high resolution in the nearshore and inlet regions where there are small scale irregularities in bathymetric geometry. The model driving forces were the Gulf of Mexico water level fluctuations resulting from astronomical tides. The water levels were computed based on tidal and wind forcing. The tidal forcing was calculated at the gulf boundary based on tidal constituents from two databases: Le Provost et al (1994) and ADCIRC (Mukai et al. 2002). The Le Provost Database provides major and minor tidal constituents of the world oceans; the ADCIRC Tidal Databases was developed by the USACE Coastal Inlets Research Program for use as boundary conditions for local area circulation. Both inputs were used for separate runs, and comparisons with measured water levels at a NOAA station in Tampa bay were used for model calibration. The wind forcing was based on measured wind speeds at NOAA Station ST8726520 inside Tampa Bay. The simulation date was chosen to represent average and spring tide ranges and 8-day simulation runs were chosen for each temporal condition.

## 2.3 Model Calibration and Verification

The model was calibrated with available measured water levels and magnitudes of velocities and tidal prism measurements cited in the previous studies (Sheng et al 1994, 1995). **Figure 2.2** shows a comparison of measured and calculated water levels for NOAA Station ST8726520 in Tampa Bay. The results of the model calibration show generally good agreement between simulated and measured water levels with a margin of error less than 10%. The calculated and measured water levels indicate that the tide is predominantly diurnal with a mixed semi-diurnal component in this region depending on the stage of the lunar cycle.

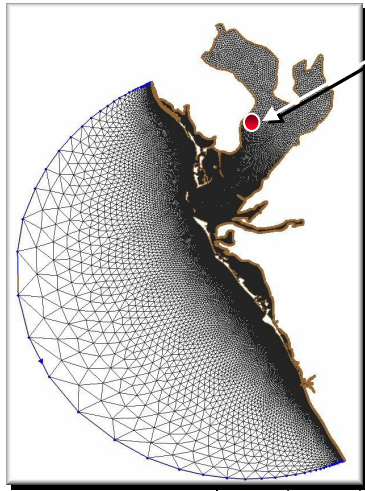
Model verification was achieved by running the calibrated model for a different time than the calibration and comparing the calculated and measured water levels at locations within the model coverage. The two stations used for model





**Figure 2.1. ADCIRC Regional Mesh, Bathymetry, and Geographic References**





NOAA Station  
ST8726520

Regional Model Calibration  
NOAA ST8726520

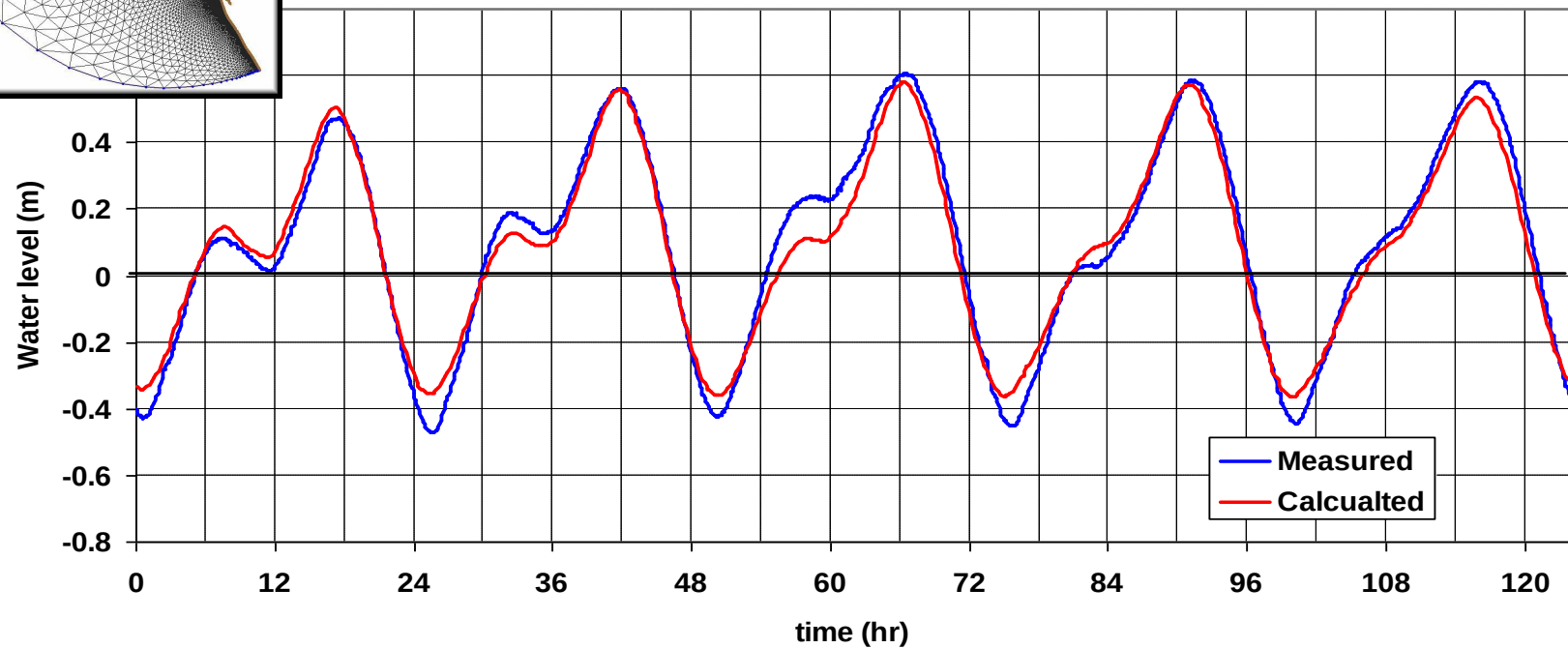


Figure 2.2. ADCIRC Model Calibration with Measured Water Levels at NOAA Station Inside Tampa Bay

verification were NOAA Station ST8726520 in Tampa Bay, and the Mote Marine Station at New Pass. **Figure 2.3** shows model verification results comparing calculated and measured water levels at both stations.

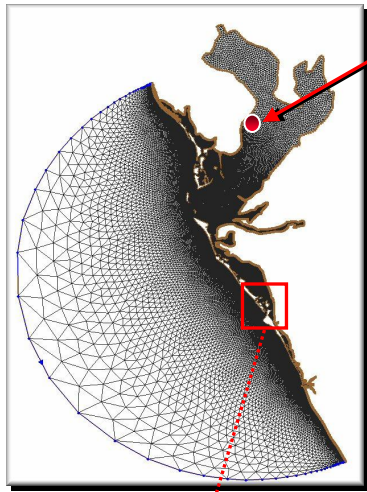
## 2.4 Regional Model Case Studies

The regional hydrodynamic model was used to simulate two different time periods; the 1950's and present conditions. This was done to examine the influence on regional hydrodynamics from transformations which occurred during that interval, and how those changes affected the two inlets which are the subject of this study. All simulations were performed using the same forcing conditions (time series of astronomical tides at the model boundary) to allow comparison of individual inlet tidal prisms in the 1950's to present conditions.

**Figures 2.4 to 2.7** show the bathymetry from the 1950's and from 2006 which were used as input to the regional model for the two different temporal conditions. The depth color scale was chosen to identify shallow water and shoal areas (0 to 2 meters depth) by the yellow shades, the offshore zone from depths 2 to 7 meter by the green shades, and water deeper than the depth of closure by the blue shades. The right side of **Figures 2.4 through 2.7** shows contours of depth change between the 1950's and 2006. Depth change color scale was chosen such that yellow to red shades (warm colors) indicate shoaling areas and shades of blue (cold colors) indicate scour, erosion, or dredging.

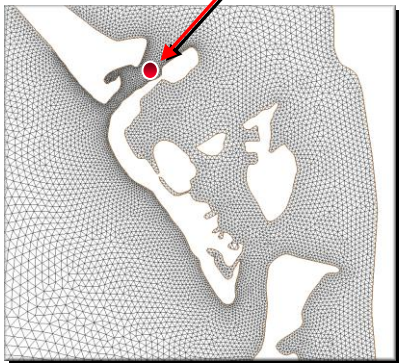
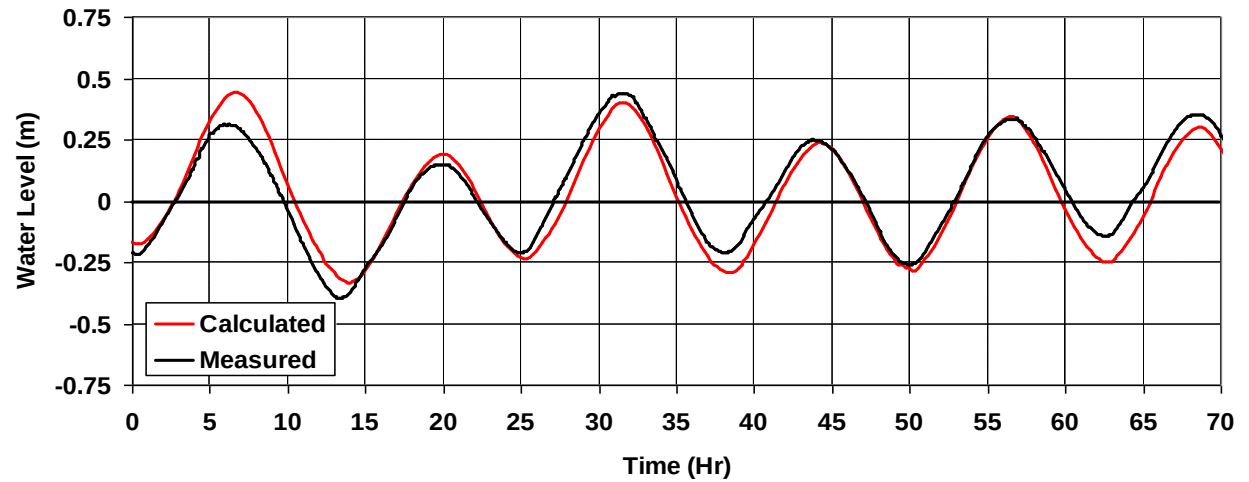
**Figure 2.4** shows the 1950's and present conditions at Venice Inlet and Little Sarasota Bay. The Figure shows the change in water depths associated with the construction of the ICW, deepening of Venice Inlet and growth of its ebb shoal. **Figure 2.5** shows the 1950's and present conditions for the north part of Little Sarasota Bay including Midnight Pass which closed in 1983. The figure shows the change in water depths associated with the construction of the ICW. The figure also shows morphologic changes due to the closure of Midnight Pass and collapse of its ebb shoal.

**Figure 2.6** shows the 1950's and present conditions at New Pass and Big Sarasota Pass. The figure shows southward migration of the New Pass channel, a change of channel orientation toward the southwest direction, and associated southward migration of the ebb shoal. The figure also shows erosion of the north lobe of the ebb shoal at New Pass near the location of the borrow area that was dredged in 1993 to obtain sand for beach nourishment. **Figure 2.6** also shows morphological changes at Big Sarasota Pass including erosion of the seaward side of the north lobe of ebb shoal, and infilling of the 1950's channel location which caused the channel to migrate south toward Siesta Key. As a result, that part of Siesta key was armored to protect upland properties from inlet related erosion. **Figure 2.6** also shows the growth of the sand bypassing bar south of Big Sarasota Pass.



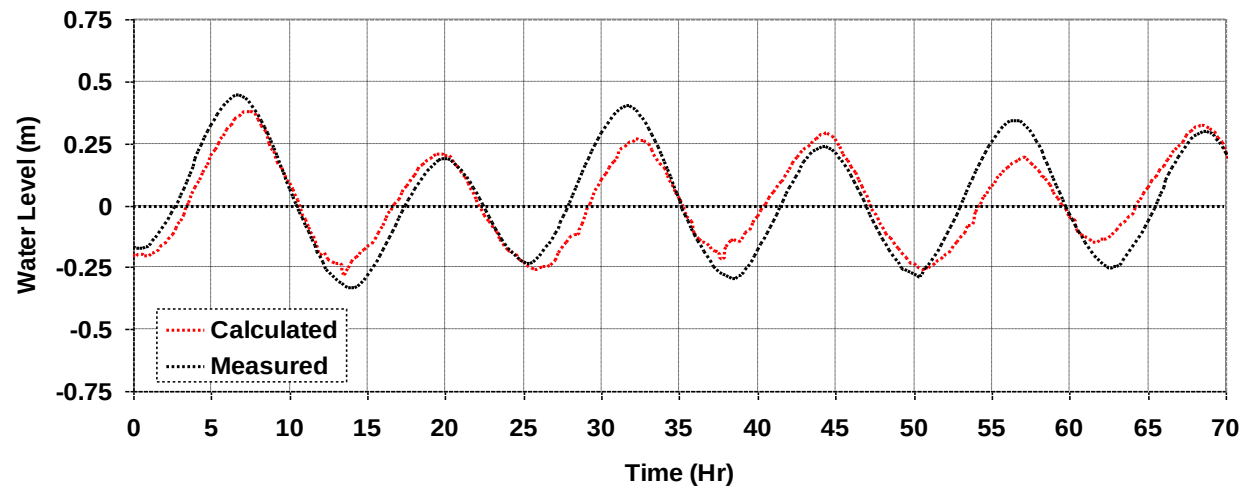
**NOAA Station  
ST8726520**

**Tampa Bay NOAA Station ST8726520**

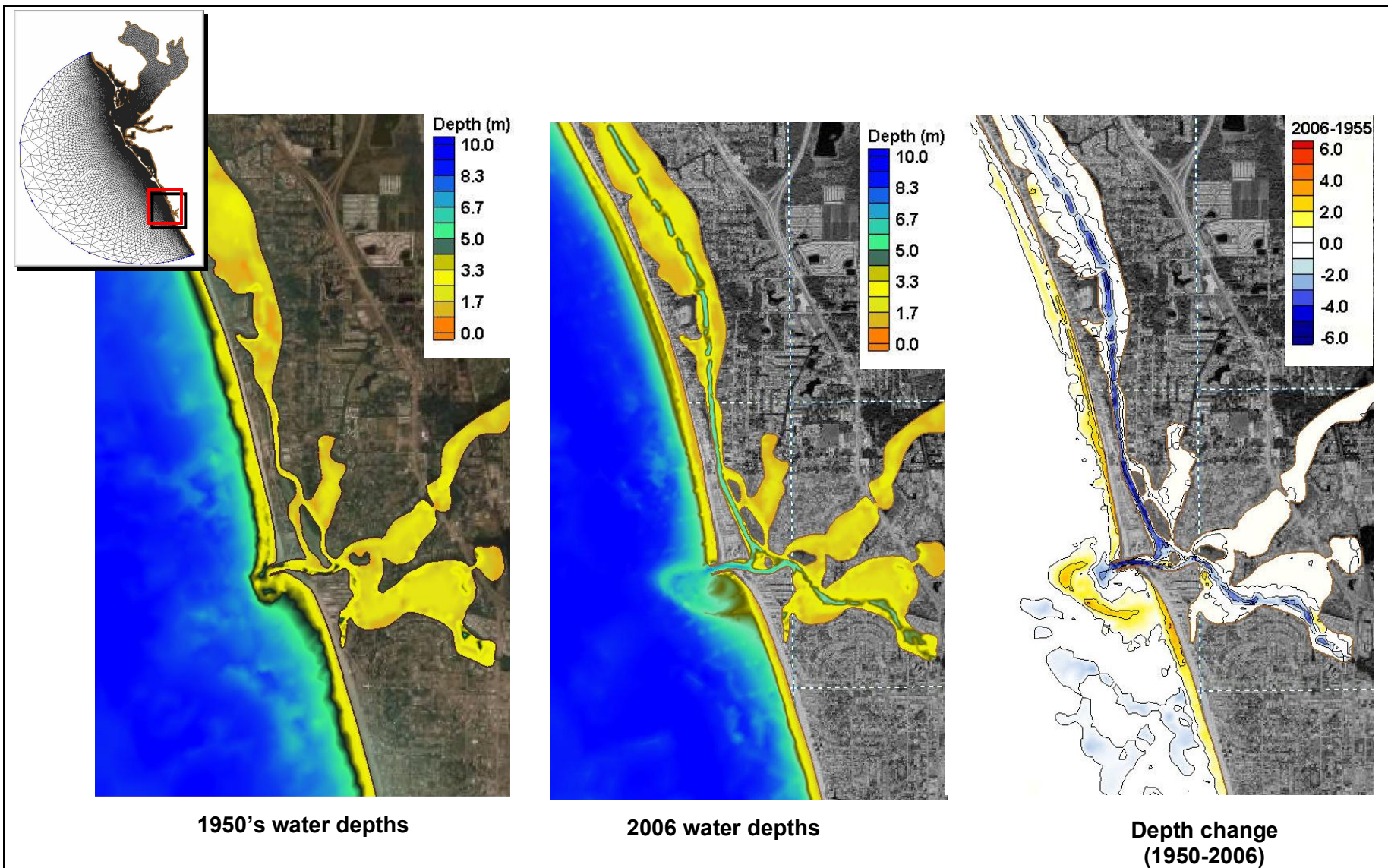


**Mote Marine  
New Pass Station**

**Mote Marine New Pass Station**

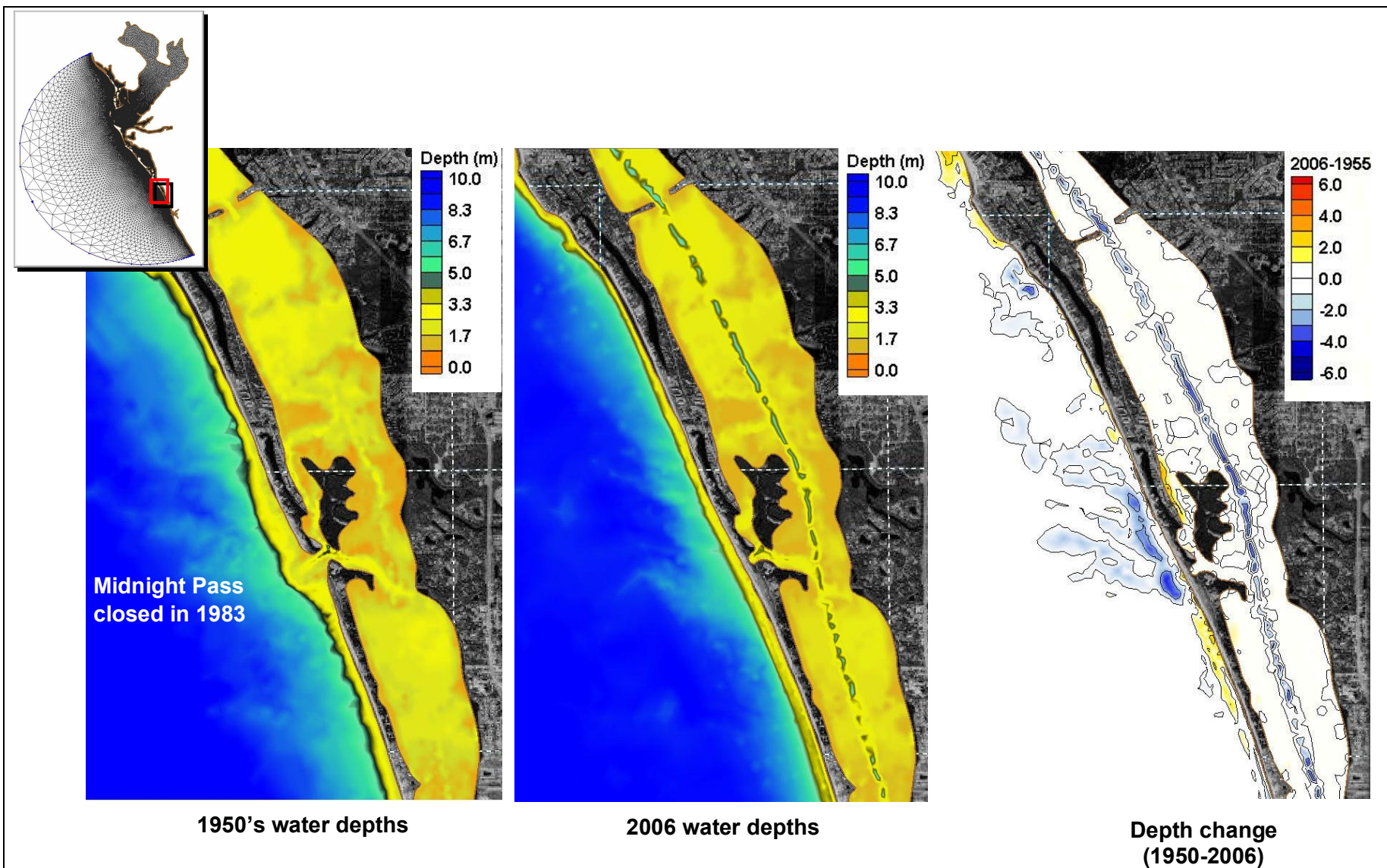


**Figure 2.3. ADCIRC Model Verification with Measured Water Levels at Tampa Bay and New Pass**

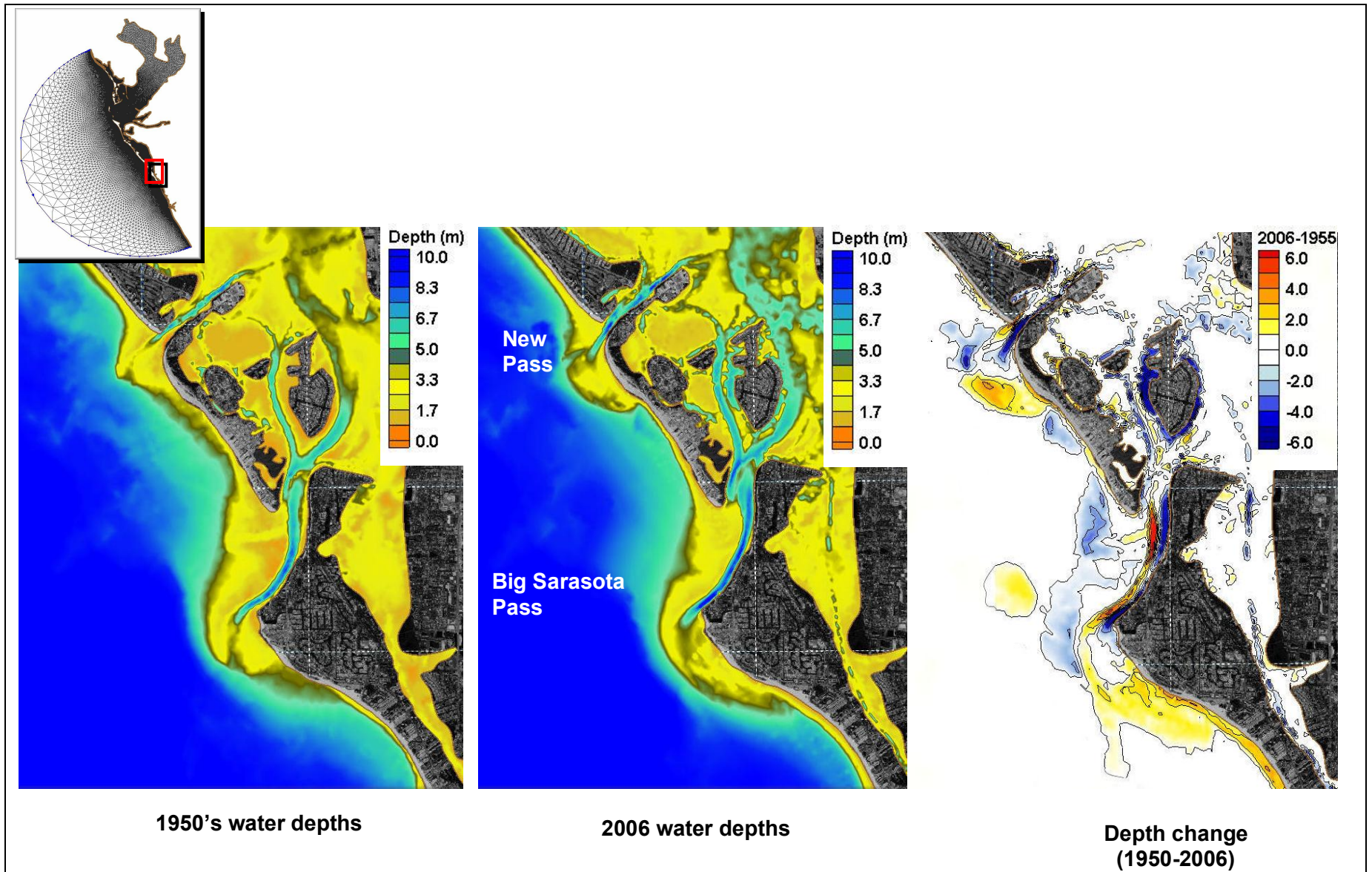


**Figure 2.4. Morphologic Change for Venice Inlet and Little Sarasota Bay (1950's to Present Conditions)**



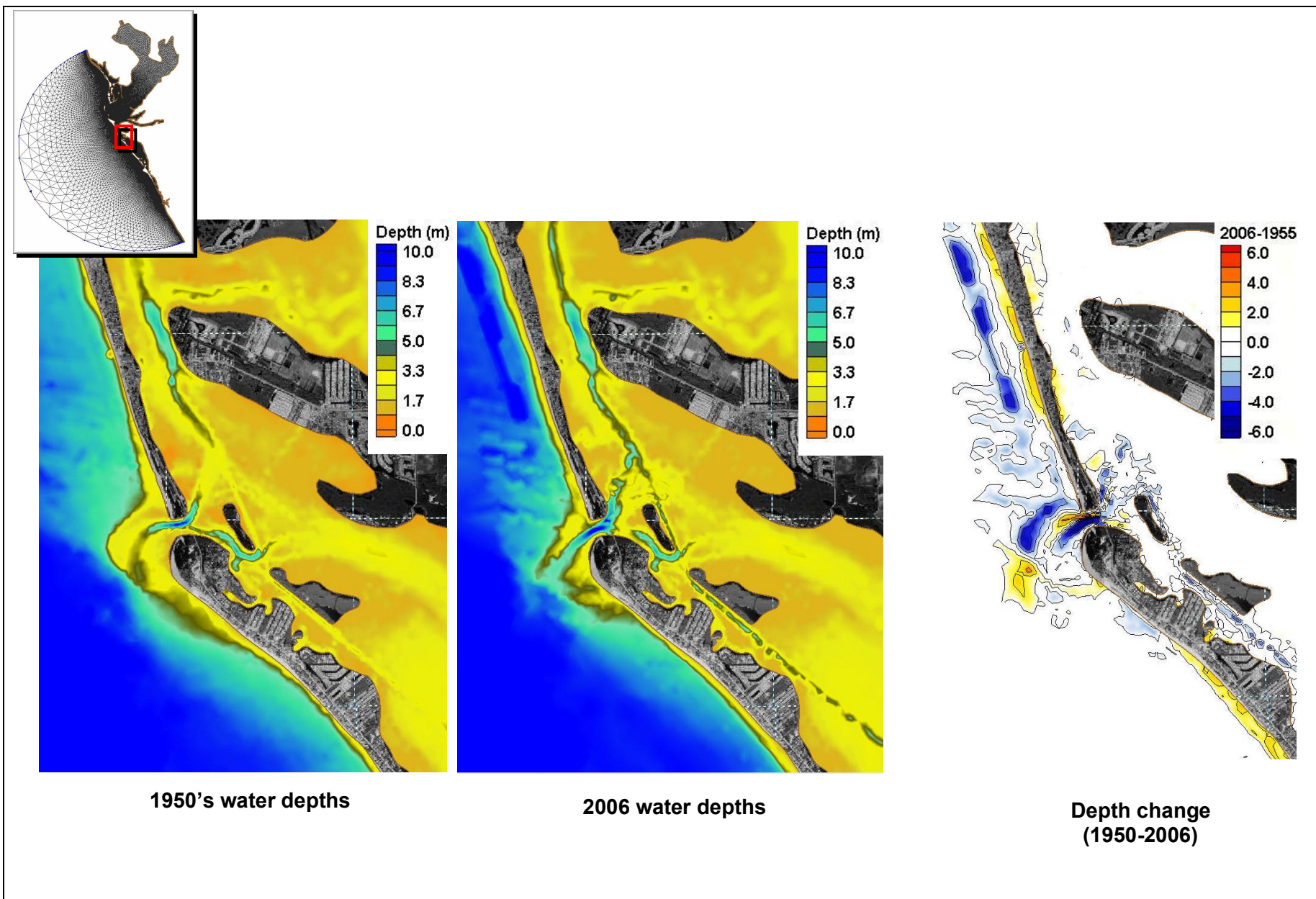


**Figure 2.5. Morphologic Change for Midnight Pass and Little Sarasota Bay (1950's to Present Conditions)**



**Figure 2.6. Morphologic Change for Big Sarasota Pass and New Pass (1950's to Present Conditions)**





**Figure 2.7. Morphologic Change for Longboat Pass (1950's to Present Conditions)**

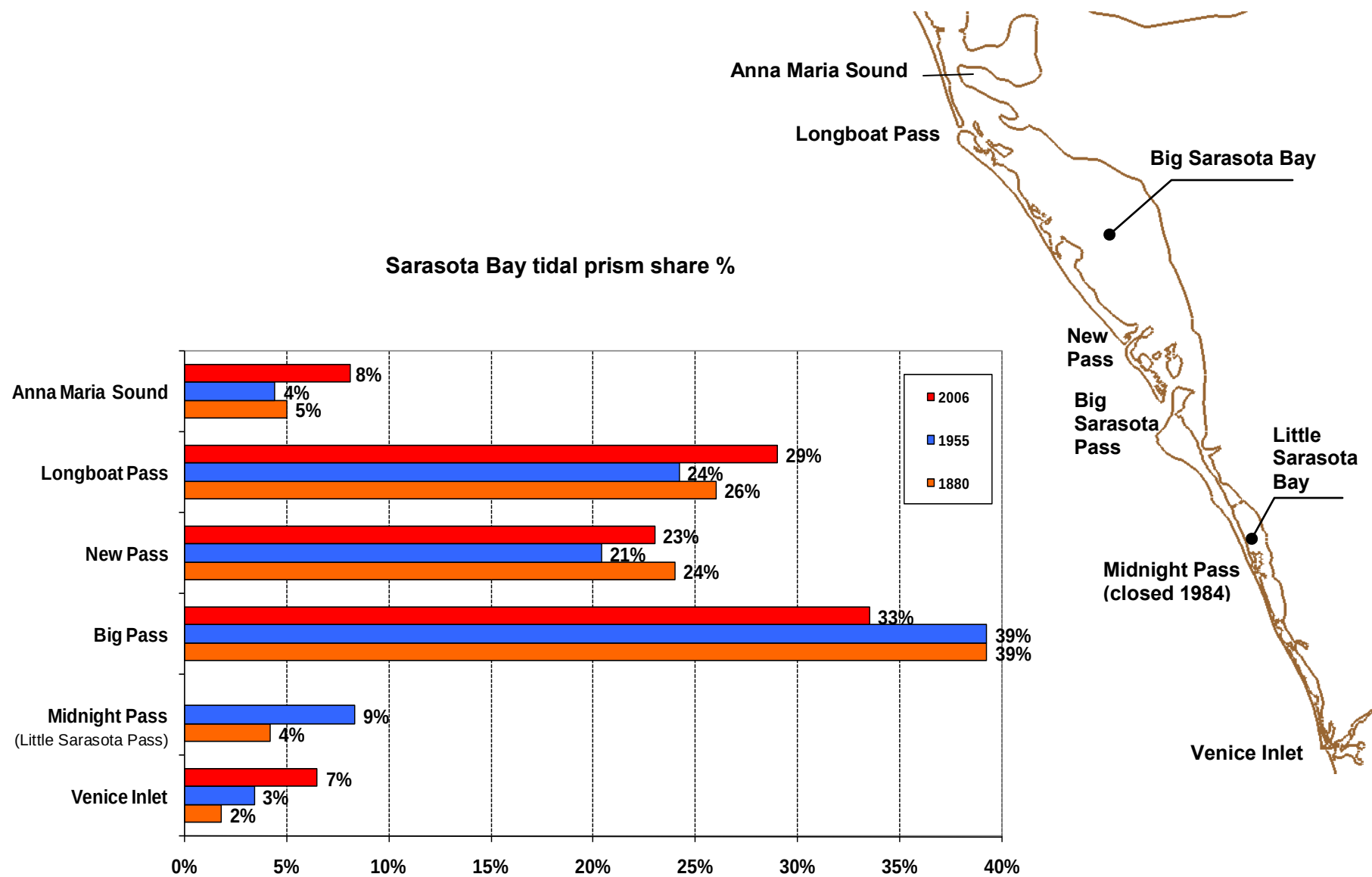
**Figure 2.7** shows the 1950's and 2000 conditions in the vicinity of Longboat Pass. The change in morphology during that period was a result of the construction of the ICW in Sarasota Bay, construction of a jetty at the north side of the inlet in 1957, authorization and maintenance dredging of a federal navigation channel since 1977, and mining of the outer part of the ebb shoal for Longboat Key beach nourishment in 1993. The figure also shows the location of another borrow area which was dredged in 1992 in the nearshore area along Anna Maria Island. This borrow area is approximately a mile north of the inlet, and it was dredged to obtain sand for Anna Maria Island beach nourishment. Details of these events are discussed further in the Longboat Pass section of this report.

## 2.5 Regional Model Results

**Figure 2.8** shows how the tidal prism of the interconnected bay system is distributed amongst the various inlets for the 1880's, the 1950's and 2006 conditions. The figure shows how the share of tidal prism for each inlet has changed. The model results indicate the changing distribution of tidal prism among the inlets and the effect of the developments of the last century and major morphological changes including closure of Midnight Pass. **Figure 2.8** shows that along with elimination of flow through Midnight Pass there was a decrease in the tidal prism of Big Sarasota Pass, and an increase in tidal prism shares for Anna Maria Sound, Longboat Pass, New Pass, and Venice Inlet.

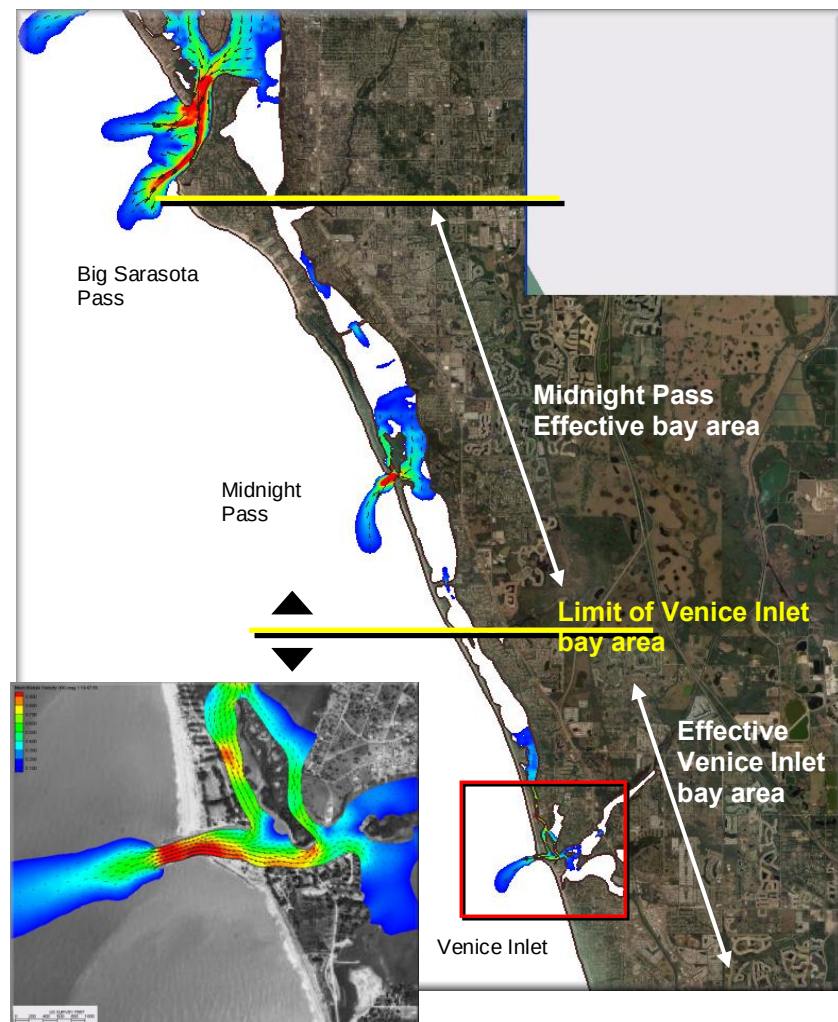
### 2.5.1 Venice Inlet

The model indicates that the improvements of the ICW and the closure of Midnight Pass resulted in an increase of Venice Inlet tidal prism. **Figure 2.9** shows the maximum ebb tidal current velocities for Little Sarasota Bay and its inlets for the 1950's and 2006 conditions. The figure indicates the velocity magnitudes, directions and extents of areas of active ebb velocities within the bay and ebb shoal areas. Red-colored areas indicate velocities greater than the critical velocity for sediment movement. Yellow, green, and light blue indicate areas of active velocities and currents, and the darker blue indicates very low velocities. The yellow lines on **Figure 2.9** signify the approximate limits of each inlet's effective bay area. The tidal prism of the bay was shared between Venice Inlet, Midnight Pass and Big Sarasota Pass in the 1950's. The 2006 illustration represents present conditions with Midnight Pass closed. The results indicate that as a result of the increased tidal prism, higher velocities through Venice Inlet extended the ebb jet further offshore resulting in the growth of the ebb shoal as shown in **Figure 2.4**. A more detailed discussion of Venice Inlet evolution is provided in the Venice Inlet section of this report.

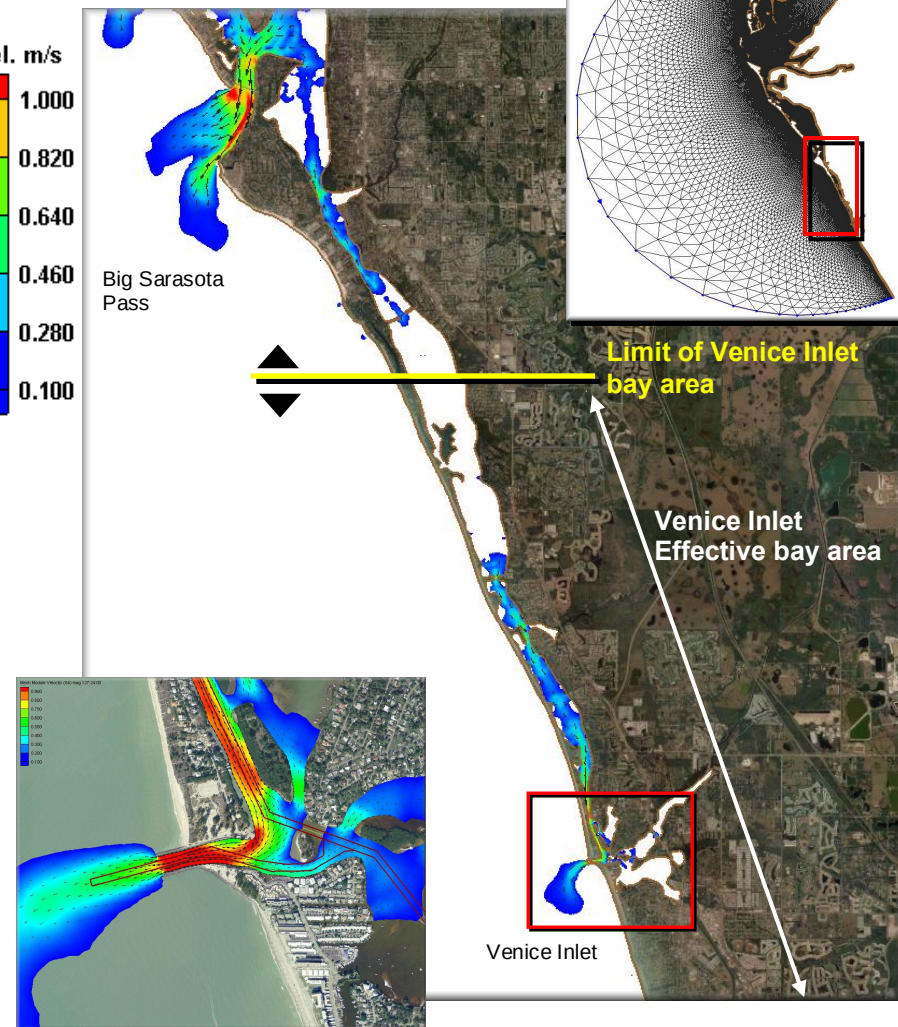


**Figure 2.8. Tidal Prism Distribution between Sarasota Bay Inlets (1880's, 1950's and Present Conditions)**





1950's Ebb Velocities



2006 Ebb Velocities

Figure 2.9. Ebb Velocities for Little Sarasota Bay (1950's to Present Conditions)



### 2.5.2 Big Sarasota Pass and New Pass

The regional model results indicate that the tidal prism of Big Sarasota Pass decreased in spite of the Midnight Pass closure. The increase in the New Pass tidal prism during the same period is related to the decrease in the Big Sarasota Pass share of the tidal prism. However, in spite of this decrease, Big Sarasota Pass still carries the largest share of tidal prism of all inlets in this interconnected system.

The navigation improvements at Venice Inlet, Longboat Pass and New Pass have provided deeper and shorter channels between the gulf and bay system with more hydraulically efficient connections than previously existed. This resulted in drawing an increased tidal prism through these inlets. As a result, the tidal prisms of the unimproved inlets, Big Sarasota Pass and Midnight Pass decreased. This may have partially contributed to the closure of Midnight Pass.

**Figure 2.10** shows the maximum ebb tidal current velocities for Big Sarasota Bay and its inlets for the 1950's and 2006 conditions. The figure shows a decrease in velocities and the seaward extent of the ebb tidal plume for Big Sarasota Pass in 2006 in comparison with the 1950's conditions. The decrease in the tidal prism of Big Sarasota Pass resulted in a gradual decrease in volume of sand within the inlet ebb shoal delta as the shoal size changed to be in equilibrium with the new smaller tidal prism. As a result, the ebb jet and its associated circulation no longer covered the entire ebb delta, which allowed waves to dominant sand transport at the outer parts of the ebb delta, which results in movement of sediment onshore. This process eroded the outer portion of the ebb shoal, caused shoaling along the north side of the channel and forced the inlet channel to migrate closer to the shoreline south of the inlet. The onshore movement and channel migration resulted in growth of the downdrift bypassing bar and attachment to Siesta Key. These trends are indicated in the morphological changes shown on **Figure 2.6**.

### 2.5.3 Longboat Pass

The regional model results indicate an increase in tidal prism through Longboat Pass between 1950's and present conditions. This increase occurred due to expansion of the northern limit of the inlet's effective bay to include portions of the bay system from Palma Sola Bay and Anna Maria Sound. Changes that contributed to this include construction of the Longboat Pass north jetty in 1957, the improvement of the ICW, and the dredging of the federal inlet navigation channel in 1977. Prior to the 1950's, the bay areas of Palma Sola Bay and Anna Maria Sound outlet to the gulf were through Tampa Bay entrance. Although the tidal wave propagates from south of north along the Florida gulf coast, i.e. tide occurs at Longboat Pass before to Tampa Bay entrance, the tide moves more quickly in the deeper water and wider connection to the gulf of Tampa Bay, so

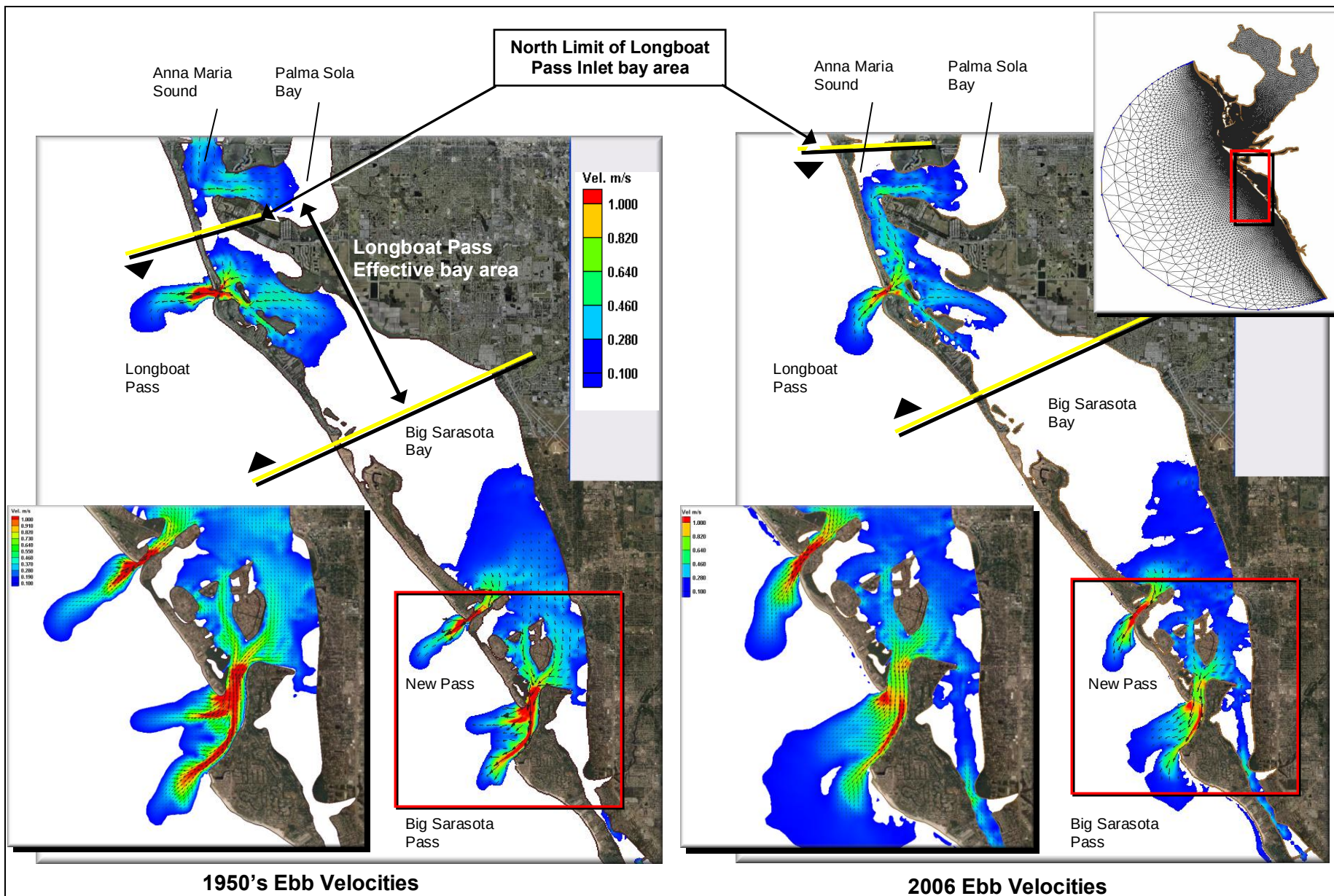


Figure 2.10. Ebb Velocities for Big Sarasota Bay (1950's to Present Conditions)

the phase of the tide in Tampa Bay is typically ahead of the tide phase on the Longboat Pass shoals and shallower Sarasota Bay waters. Following the improvements to Longboat Pass, the improved hydraulic efficiency of the pass made it easier for Palma Sola Bay and Anna Maria Sound to flush through Longboat Pass. **Figure 2.10** shows the change of ebb velocities and limits of effective bay area for Big Sarasota Bay including Longboat Pass.

#### 2.5.4 Midnight Pass Closure

As discussed earlier, the navigation improvements at Venice Inlet and the ICW provided a deeper shorter channel between the gulf and Little Sarasota Bay, and the phase of the tide at Venice Inlet is typically slightly ahead of Midnight Pass. This resulted in drawing an increased tidal prism through Venice Inlet and a smaller share of the tidal prism through Midnight Pass. Since Midnight Pass was a small inlet to begin with, the decrease in tidal prism could have reduced inlet stability causing sand transport on the ebb shoal to be dominated by waves rather than tides. The inlet eventually closed following the 1983 El Nino extra-tropical storms. The 1983 storms followed by Hurricane Elena and Tropical Storm Juan in 1985 may have accelerated the closure of Midnight Pass and the rapid onshore migration of its ebb shoal. **Figure 2.11** shows the calculated annual gross sediment transport rates relative to the 20 year average rate for the shoreline in the vicinity of Midnight Pass. The sediment transport rates were calculated by the ONELINE model (Dabees and Kamphuis, 1998) using the 20-years (1980-1999) of wave data from WIS station 277 located approximately 10 km offshore of Longboat Key, in a water depth of approximately 18 m. The 20-year analysis of sediment transport rates confirms the much higher than average potential sediment transport rates associated with storm activity. It is likely that these high transport rates and the decrease in tidal prism both contributed to Midnight Pass closure.

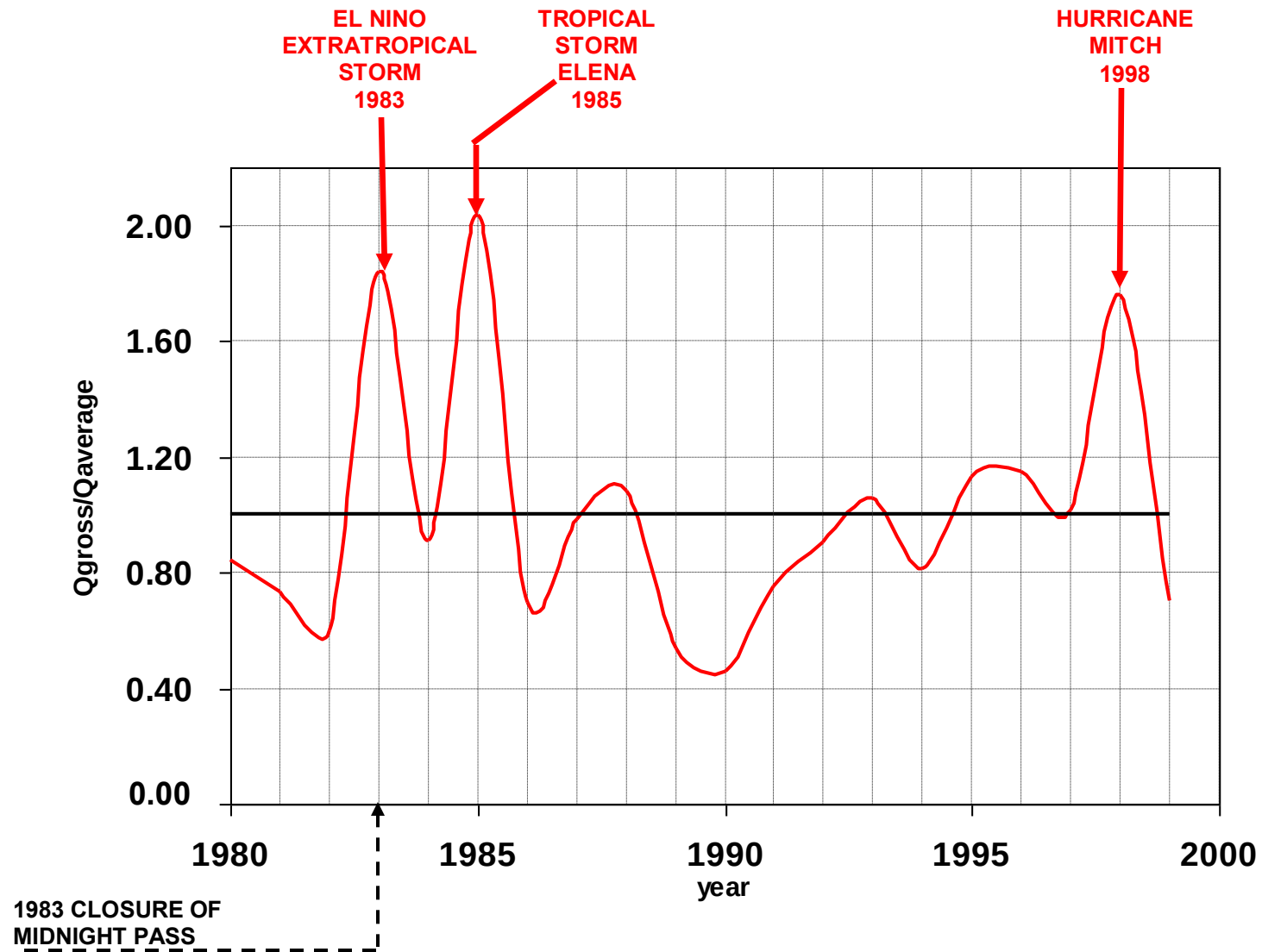


Figure 2.11. Calculated Annual Gross Sediment Transport Rates Relative to 20-Year Average Rate



### **3. LONGBOAT PASS INLET EVOLUTION MODELING AND ANALYSIS**

#### **3.1 Background**

Longboat Pass is a tidal inlet connecting the north part of Big Sarasota Bay to the Gulf of Mexico. The inlet is part of a large multi-inlet bay system, made up of the large and shallow bay areas of Little Sarasota Bay and Big Sarasota Bay which are connected to the Gulf of Mexico by several tidal inlets. Longboat Pass is located between Anna Maria Island to the north and Longboat Key south. **Figure 3.1** shows the project location and extent of the local detailed model area for Longboat Pass. A detailed discussion of the regional system and its dynamics is included in the previous section. This section summarizes the detailed modeling and analysis of the evolution of Longboat Pass. The study aims at evaluating the impacts of previous dredging and ebb shoal mining on the pass and adjacent beaches.

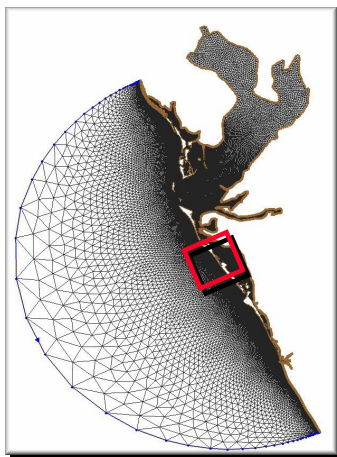
The present study compiled recent and historic surveys, aerial photographs, and other data to quantify morphologic change throughout the inlet evolution and to provide input for numerical models. The complex nature of the inlet required analysis of inlet evolution over a large time scale from (1880's to present). Compilation of historical data was critical to verification of the accuracy of model computations to improve confidence levels in model results.

The detailed models for Longboat Pass include wave and sediment transport modeling with the Coastal Modeling System (CMS) (Buttolph, et al. 2006) and long-term morphology evolution used the Inlet Reservoir Model (IRM) (Kraus 2000a, 2000b). The regional model discussed in the previous section provided tidal driven current velocities and water level boundary conditions needed for input to the detailed model grid for Longboat Pass for each temporal condition.

The combination of the CMS 2D flow/sediment transport model with the simple long-term morphology of the IRM provides a practical application tool to help to identify morphologic features and sediment pathways for; conditions which existed before any dredging or inlet modifications, which describes how the system naturally evolved; for present conditions, to describe ongoing processes, and; for potential alternative inlet management strategies to provide a basis for management policy decisions.

The Longboat Pass analysis discussed in this chapter is divided three sections;

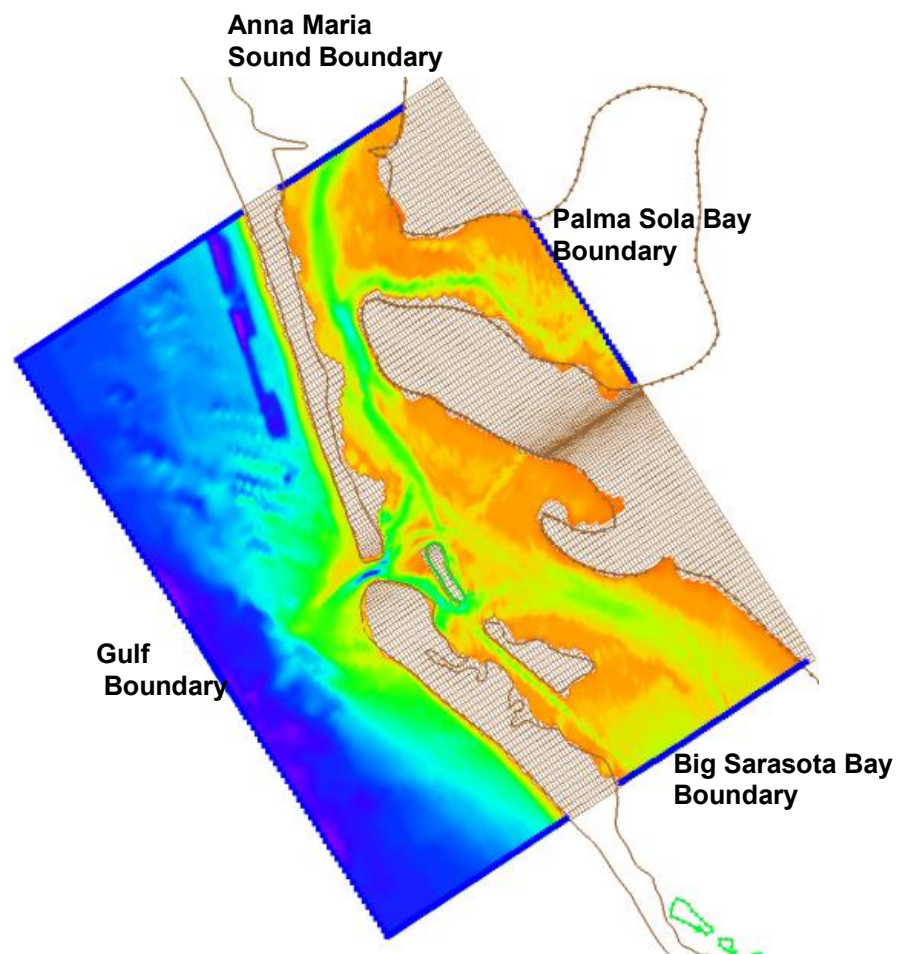
- Section 3.2 provides a discussion of the different stages of the inlet evolution based on data analysis and coastal process modeling results.
- Section 3.3 describes how the inlet morphology evolution model illustrates the evolution of the various morphologic features of Longboat Pass and how the model is used to project future trends.
- Section 3.4 is a summary of findings and recommendations.



**Regional ADCIRC mesh**



**Longboat Pass Federal  
Navigation Channel**



**Longboat Pass CMS grid  
(Present conditions)**

**Figure 3.1. Longboat Detailed Model Coverage**

## 3.2 Inlet Evolution

The inlet evolution discussion covers three periods in the evolution of Longboat Pass; 1880 to 1950's, 1950's to 1990's, and 1993 to present conditions. The 1880 to 1950 period covers the natural inlet evolution. The 1950's to the 1990 period covers the inlet navigation improvements including the north jetty construction in 1957 and federally authorized maintenance dredging of the navigation channel and the ICW. The time period from the 1990's to present covers the long-term effects of the ebb shoal mining in 1993, recent inlet evolution, and inlet effects on adjacent beaches.

### 3.2.1 1880's to 1950's

The earliest bathymetric data available are the 1876 and 1883 U.S. Coast and Geodetic Surveys. These surveys provided background conditions prior to any development that might have affected the Longboat Pass tributary area, including improvements to the Intracoastal Waterway (ICW), and modifications to the bay, as well as upland development that may have altered storm water input to the system. The surveys of the 1880's provided means to quantify the morphologic features at the time of the opening of the present-time inlet, the ebb shoal of the previous derelict inlet, and conditions in the nearshore and on adjacent beaches. At that time Longboat Pass was approximately 1,400 ft south of its present location, as illustrated in **Figure 3.2** (the federal channel authorized in 1977 is superimposed on this figure and on other historic exhibits for illustrative reference). The survey of 1876 shows a single inlet and a large ebb shoal with a southwest orientation of the gulf channel. The 1883 survey of the bay indicates another inlet opening to the north creating a dual inlet system.

The 1940's inlet configuration consisted of a two channel system with the northernmost channel located at approximately the same location as the present channel, as shown in **Figure 3.3**. The right side of the figure also shows the contours of the 1883 superimposed on the aerial of the 1940's. The bay being connected to the gulf by two channels resulted in dividing the flow into two smaller tidal prisms flowing through each channel in comparison to the entire bay tidal prism flowing through a single channel. The dual inlet system formed in the 1880's with a smaller tidal prism for the newer north inlet channel and most of the prism flowing through the original south inlet channel. As the original inlet was more restrictive, the newer inlet became more dominant as it gradually captured a larger share of the tidal prism. This dual inlet process continued until the south inlet closed in the 1950's. The onshore movement of the ebb shoal at the closed inlet provided large volume of material to the downdrift beach (Longboat Key) and the formation of the active ebb shoal to the north. The formation of the new ebb shoal caused significant erosion on the north side of inlet, along the south end of Anna Maria Island. Comparisons of 1880's and 1955 surveys indicate over 3 million cubic yards eroded from the beach and nearshore shoals along the beach of Anna Maria Island to form the Longboat Pass shoal system. The 1940's aerials show

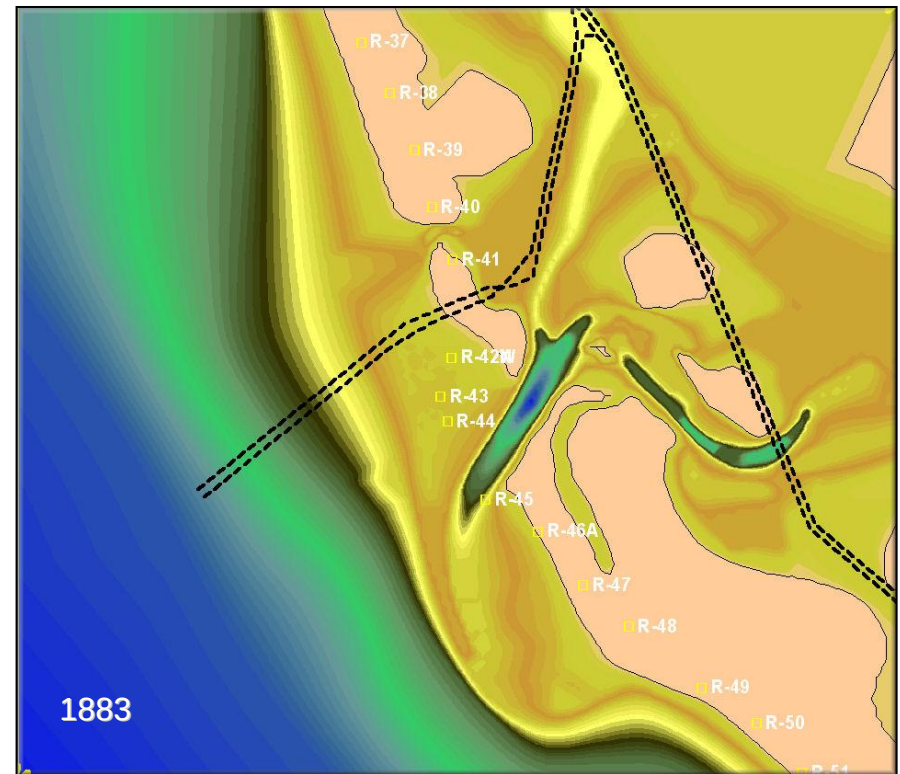
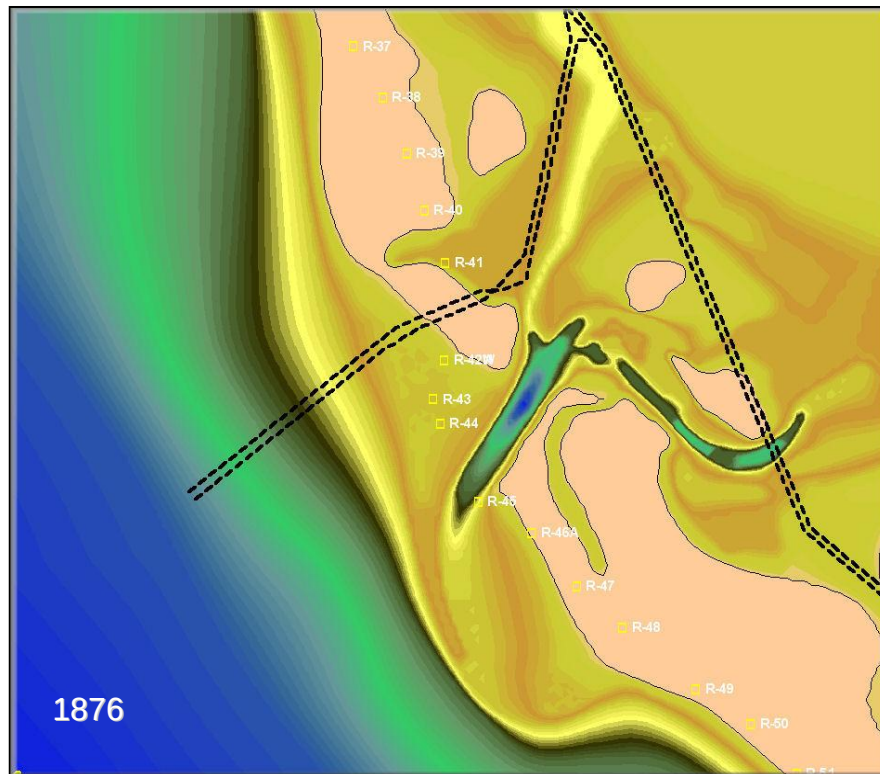
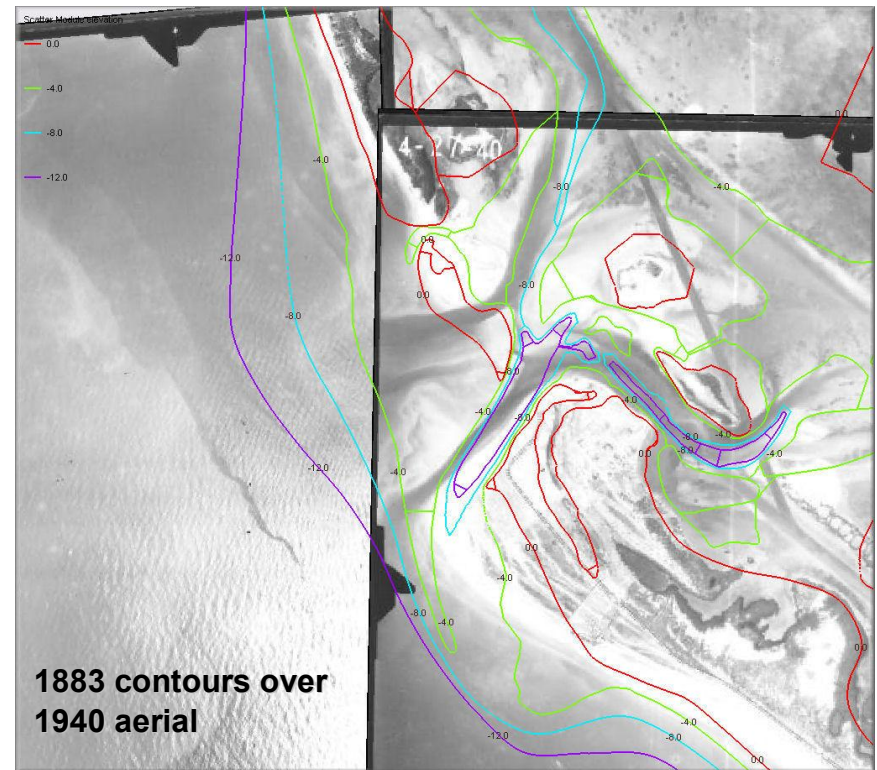
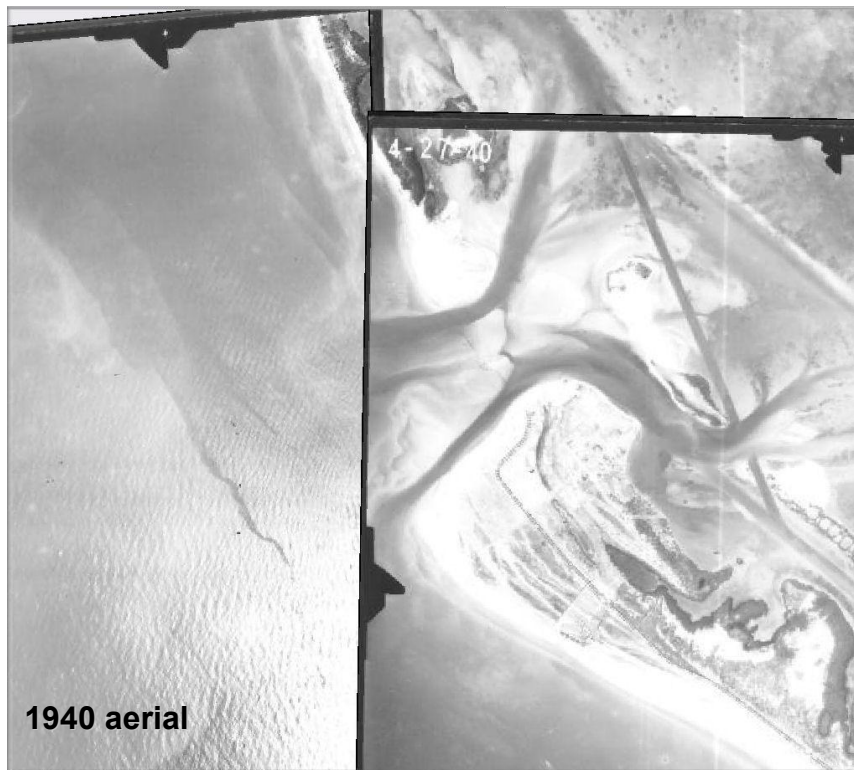


Figure 3.2. Longboat Pass Morphology 1876 and 1883





**Figure 3.3. Longboat Pass Morphology Change 1883 to 1940**

multiple sand ridge formations indicating the large advance of the shoreline along the north end of Longboat Key and the erosion and shoreline retreat along the south end of Anna Maria Island. The aerials also indicate early signs of development started in the area around the same time.

**Figure 3.4** shows the growth of the flood shoal from the 1880's to the 1950's, the deepening of the inlet channels due to tidal currents, and dredging of the ICW across the flood shoal area. The 1880's surveys and 1940's aerial photos suggest that emergent portions of the flood shoal were connected using dredging disposal from the establishment of the ICW, creating a larger island known as Jewfish Key. Since the ICW cuts across the inner part of the flood shoal, the channel would have been subject to frequent shoaling. However, Jewfish Key provided sand holding capacity to the west reducing potential for shoaling of the ICW.

**Figure 3.5** shows selected aerial photos of the conditions in the vicinity of Longboat Pass from 1940 to 1969. **Appendix 3A** includes available aerial photos for Longboat Pass. Closure of the old inlet in the early 1950's and the onshore migration of the ebb shoal resulted in the formation and growth of a sand spit at the north end of Longboat key. The sand spit became known as Beer Can Island. The seaward advance of the shoreline at south side of the inlet coupled with the shoreline retreat on the north side created a shoreline offset between the two sides of the inlet. **Figure 3.6** shows the 1952 aerial and 1955 survey data. The figure shows the water depths using a color scale that identifies shallow water and shoal areas of 0 to 2 meters depth by the yellow shades, the offshore zone from depths of 2 to 7 meters by the green shades, and the deep water out to and beyond the depth of closure by the blue shades.

**Figure 3.7** shows results of the wave and current modeling at Longboat Pass for 1955. The wave input used in the case shown represents storm conditions of 5-foot waves from the northwest generating southward transport. The figure shows the flow patterns at maximum ebb and flood current velocities, and the tidal flow interaction with wave driven currents. The figure shows that during flood tide the shoal provided a pathway for littoral transport to bypass the inlet, and it sheltered the shoreline from direct wave action. The shoal therefore provided a level of natural shoreline erosion control and reduced sediment transport into the inlet during flood tide. During ebb flow, in the 1950's, the symmetric ebb shoal provided channel banks on both sides which extended the ebb jet seaward. The presence of the sand spit of Beer Can Island forced the ebb channel to point slightly to the north of the normal orientation. The ebb currents created a symmetric ebb shoal by allowing sediment carried by the ebb jet to be deposited on both the north side as well as south side of the inlet. Although strong directional storm wave activity could skew the shoal in one direction or another, tidal flow would tend to restore the symmetry. The figure also indicates the location of reversal of sediment transport along the north part of Longboat Key. This reversal results in the current circulation that provides sediment to the Beer Can Island shoal and sand spit.

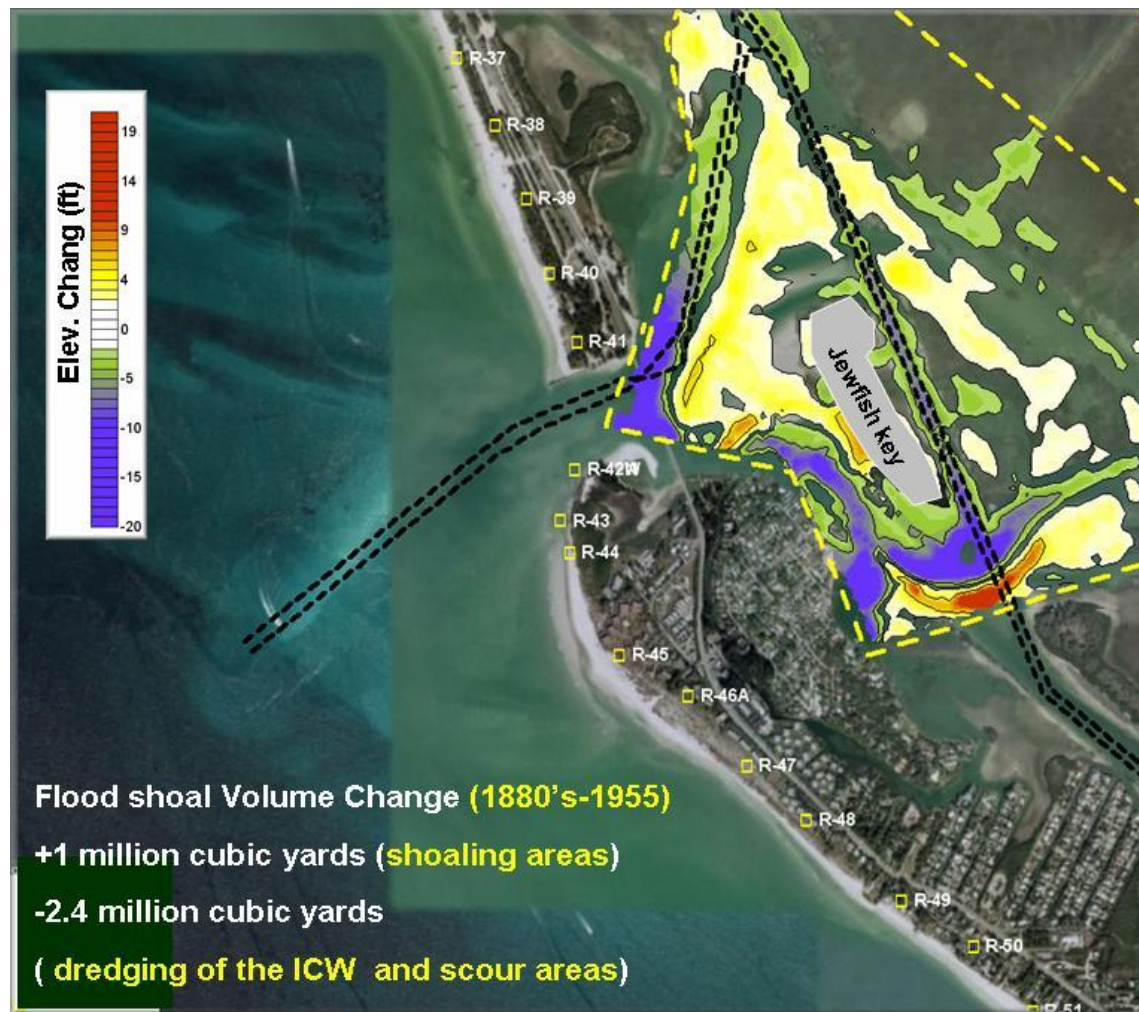
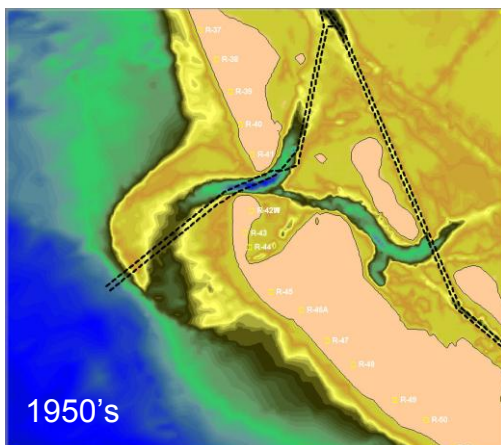
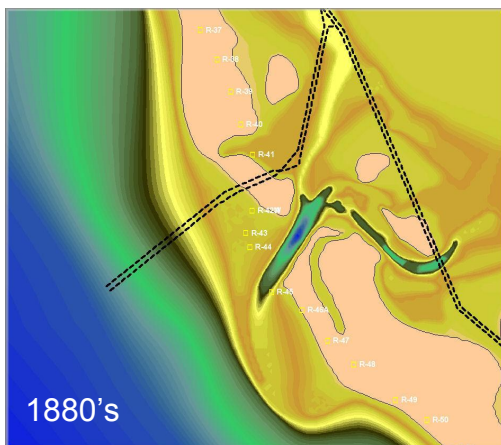
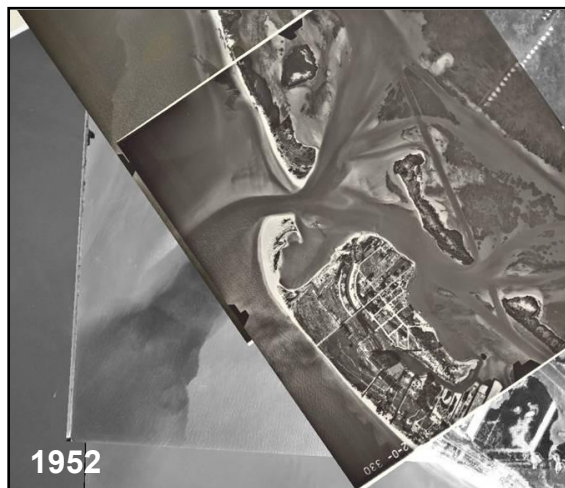


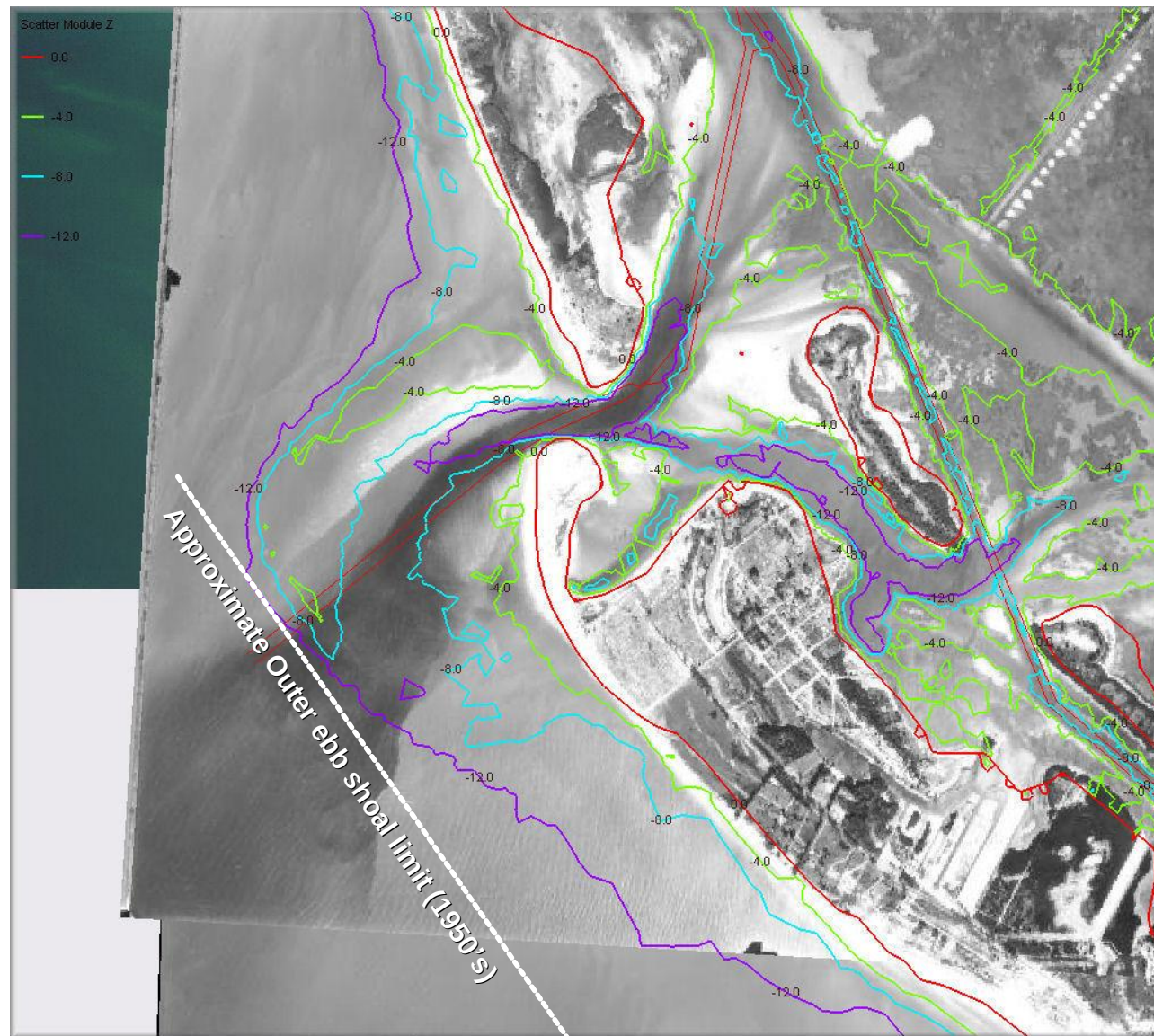
Figure 3.4. Longboat Pass Flood Shoal 1880 to 1950's Volume Change



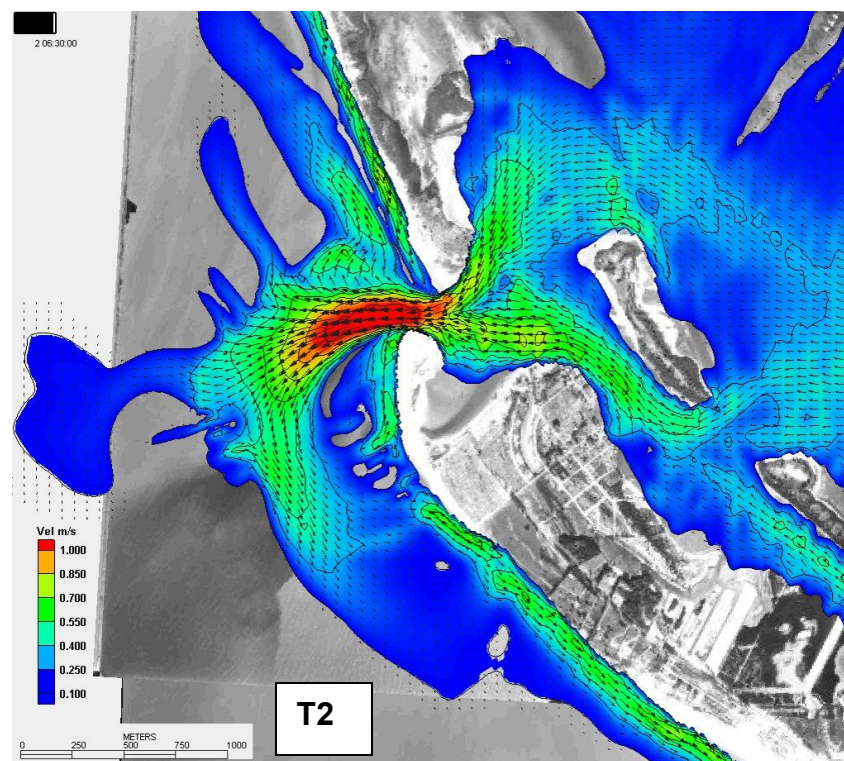
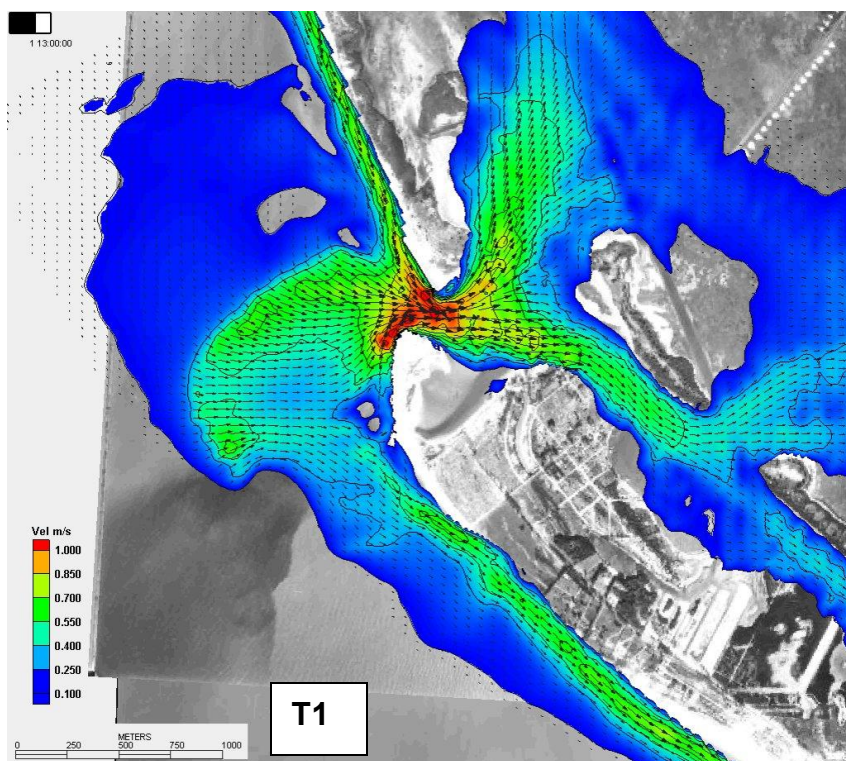
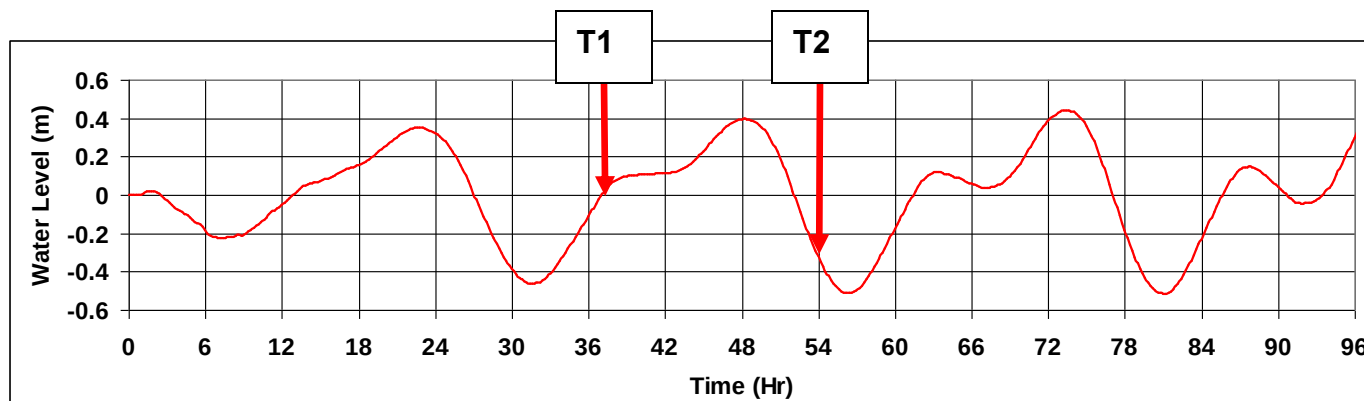
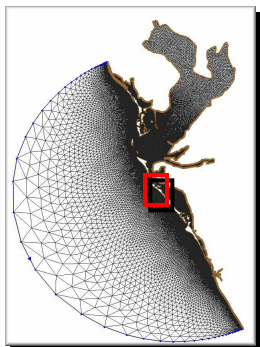


**Figure 3.5. Longboat Pass 1940 to 1969 Aerials**





**Figure 3.6. Longboat Pass 1950's Contours over 1952 Aerial**



**Figure 3.7. Wave/Current Interaction – Ebb and Flood Stages 1955**



### 3.2.2 1950's to 1990's

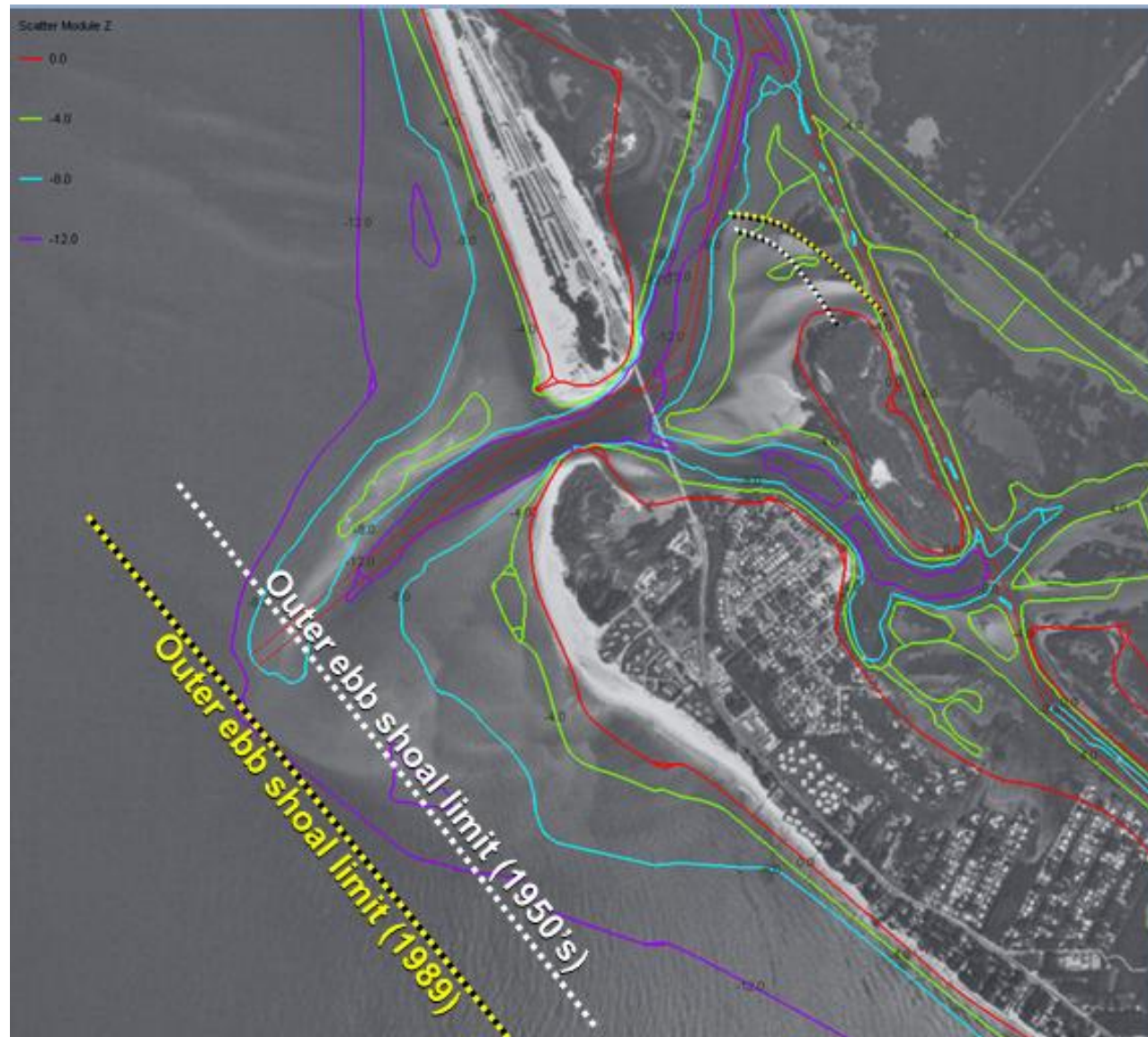
Major development in the region during the late 1950's included construction of the jetty at the north side of the inlet to support the landing for the bridge across the inlet in 1957. The long jetty interrupted sediment flow to the inlet and could have reduced bypassing to the downdrift side. This resulted in increased erosion along the downdrift shoreline on Longboat Key and may have caused the breaching of the Beer Can Island sand spit as shown on the 1962 aerial in **Figure 3.5**. Bypassing appears to have been reestablished a few years later as the jetty impoundment approached capacity and the spit reattached to Longboat Key as shown in the 1969 aerial. The jetty impoundment over the years helped advance the shoreline on the north side of the inlet and pushed the ebb jet further offshore. As discussed in the regional modeling section, the dredging of the navigation channels and jetty construction improved the hydraulic efficiency of Longboat Pass which increased the tidal prism through the inlet. As a result, the ebb shoal grew in volume and extended further offshore. The growth of the ebb shoal can be observed in the aerial photos and the survey data of the 1980's and 1990's. **Figure 3.8** shows an overlay of 1989 contours on the 1980 aerial, with the outer limit of the 1989 ebb shoal further offshore than it was in the 1950's. The figure shows the 1989 contours defining the ebb shoal superimposed on the 1980 aerial to illustrate the growth of the shoal.

### 3.2.3 Federal Channel Dredging Records

Longboat Pass was dredged for navigation in 1951 and 1959 but wasn't maintained on a regular basis until after the Corps of Engineers Detailed Project Report on Longboat Pass was completed in 1975. That report describes the pass as a dynamic natural inlet with a history of migration and transformation. The Corps of Engineers Detailed Project Report led to the authorization of the Longboat Pass navigation channel as a federal project in 1977. Including the initial dredging of that project in 1977, the inlet has been dredged five times as a federal project (CEC 1989, Taylor 2002).

### 3.2.4 1993 Mining of the Ebb Shoal

In addition to maintenance dredging of the navigation channel, the seaward portion of the Longboat Pass ebb shoal was dredged in 1993 to mine approximately 2,000,000 cubic yards of sand for beach restoration on Longboat Key. Surveys show that an additional sand volume of approximately 300,000 cubic



**Figure 3.8. Longboat Pass 1989 Contours over 1980 Aerial**



yards was also dredged from the more landward portion of the shoal along the north side of the navigation channel, although no other documentation of this dredging was available. A history of the inlet dredging is provided in Table 3.1.

**Table 3.1.** Longboat Pass Dredging History

| Date | Description                      | Quantity, cu yd | Disposal                 |
|------|----------------------------------|-----------------|--------------------------|
| 1951 | Navigation Maintenance           | Not Known       | Not Known                |
| 1957 | Jetty Constructed on Anna Maria  |                 |                          |
| 1959 | Navigation Maintenance           | Not Known       | Not Known                |
| 1975 | Corps Detailed Navigation Report |                 |                          |
| 1977 | Initial Federal Dredging         | 300,000         | Anna Maria and Longboat  |
| 1981 | Navigation Maintenance           | 165,000         | Anna Maria and Longboat  |
| 1985 | Navigation Maintenance           | 150,000         | Anna Maria               |
| 1991 | Navigation Maintenance           | 200,000         | Anna Maria and Longboat  |
| 1993 | Ebb Shoal dredging               | 2,000,000       | Longboat Key Nourishment |
| 1993 | Other Dredging                   | 300,000         | Not Known                |
| 1997 | Navigation Maintenance           | 150,000         | Anna Maria and Longboat  |

From its authorization until the early 1990's, the federal channel was located substantially along the natural channel alignment. The maintenance dredging was primarily limited to the entrance of the channel to maintain the authorized 12-foot channel depth. From the available information it does not appear as if the maintenance dredging up to this point had any significant detrimental effects on the shoal system.

The dredging which took place in 1993 significantly altered the geometry and volume of sand in the ebb shoal. **Figures 3.9** and **3.11** show the borrow area that was dredged in 1993 to obtain approximately 2 million cubic yards of sand for the nourishment of the beach along the northern half of Longboat Key. (Sand for the southern part of the Longboat Key nourishment project was obtained from the ebb shoal at New Pass).

At approximately the same time as the dredging of the borrow area at Longboat Pass, an area roughly parallel to the beach and close to shore on Anna Maria Island was dredged to obtain 2.3 million cubic yards of sand for the Anna Maria nourishment project, as illustrated in **Figure 3.10**. Surveys of the inlet from this period show that an additional amount of sand, estimated to be approximately 300,000 cubic yards, was dredged from the landward portion of the Longboat Pass ebb shoal as illustrated in **Figure 3.9**. This is also evident in **Figure 3.10**. This additional dredging was probably to obtain more sand for the Anna Maria Island nourishment, the Longboat Key nourishment, or possibly an emergency storm impact recovery project; however, no substantiating records have been found.

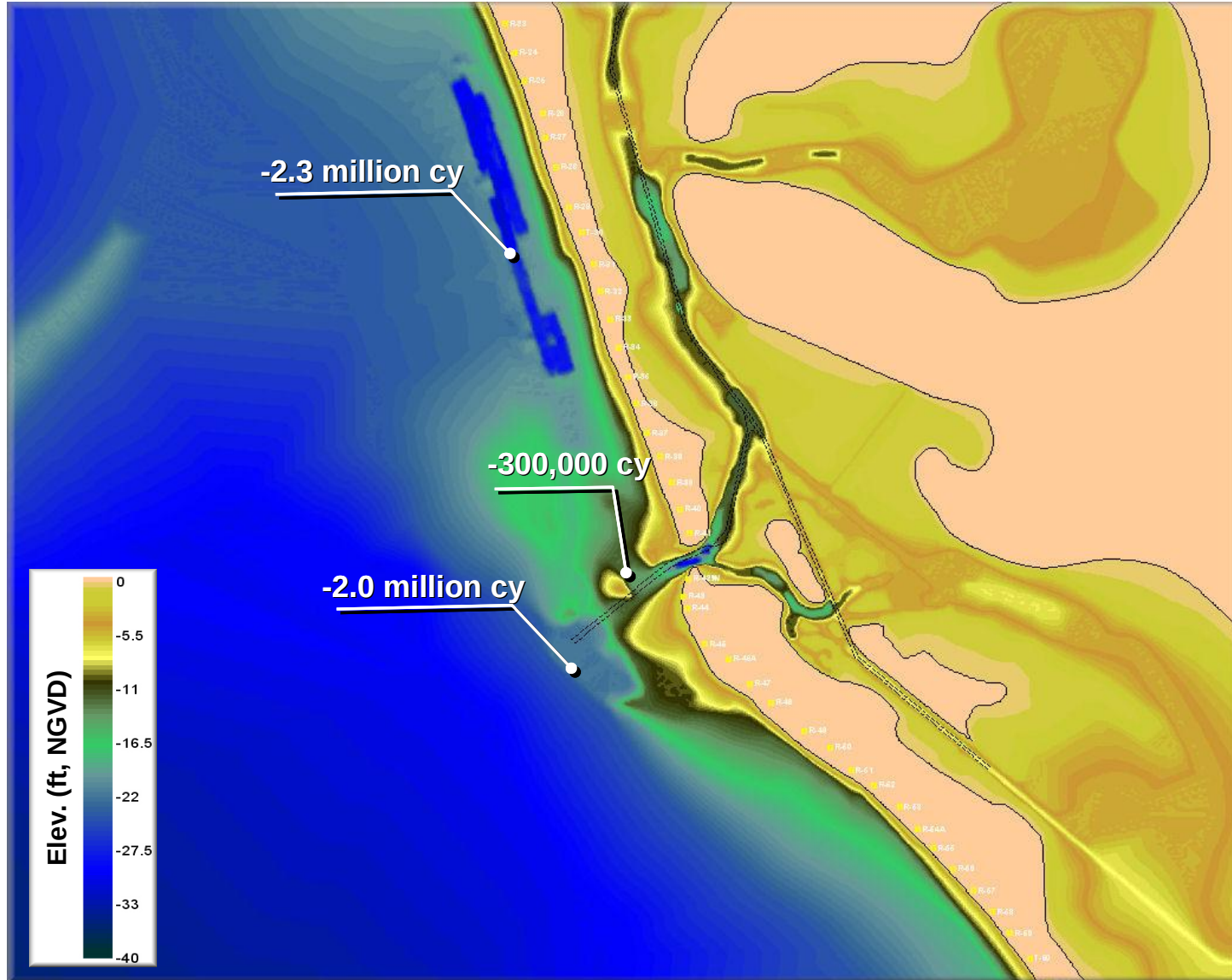
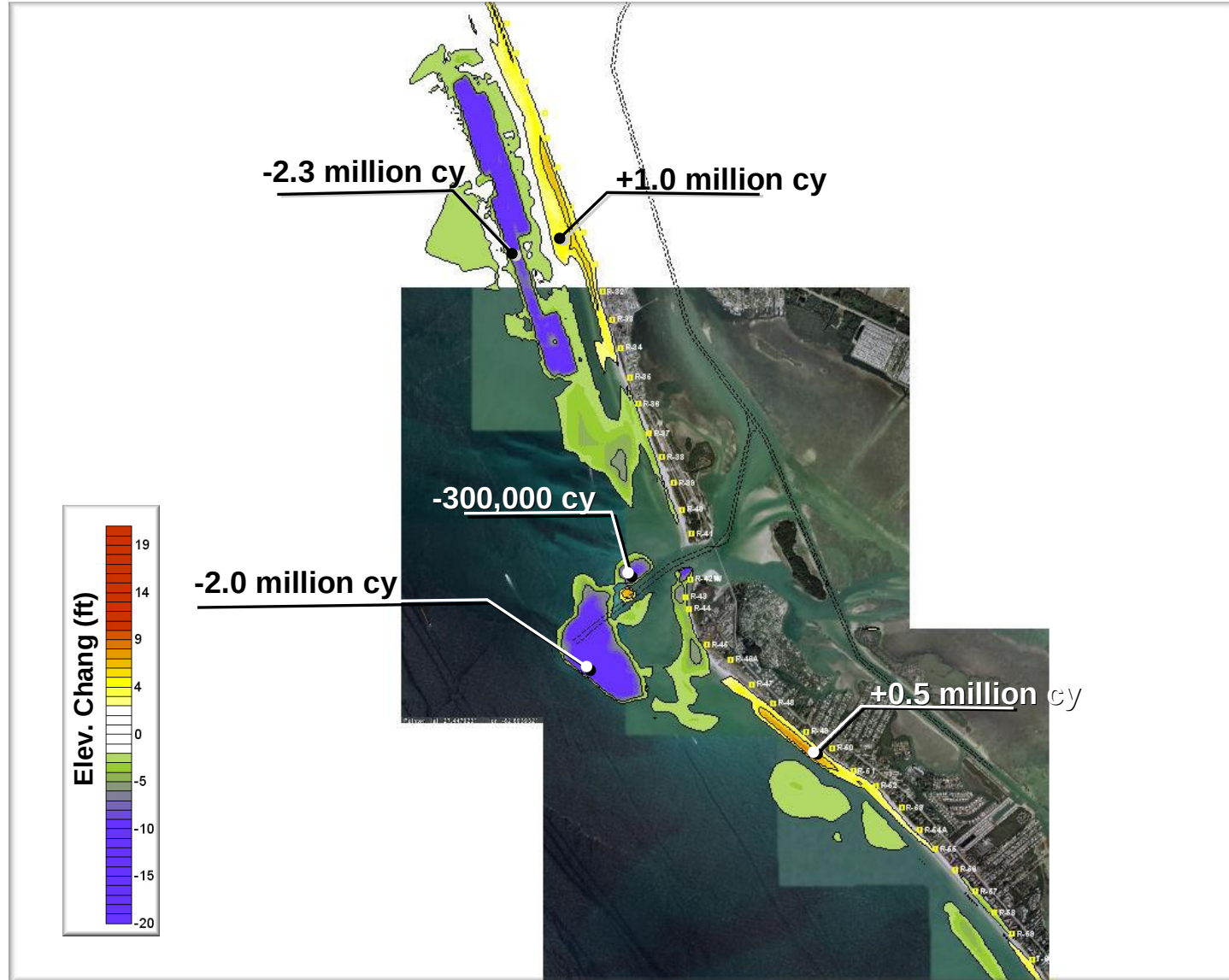
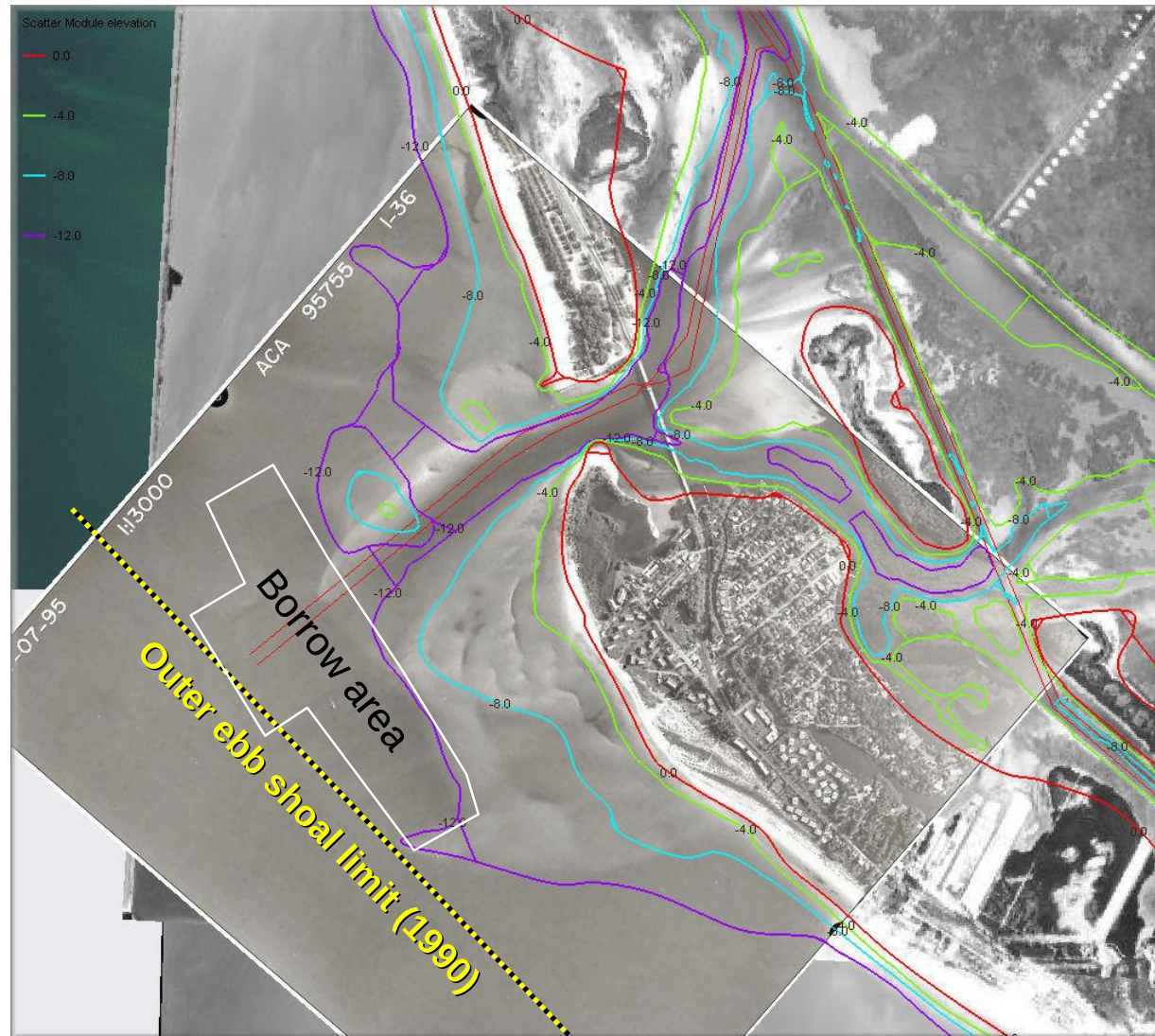


Figure 3.9. Longboat Pass 1993 Morphology and Dredging Locations







**Figure 3.11. Longboat Pass 1993's Contours over 1995 Aerial with Borrow Area Location**



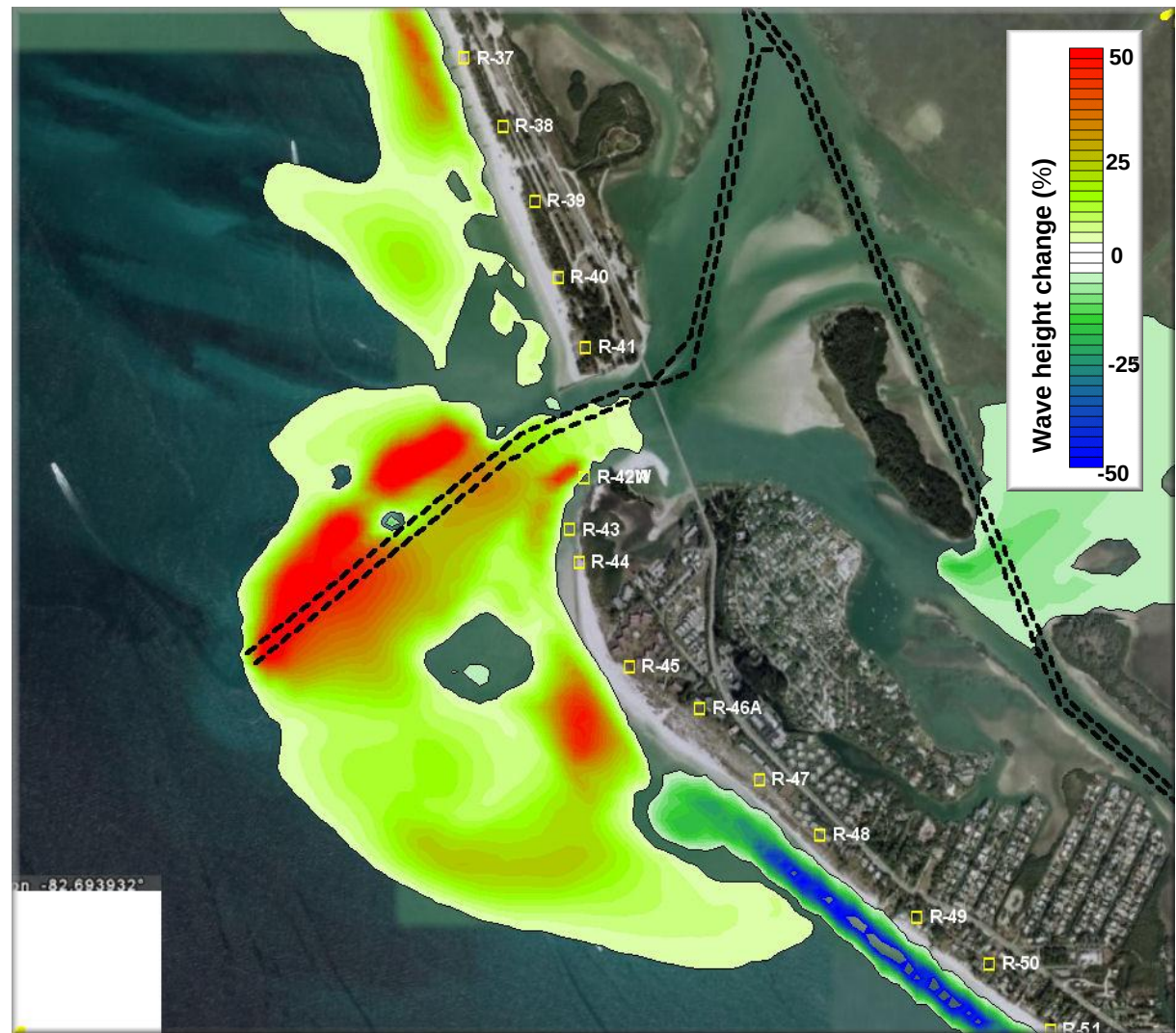
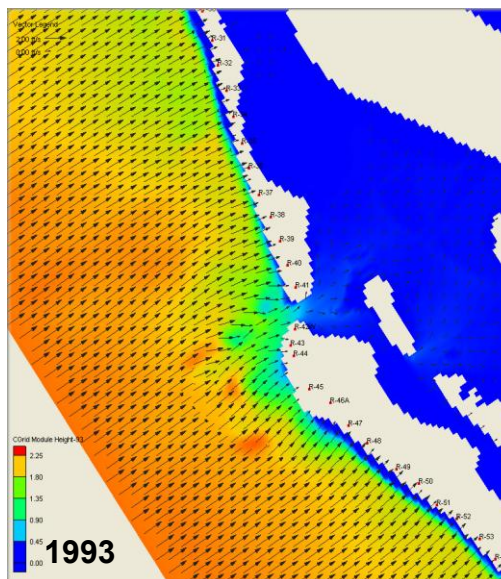
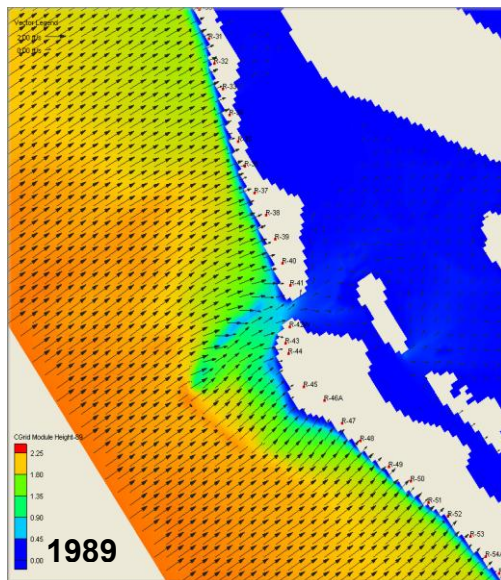
### 3.2.5 Post 1993 Dredging to Present Conditions

Wave and sediment transport modeling of pre and post 1993 dredging were simulated to evaluate the changes due to the dredging. **Figure 3.12** shows a representative wave refraction example for a 5ft offshore southwest wave event for pre and post construction conditions. The figure shows increased wave intensity at the location of the borrow area and along the shoreline of Beer Can Island. The figure also shows an increase in wave intensity south of the 1993 Anna Maria Island nearshore borrow area. The increase of wave intensity related to the borrow area results in higher sediment transport gradients, chronic erosion problem for that beach area, and an increased sediment input to Longboat Pass. The mining of the Longboat Pass ebb shoal exposed Beer Can Island to higher wave energy and increased erosion rates.

**Figure 3.13** shows a comparison of the wave heights from the wave refraction results for pre dredging and 2007 post dredging conditions. Although the post dredging conditions represent 14 years after the dredging event, recovery to pre-dredging conditions doesn't seem to have occurred with respect to wave intensity along Beer Can Island. To the contrary, the wave intensity along Beer Can Island and the wave height have increased. It therefore appears as if the erosion which resulted from the dredging is still ongoing.

Sediment transport along the shoreline and nearshore were computed for pre and immediately post dredging conditions to quantify the effect of the dredging on wave driven sediment transport. Wave driven sediment transport potentials were computed from modeled breaking conditions for each representative wave condition. Sediment transport potentials were calculated based on the Kamphuis (1991) formula and probability of occurrence of each case. Results of all cases were grouped to calculate annual longshore sediment transport potentials as well as gross and net transport rates along the shorelines of Anna Maria Island and Longboat Key. Sediment transport computations for the pre and post 1993 dredging conditions were performed by calculating the sediment transport potentials across two elevation ranges. The first range runs from the shoreline to a depth of 1.5 m, and the second from 1.5 m depth to the depth of closure (4.5m). The sediment transport computation was done over two depth ranges to provide more detail of the sediment transport patterns near the inlet where the contours are irregular and not parallel to the shoreline. This procedure results in a more accurate estimate of the sediment transport circulation at the ebb shoals.

**Figure 3.14** shows the computed sediment transport potential for pre and post dredging conditions. The scaled vectors in the figure indicate the magnitude and direction of the sediment transport. The results show the impact the dredging has had on wave driven sediment transport. The results show the influence of the ebb shoal as waves move sand along the shoreline to the inlet where it is then moved to the outer limits of the ebb shoal by the tidal currents before wave action takes over south of the channel and moves the sand back to the beach. The pre dredging results showed that because of the presence of the outer ebb shoal, the



**Figure 3.12. Longboat Pass Typical SW Wave Elevation Change 1989 to 1993**



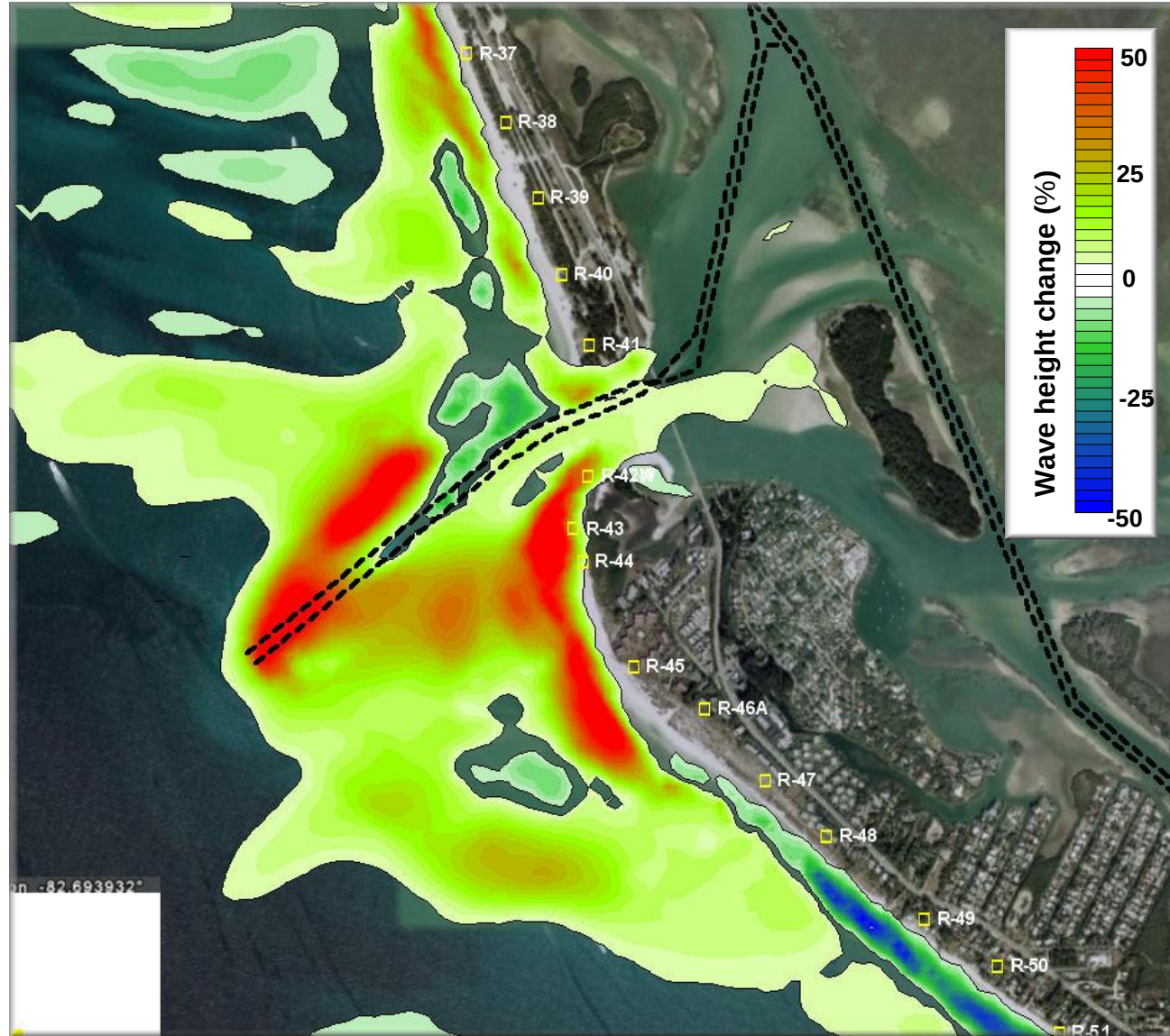
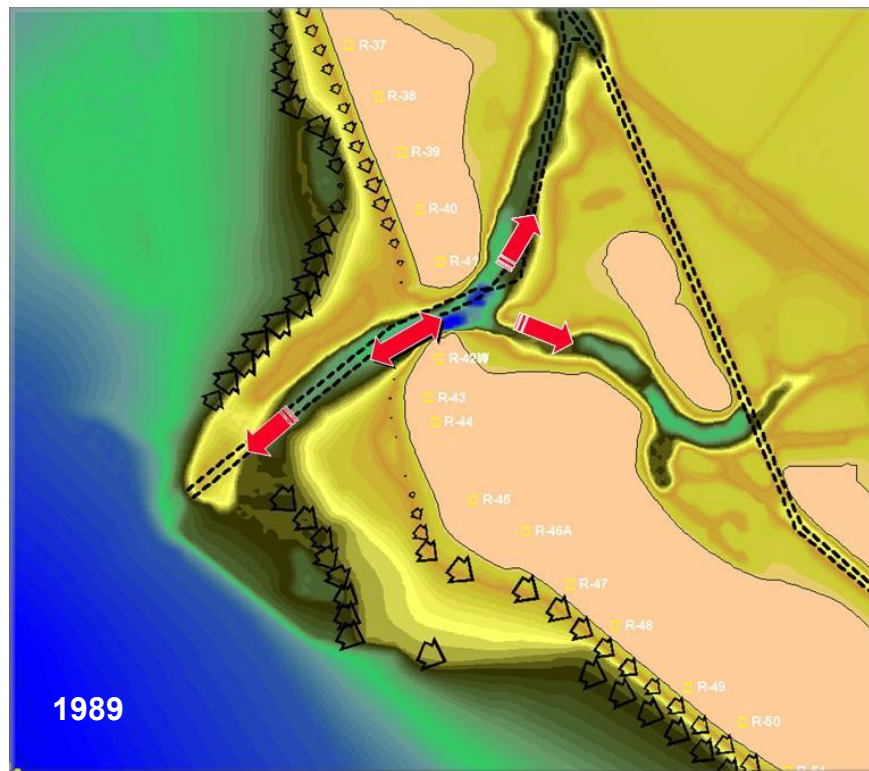
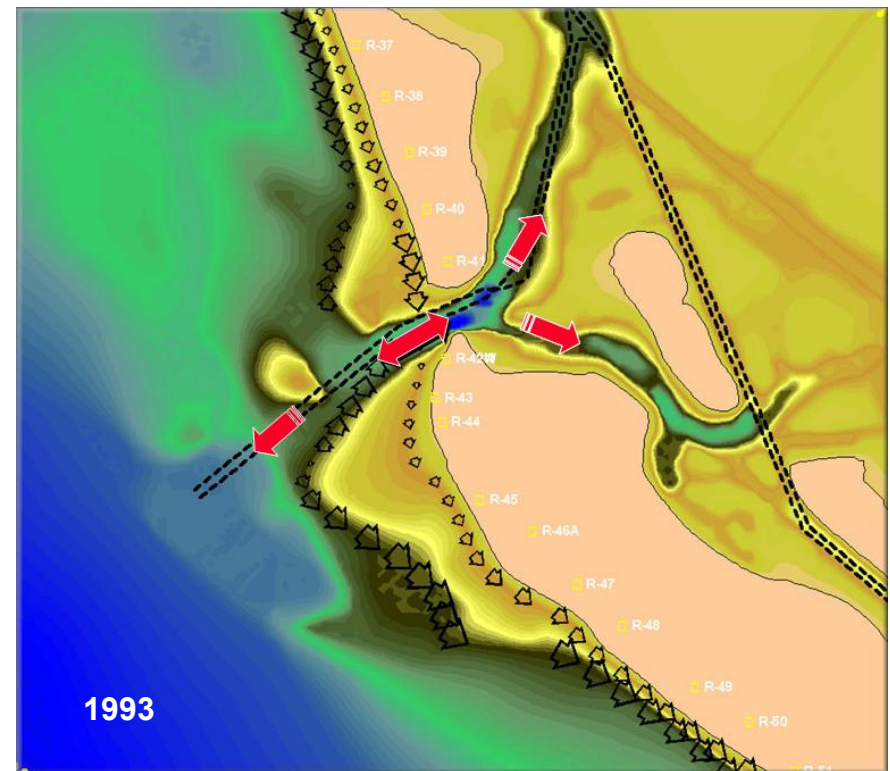


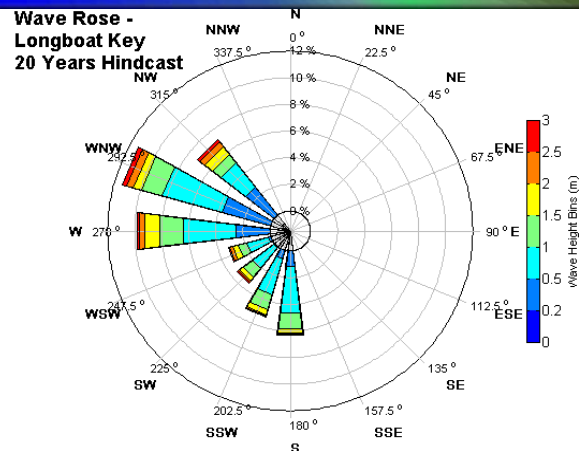
Figure 3.13. Longboat Pass Typical SW Wave Elevation Change 1993 to 2007



1989



1993



Note:

Wave rose generated from statistical analysis of 20 year hindcast WIS data.  
Wave statistics computed for 7 representative wave directions.  
Sediment transport computed from representative wave cases using STWave.

**Figure 3.14. Longboat Pass Sediment Transport Potential for 1989 and 1993**



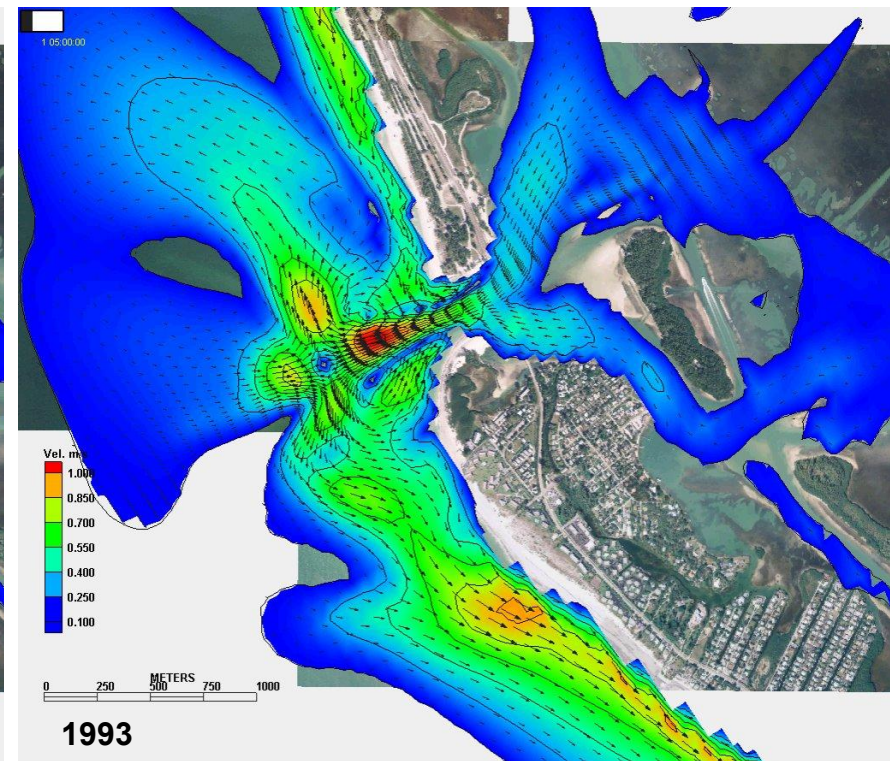
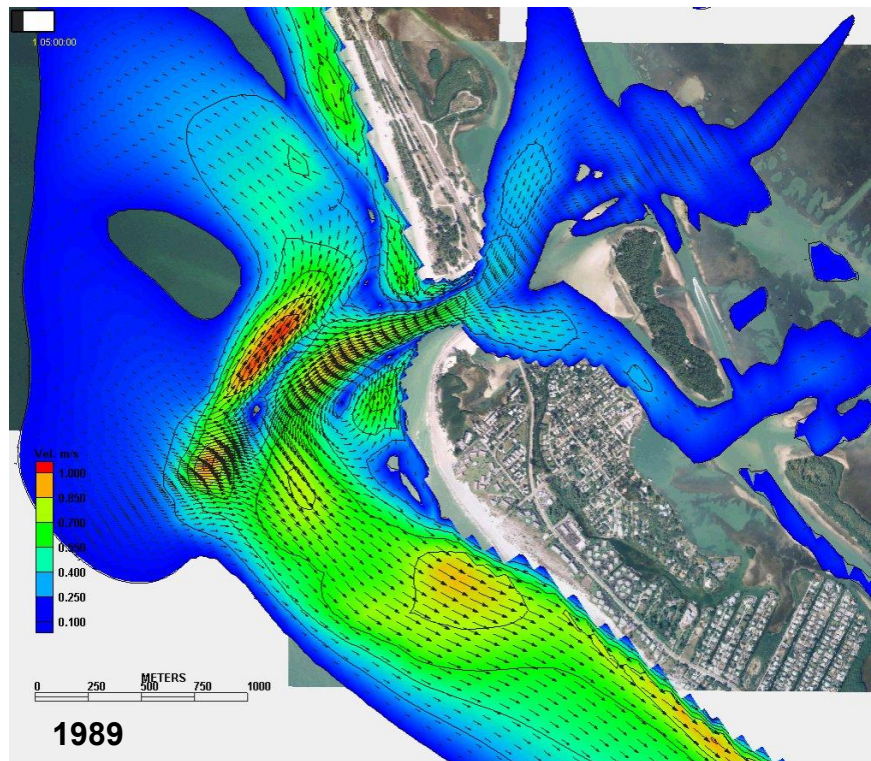
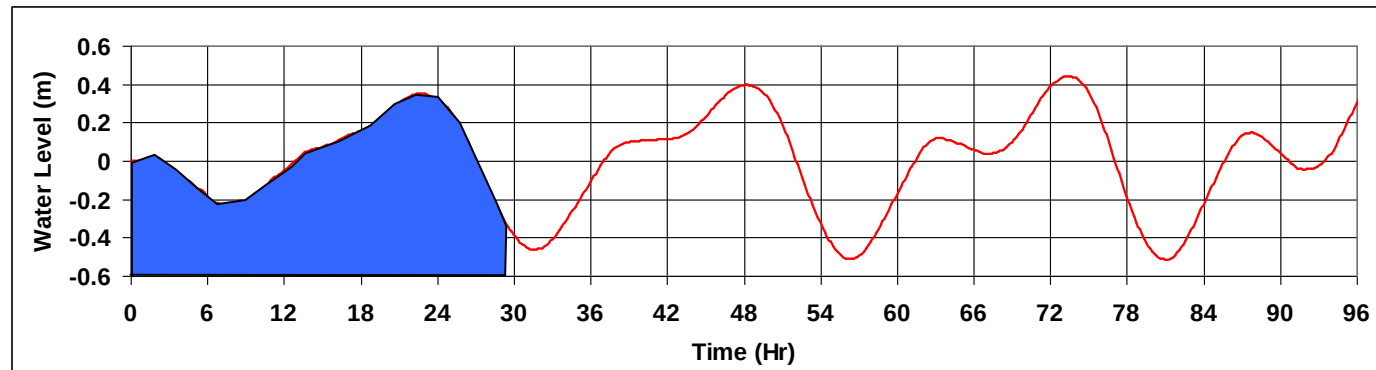
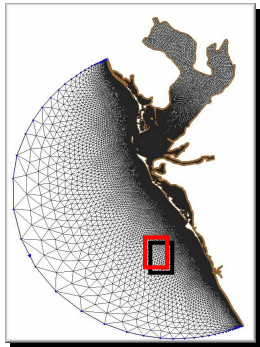
north part Longboat Key was sheltered from waves allowing the reversal to provide adequate sand supply to maintain the shoreline of Beer Can Island. The pre dredging condition also showed that the Beer Can Island shoal was also sheltered from wave action by the outer ebb shoal that was mined in 1993. However, the post dredging condition allowed wave energy to erode Beer Can Island, while the supply of sand through the inlet was interrupted by the deeper borrow area. This resulted in rapid erosion of these shoals. The erosion of material from the downdrift shoal forced the inlet to migrate southward as the predominant sediment input is from the north.

Wave and current interaction for the pre and post dredging conditions were simulated with the model to quantify the change in sediment exchange pattern between features. **Figures 3.15 and 3.16** show typical model results of the wave and current interaction for Longboat Pass, for 1989 and post 1993 dredging conditions. The wave input used in the selected case shown represented storm conditions of 5-foot waves from the northwest generating southward transport. The figures show the flow patterns at maximum ebb and flood tidal currents and the tidal flow interaction with wave driven currents. The figure indicates the effect of the dredging on changing the current circulation across the ebb shoal. Under the post dredging conditions, the seaward extent of the ebb jet current became much shorter due to the widening of the cross section area near the dredging location. The erosion of Beer Can Island shoreline threatened some existing buildings as shown in **Figure 3.17**.

**Figure 3.18** shows the 5-year post dredging inlet morphology change between 1993 and 1998. The figure shows the inlet adjustment to reestablish bypassing across a smaller ebb shoal. The figure shows that the seaward limit of the shoal system is similar to the post dredging conditions indicating limited recovery on the outer portion of the shoal. The figure indicates the channel migrated to the south as a result of the erosion of Beer Can Island shoal and shoreline. The figure also shows the formation of a smaller bypassing and attachment bar than was evident under the pre 1993 dredging conditions. After the formation of this bypassing bar, its attachment location occurred at the erosion hotspot, the location of which was mentioned above in Figure 3.17. The attachment provided temporary protection to the previously eroding hot spot; however as the system continued to adjust, the bypass bar migrated further south.

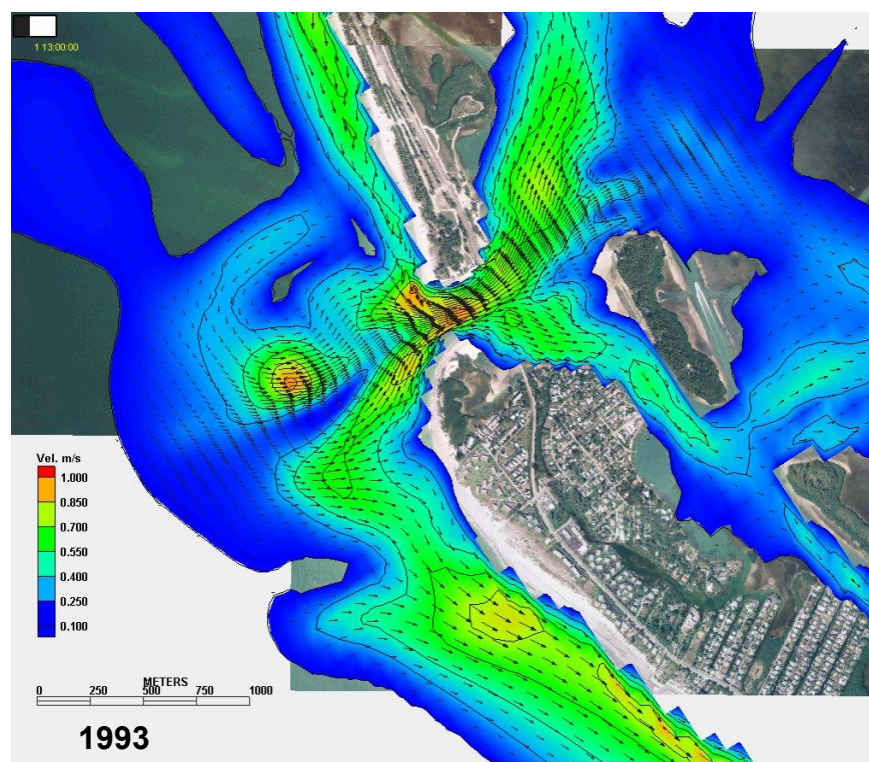
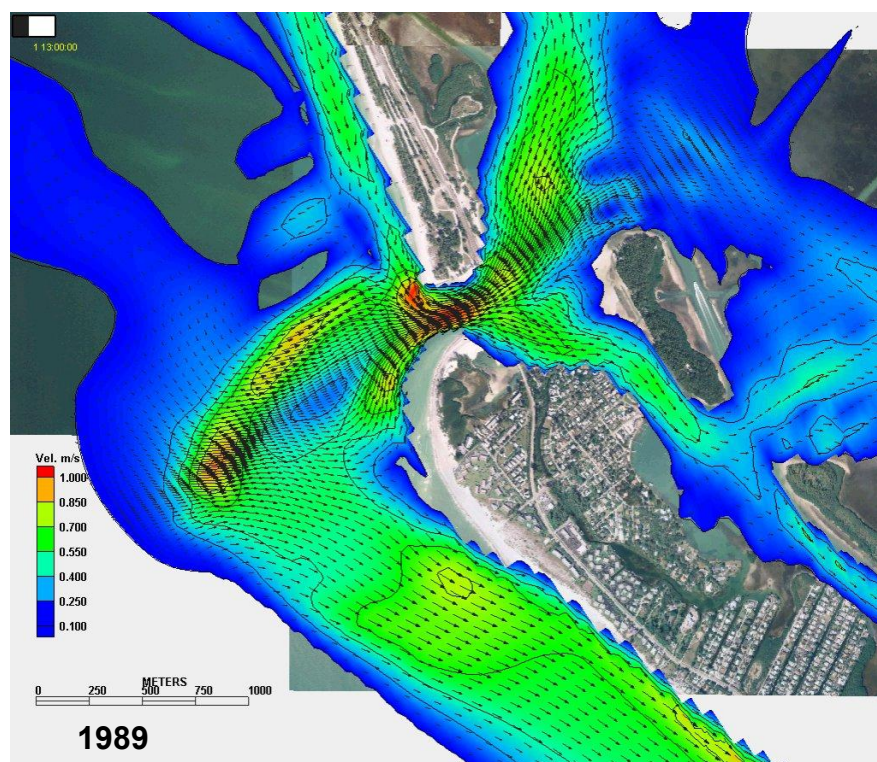
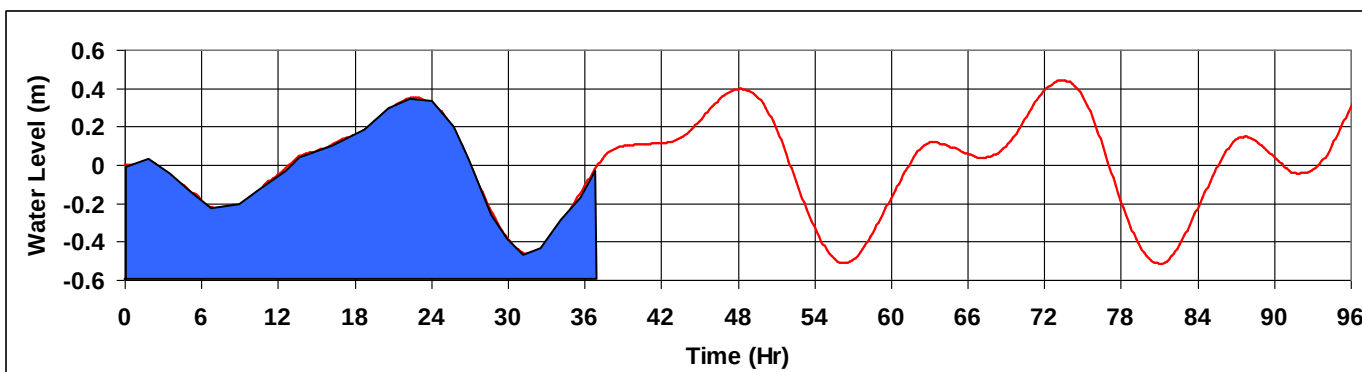
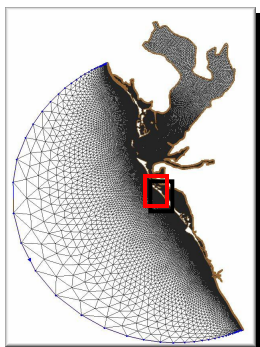
**Figure 3.19** shows the morphologic changes between 1998 and present conditions (2007) showing the infilling of the authorized federal channel as the channel migrated south in response to the downdrift shoal erosion. The migration of the bypass bar and attachment further south re-exposed the erosion hot spot discussed above.

**Figures 3.20 and 3.21** show model results of the wave and current interaction for Longboat Pass for 1998 and 2007 conditions. The figures show the change in circulation patterns as the ebb jet and morphologic features migrate further south and the erosion of Beer Can island. This resulted in the ebb shoal system moving landward and more material being transported into the flood shoal area.



**Figure 3.15. Wave/Current Interaction – Ebb Stage 1989 and 1993**





**Fig 3.16. Wave/Current Interaction – Typical Flood Stage 1989 and 1993**





**Figure 3.17. Longboat Pass Beer Can Island Hot Spot (1991, 1995, 1997, 2006)**



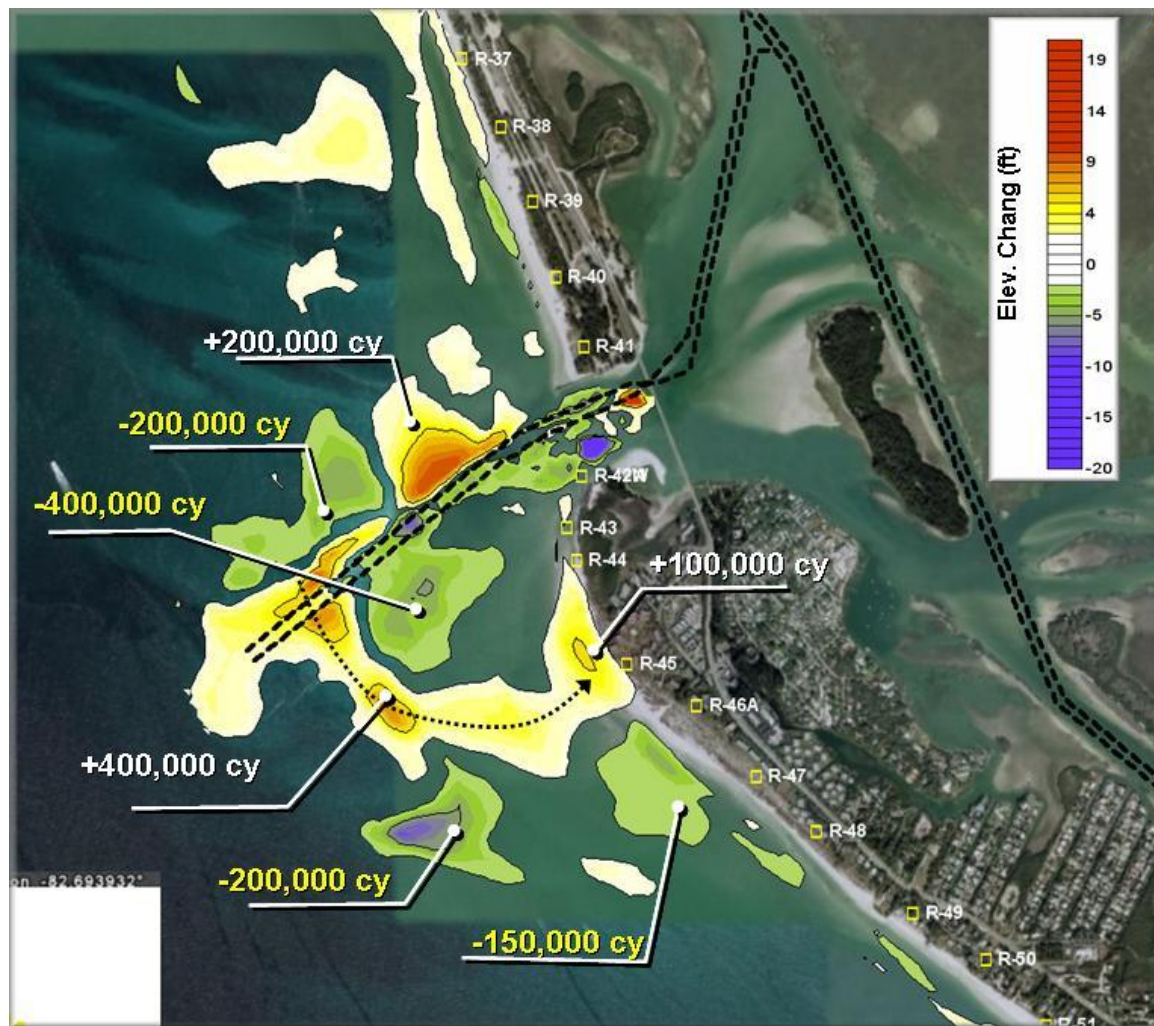
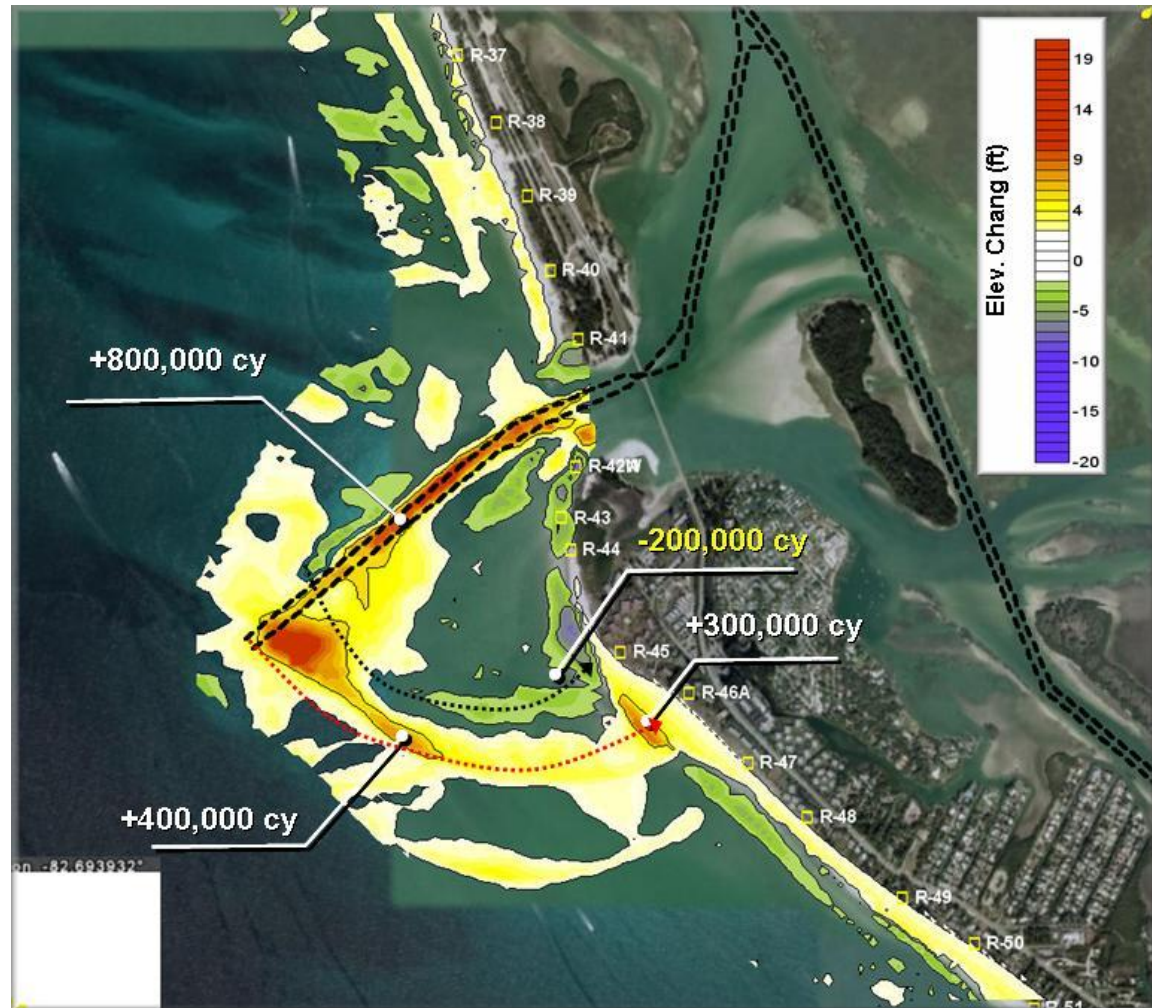
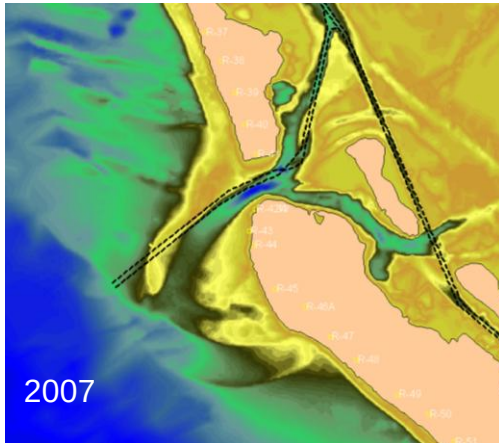
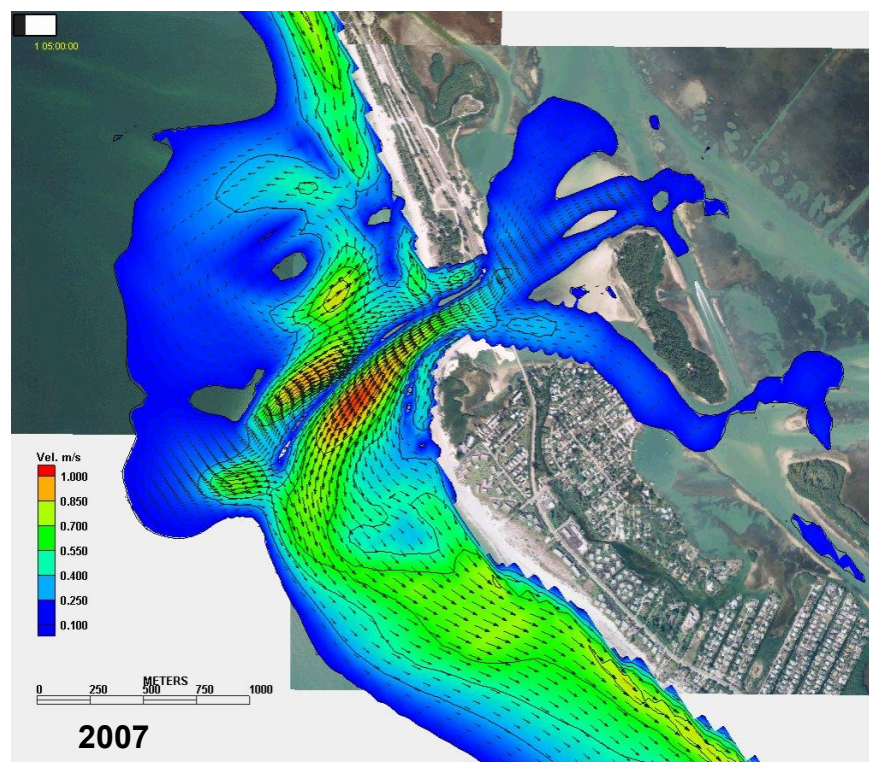
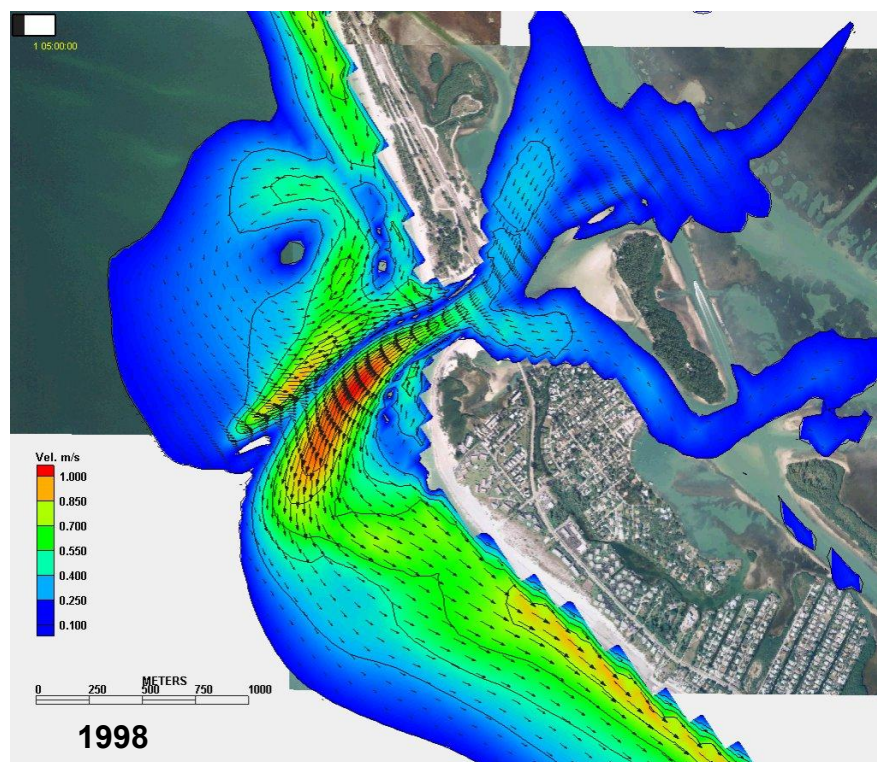
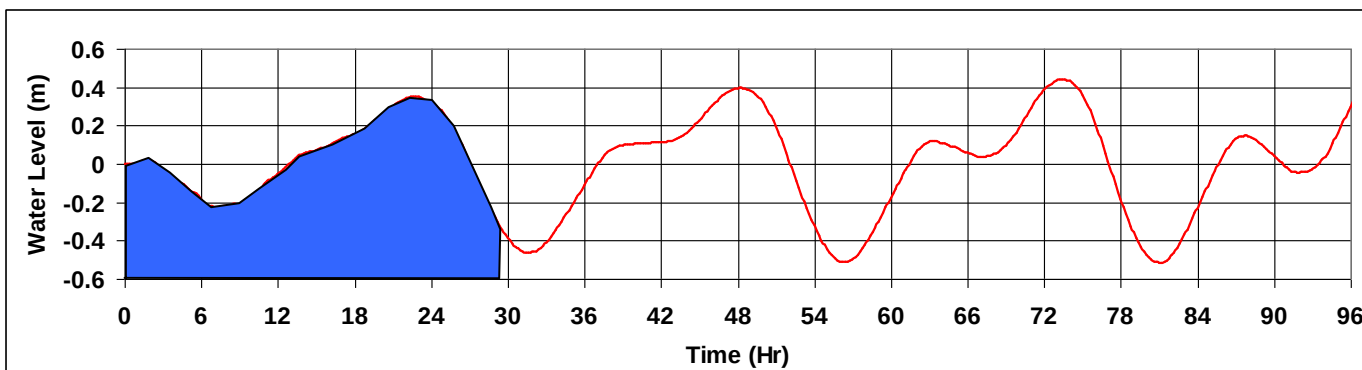
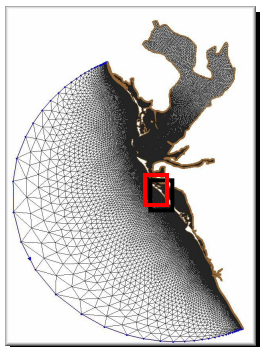


Figure 3.18. Longboat Pass Morphology Change 1993 to 1998



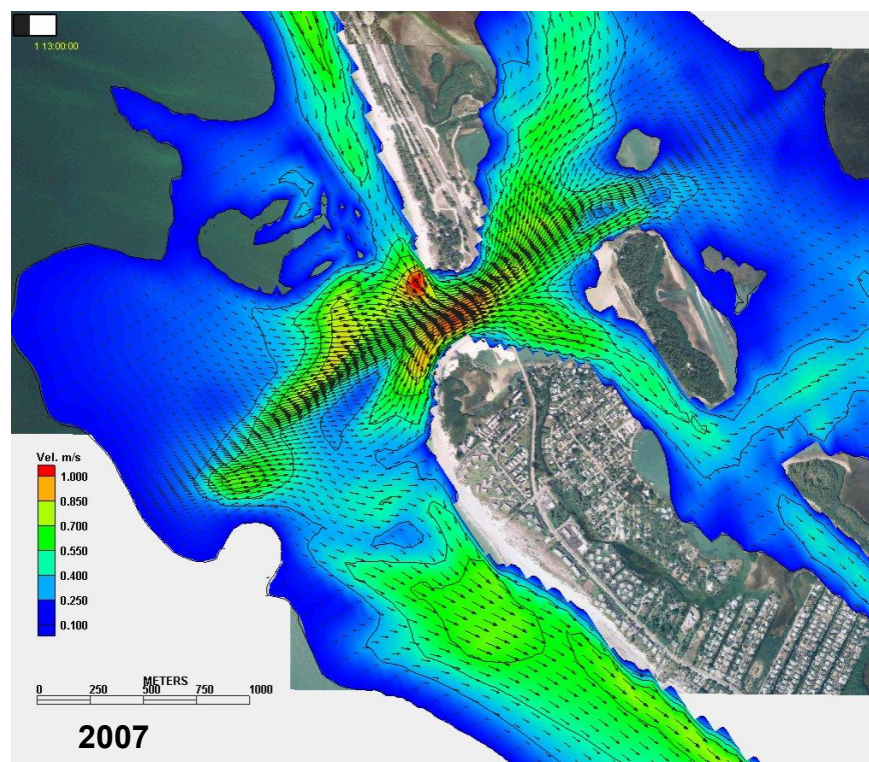
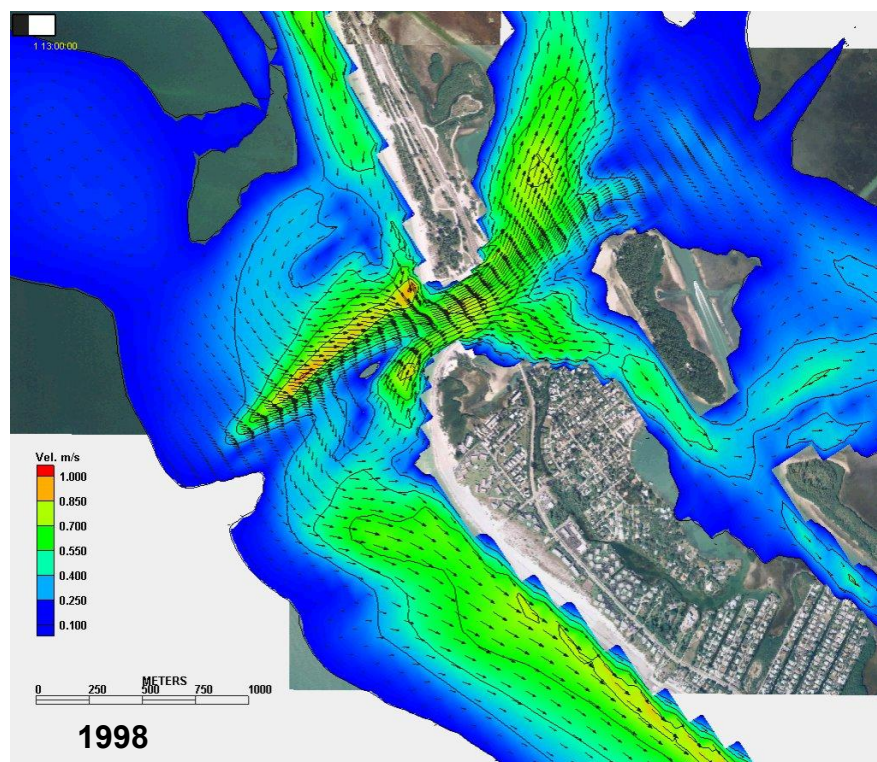
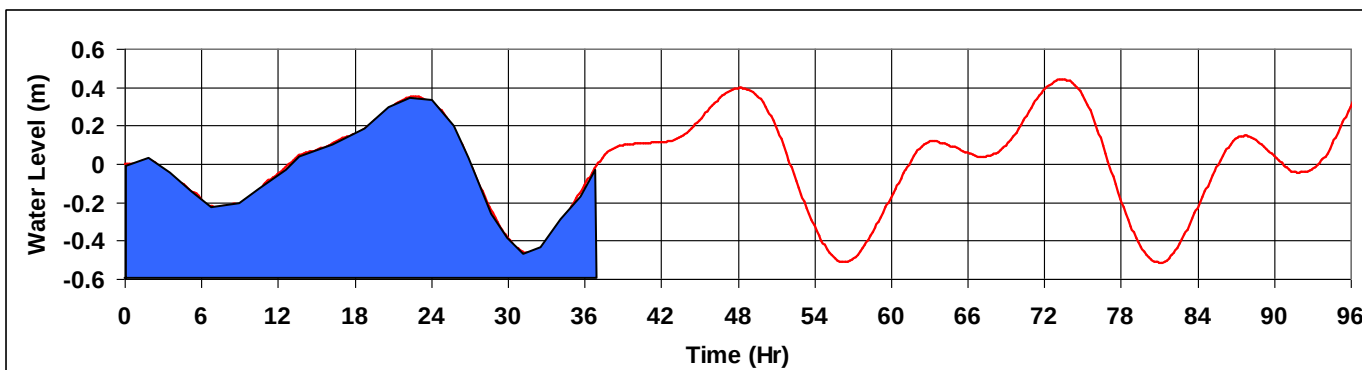
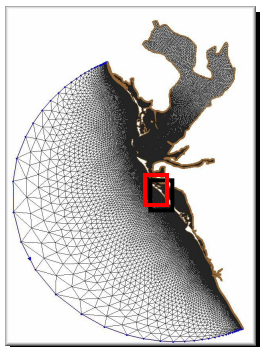
**Figure 3.19. Longboat Pass Morphology Change 1998-2007**





**Figure 3.20. Wave/Current Interaction – Ebb Stage 1 - 1998 and 2007**





**Figure 3.21. Wave/Current Interactions – Flood Stage 1 - 1998 and 2007**

### 3.3 Inlet Reservoir Model Analysis for Longboat Pass

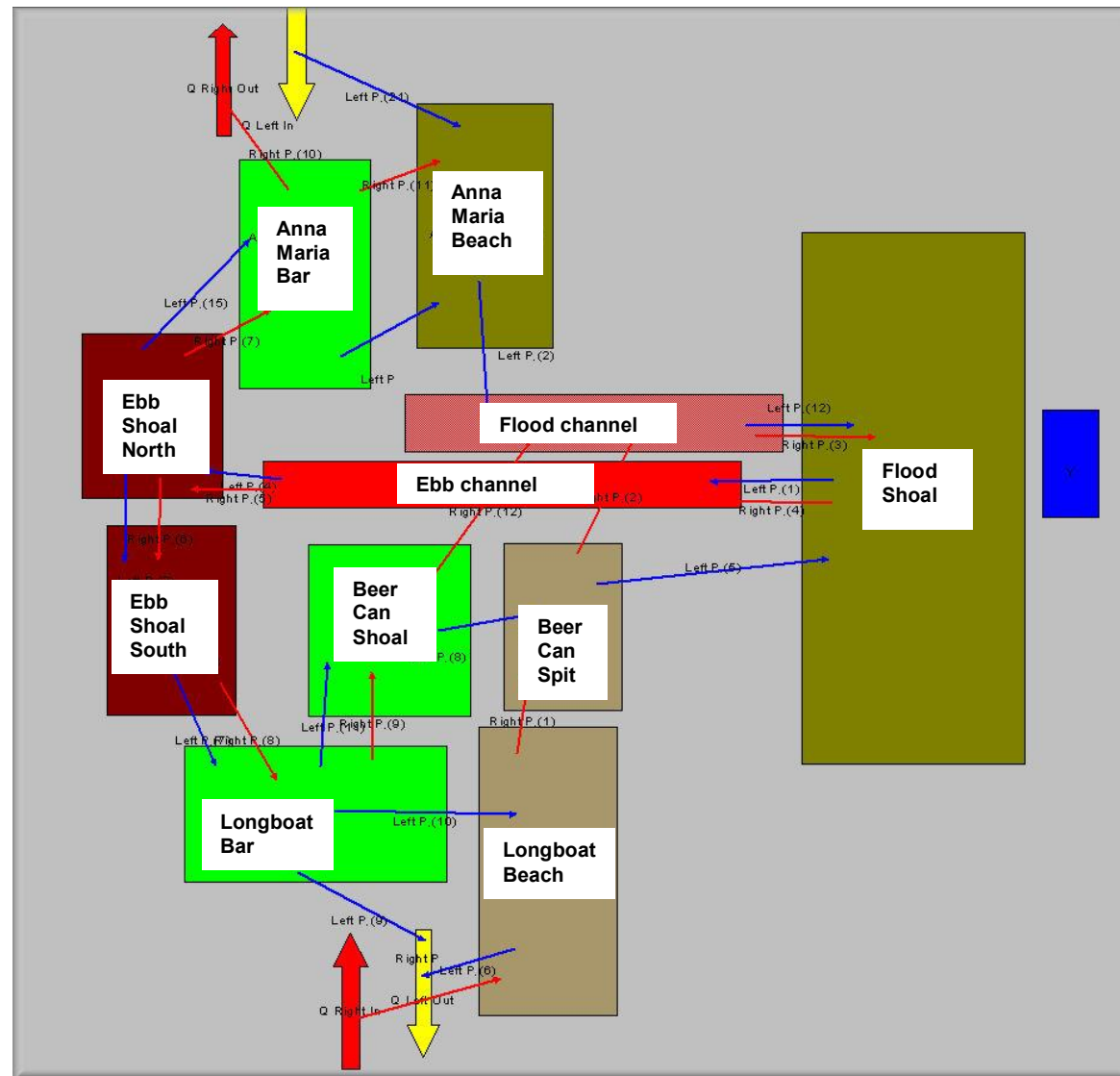
The Inlet Reservoir Model calculates sediment transport rates and volume change of identified morphologic features and bypassing rates for an inlet. It is applied in this case for the Longboat Pass tidal shoal complex. The first step is to identify sediment pathways across the ebb shoal and distinct morphologic features that form the shoal complex. In a typical wave-dominated inlet, there would be three distinct ocean-side features: an ebb shoal, bypassing bar, and an attachment bar. The concept of the Reservoir Model is based on the assumption that each feature has a maximum (equilibrium) sand-retention capacity that cannot be exceeded. Once a feature has reached capacity, all additional sediment transport to that feature will bypass to the next feature(s), and so forth until sediment arrives at the downdrift side of the inlet, or is deposited in another location such as the channel or flood shoal. If a morphologic feature is partially full, it still provides partial bypassing. The Inlet Reservoir Model calculates growth of the shoals as a function of the littoral drift and equilibrium volumes of the shoals, and it accounts for the naturally long timescales of large morphologic features and time delays in exchange of material among the features. Further information on the Inlet Reservoir Model can be found in Kraus (2000a, 2000b, 2002).

#### 3.3.1 Inlet Reservoir Model Setup

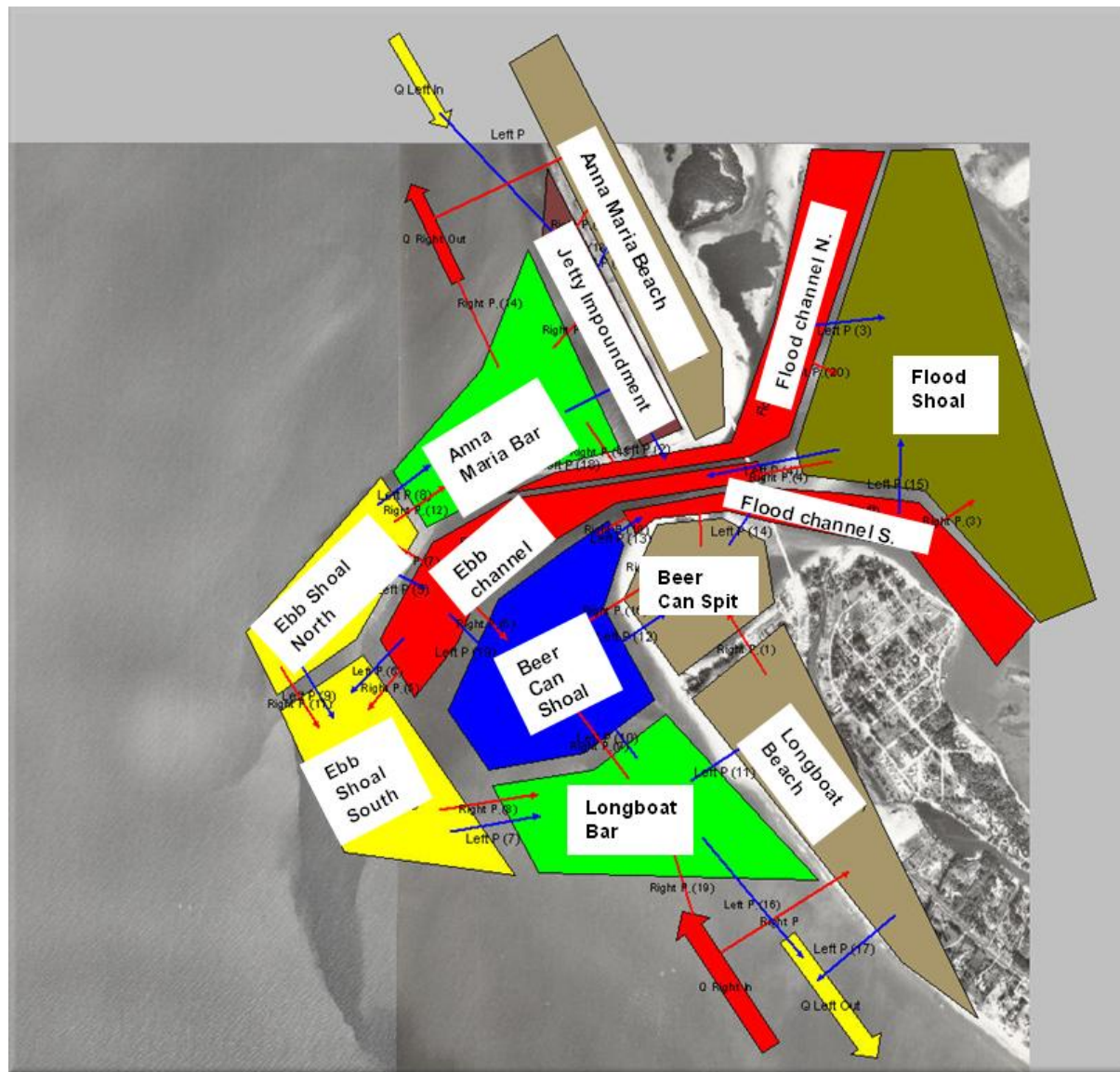
The Longboat Pass ebb-shoal system is more complex than that of a typical inlet. The complexity is the result of changes in tidal prism over time, and the resulting changes in the equilibrium volume for the ebb shoal. The Reservoir Model typically assumes a constant equilibrium volume. To overcome this limitation, the modeling was divided into three stages corresponding to different periods, each with a different constant tidal prism. The first stage, 1880-1957, is the period from the opening of the inlet until the construction of the north jetty, which increased the tidal prism by approximately 20% of the tidal prism before the jetty and ICW construction. The second stage, 1957-1993, is when the 1993 mining of the ebb shoal caused the shoal to migrate landward and its equilibrium size decreased due to erosion and southward migration of the inlet.

The wave, sediment transport, and tidal hydrodynamic modeling, in addition to the bathymetric data, were evaluated to define sediment pathways for each stage of Longboat Pass evolution. Based on the CMS modeling results and documented elevation change, the sediment pathways and morphological features are represented as illustrated in **Figures 3.22 to 3.24** for each of the three temporal stages. Sediment pathways for the both north and south transport direction were included in the model to account for all sediment inputs to the inlet system.





**Figure 3.22. Reservoir Model Setup 1880-1957**



**Figure 3.23. Reservoir Model Setup 1957-1992**

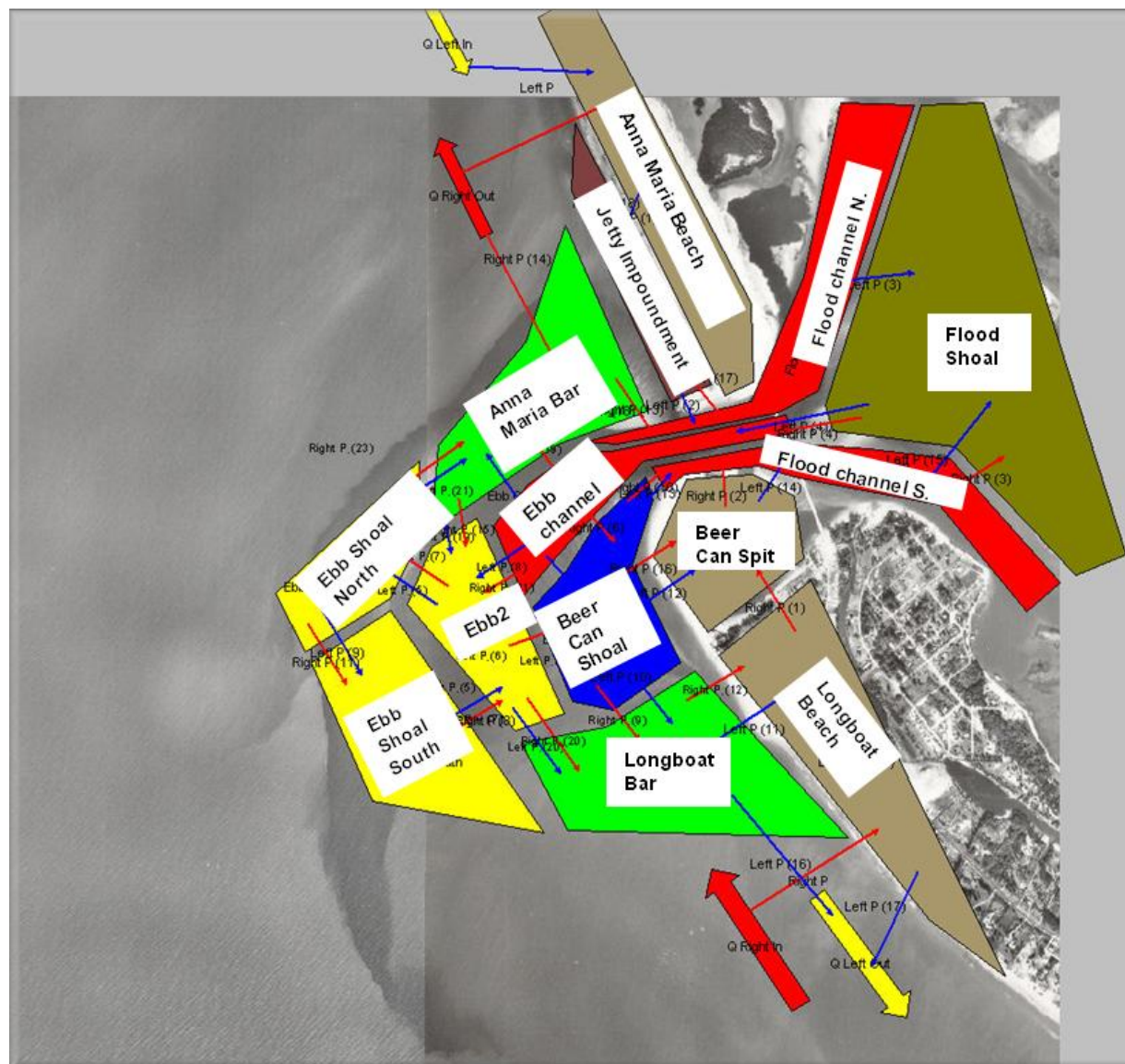


Figure 3.24. Reservoir Model Setup 1992-2040



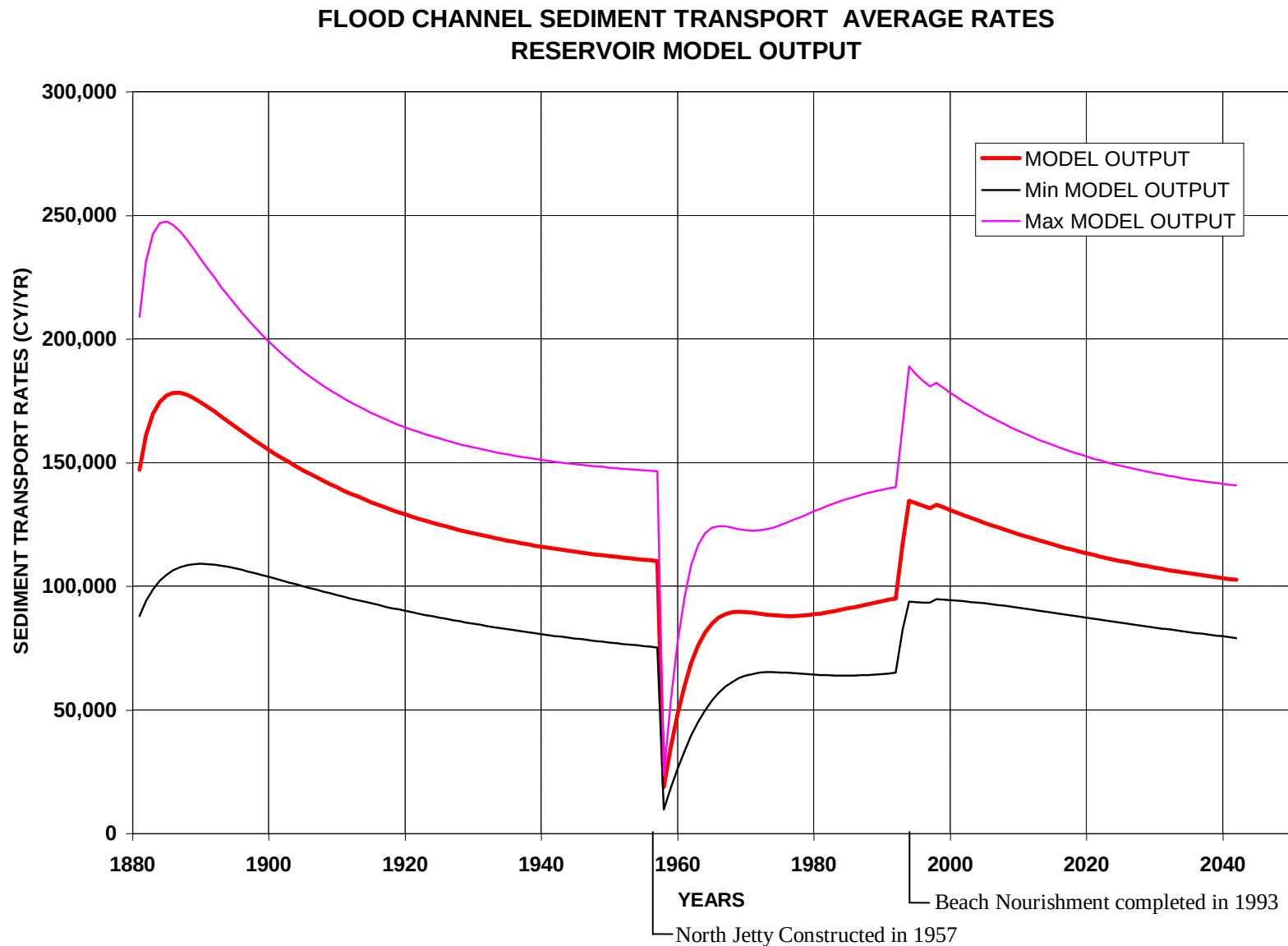
Sediment transport inputs for both directions were calculated with the ONELINE model (Dabees and Kamphuis 1998) using the 20 years (1980-1999) of wave data from WIS station 277. Potential average transport rates were computed using the 20 year record. Additionally, high and low sediment transport rates were computed based on the 20-year average rates and standard deviations to account for sediment transport variability. The model was run using the three input rates for each temporal stage.

The bathymetric data considered together with the modeling results defined the distinct morphologic features in the system. For the three temporal stages of the inlet evolution, the following features have been present: an ebb shoal, flood shoal, bypassing bars north and south of the inlet, and sand spit on the south side of the inlet (Beer Can Island). The ebb shoal feature was divided in two features prior to the 1993: ebb shoal north and ebb shoal south on either side of the channel centerline. For the Post 1993 condition, the ebb shoal was divided into three features to account for the post dredging adjustments. A jetty impoundment feature was added to account for the jetty impoundment and its effects on downdrift bypassing rates in 1957. The equilibrium volume of each feature was determined based on comparisons of available surveys and calculated volumes and rates of change for each feature. Although the features have varied somewhat in shape, location and size, they have been distinct in all available surveys and aeriels. The input sediment transport rates were specified based on the sediment transport computations for each time period.

### 3.3.2 Inlet Reservoir Model Results

Appendix B contains figures showing results for each of the morphologic features. The results show the calculated volume for each feature for average, maximum and minimum potential sediment transport rates. The figures also show the actual measured volume at times when data was available. Calculated volumes show good agreement with the observed and measured volumes and trends. The results describe the variation in volumetric change in response to the change in tidal prism in 1957 and the effects of the 1993 mining of the ebb shoal.

**Figure 3.25** shows the model results for sediment transport rates into the flood shoal from 1880 to projected rates at 2040. The rates indicate the increase of sediment transport input to the system as the new inlet opened in 1880 and material was eroding from Anna Maria Island to form the new ebb shoal to the north of the previous inlet shoal. As the ebb shoal was reaching its equilibrium to the tidal prism of the 1950's, transport to the flood shoal was leveling. Following the construction of the 1957 jetty, the sediment flow to the inlet was interrupted while the jetty was accumulating material from the littoral drift. As the jetty impoundment was filled to the jetty's capacity, the bypassing was reestablished to the prevailing rates.



**Figure 3.25. Reservoir Model Results – Flood Channel Sediment Transport**

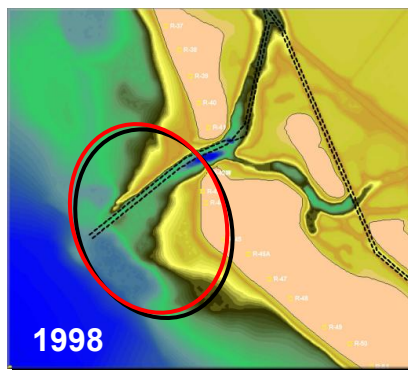
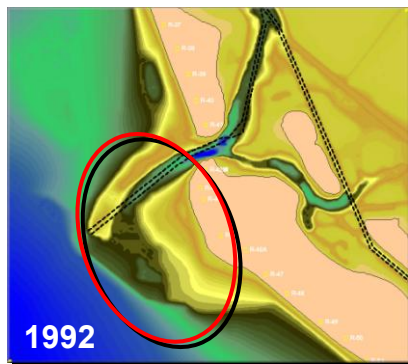
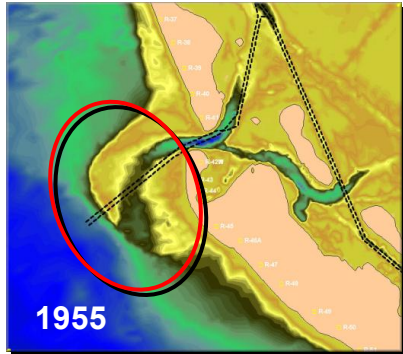
Another observation from **Figure 3.25** is the effect of the beach nourishment in 1993. The sand placement resulted in higher rates of sediment transport throughout the lifetime of the nourishment project adding more sand input to the system. The additional sediment transport input to the system coupled with the inlet migrating landward due to the 1993 dredging may have contributed to the increase of shoaling areas inside the inlet on the flood shoal and the ICW channel areas.

**Figure 3.26** shows the model results for total ebb shoal volume. The figure shows the volume of the ebb delta from 1880 when the older inlet delta existed, present conditions, and projection of future trends. The results show reasonably good model agreement with measurement from available surveys, including the relatively constant shoal volume for the early period, the increase in ebb shoal volume after construction of the jetty in 1957, and the significant impact on the ebb shoal volume from the 1993 ebb shoal mining and limited recovery.

The model projection indicates very little recovery should be expected in the future. This is an important issue because this shoal was an important and economical sand source in 1993, and it would be desirable to have such a sand source for future beach restoration needs. While the amount of data from the post 1993 dredging period is somewhat limited and collection of additional data will facilitate improved model projections, the data that is available in fact shows that over a 14-year period, the recovery has consisted of only approximately 10% of the material removed in 1993. This supports the conclusion drawn from the model results, that the inlet bypass process has been modified by the dredging in such a way that significant recovery is unlikely to occur in the near future.

**Figures 3.27** and **3.28** show the model results for beaches adjacent to inlet, Anna Maria Island and Beer Can Island, respectively. **Figure 3.27** show the initial erosion of Anna Maria Island beach as the ebb shoal was forming. The results also show the effect of the beach fill from the dredging disposal and large nourishment project in 1993. Similarly, **Figure 3.28** shows the model calculations and predications for Beer Can Island. The result indicates model agreement with measurement from available surveys. The model results also indicate the growth of the sand spit and the effect of the 1993 on the collapse of the Beer Can Island sand spit.





### EBB SHOAL TOTAL RESERVOIR MODEL OUTPUT

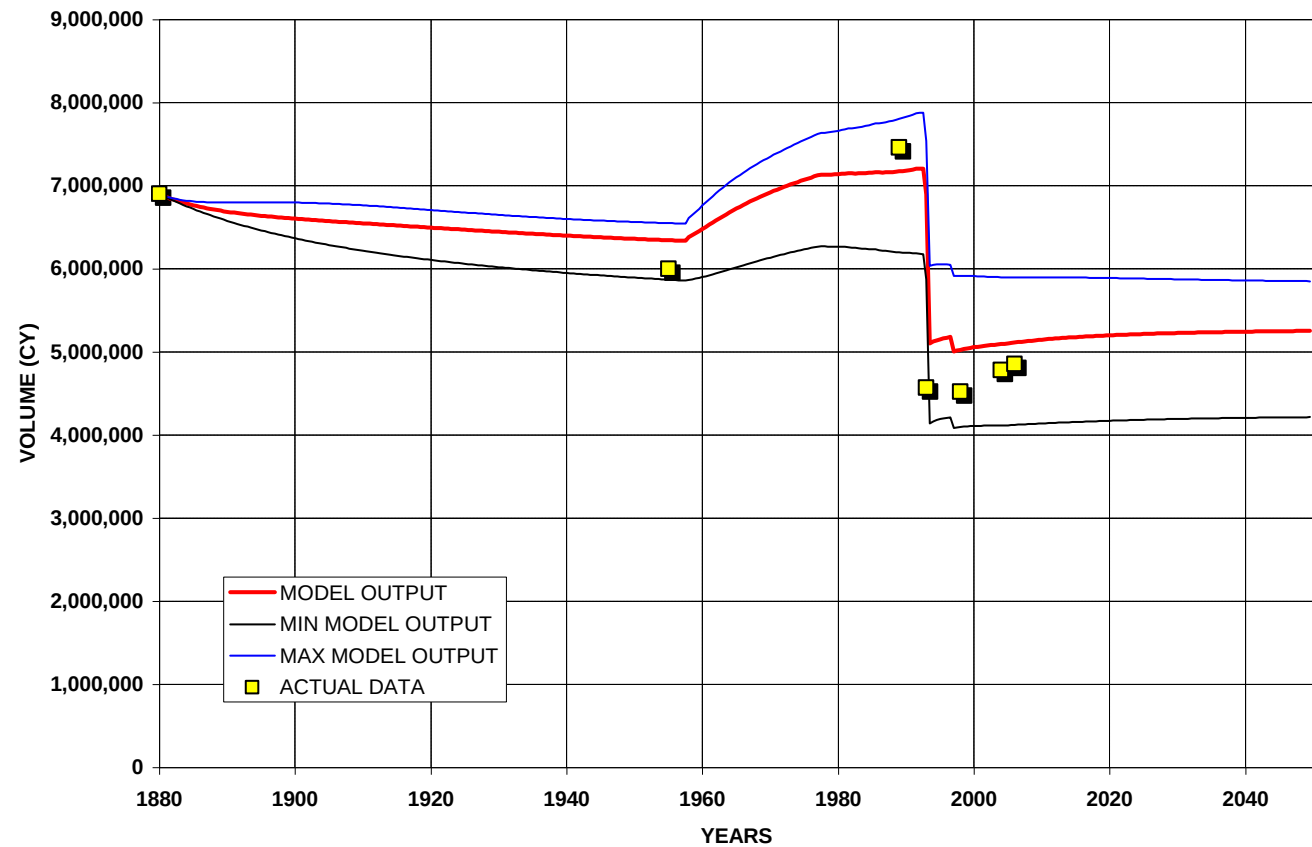
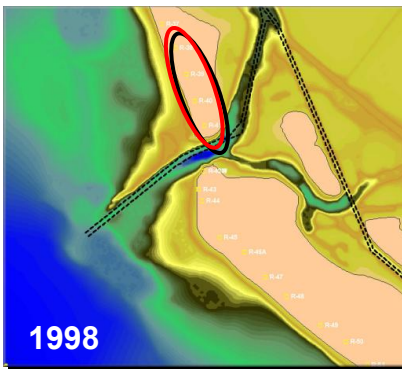
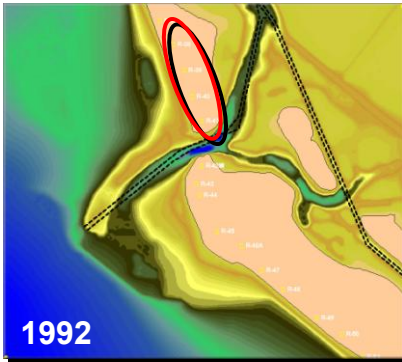
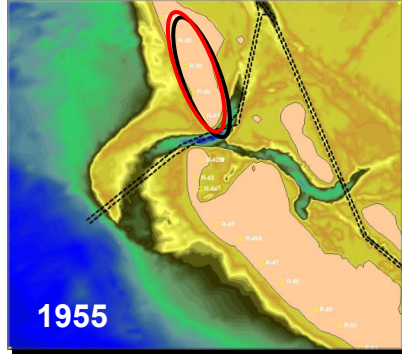


Figure 3.26. Reservoir Model Results – Ebb Shoal Total Volume



### ANNA MARIA BEACH RESERVOIR MODEL OUTPUT

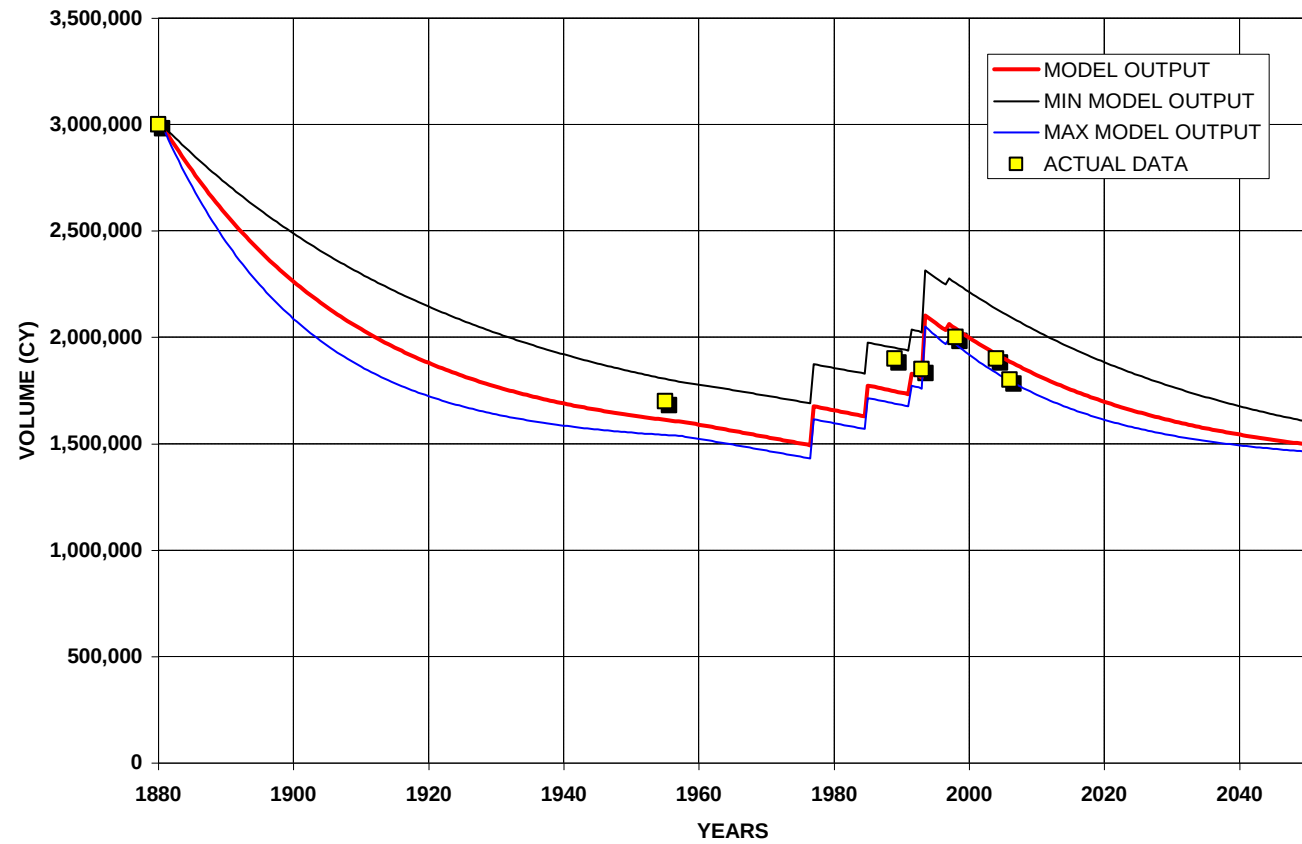
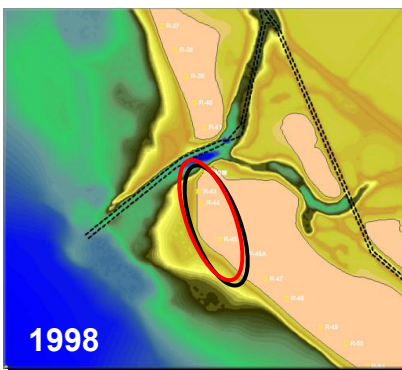
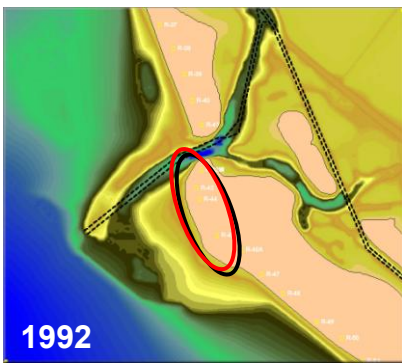
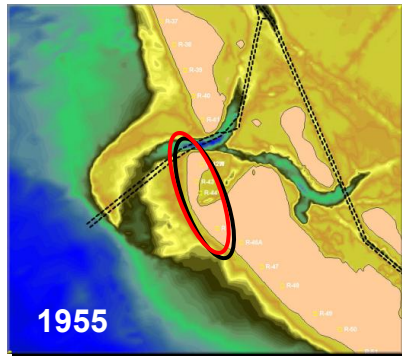
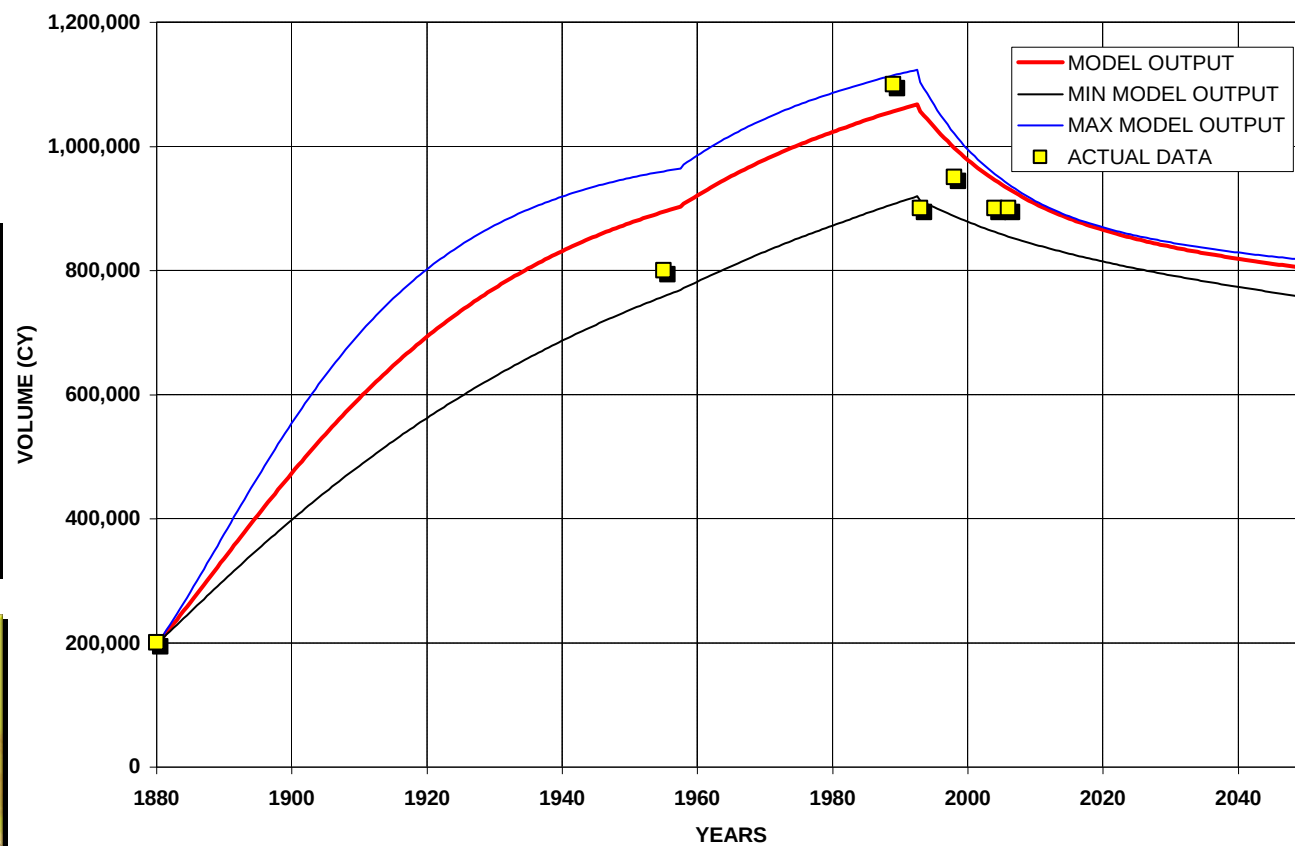


Figure 3.27. Reservoir Model Results – Anna Maria Beach Volume



**BEER CAN ISLAND  
RESERVOIR MODEL OUTPUT**



**Figure 3.28. Reservoir Model Results – Beer Can Island Volume**



### **3.4 Summary and Recommendations**

#### **3.4.1 Summary**

The purpose of this study was to evaluate issues related to the management of Longboat Pass. The scope of the evaluation includes the use of sand from maintenance dredging for mitigation of inlet impacts to adjacent beaches, as well as mining sand from other parts of the shoal system as a source of material for nourishment of beaches in areas beyond the influence of inlet.

The study was conducted by first compiling and analyzing historic aerial photography and survey data which document the evolution of inlet morphologic features. The history of morphologic evolution helps to describe local coastal processes and provides clues as to cause and effect associations, both natural and manmade, that need to be understood in order to develop effective management strategies for the inlet.

The analytical part of the study consists of the application of several numerical modeling procedures to gain a better understanding of processes and potential cause and effect associations between morphological changes at the inlet. Once the models were set up so that they could accurately simulate morphologic changes which have occurred in the system, they were used for projection of future changes, and projection of how the system would respond to various navigation maintenance alternatives and proposed mining of sand from either the ebb or flood shoals for beach nourishment.

There were three primary elements to the modeling; regional hydrodynamic modeling, detailed process modeling of wave/current interactions, and long-term morphology evaluation using the Inlet Reservoir Model. The regional modeling simulates tidal hydrodynamics of an interconnected bay and inlet system which extends 70 miles along the coast, from north of Tampa Bay to south of Venice Inlet. This model accounts for the interrelated nature of flow through the various bays and inlets and provides water level and tidal current values that are used as input for the detailed local process modeling. The detailed local modeling provides sand transport rates and transport pathway criteria for the sand reservoir model, which simulates the morphological evolution of inlet shoals and is the tool used to evaluate the consequences of mining sand, as well as the rate at which shoals should be expected to recover after dredging.

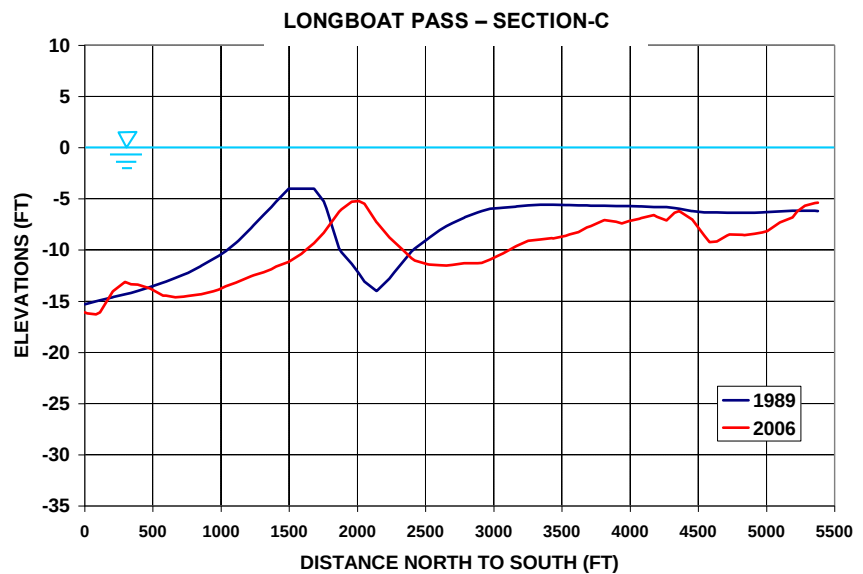
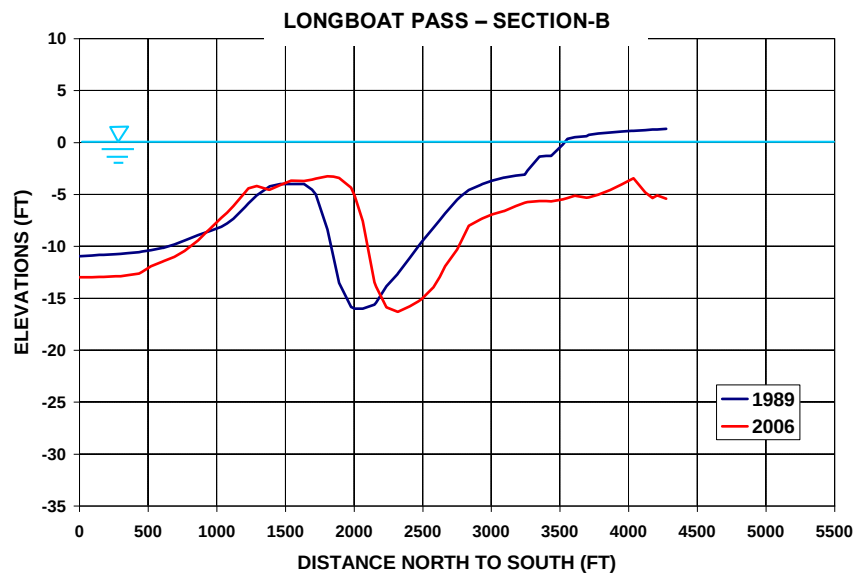
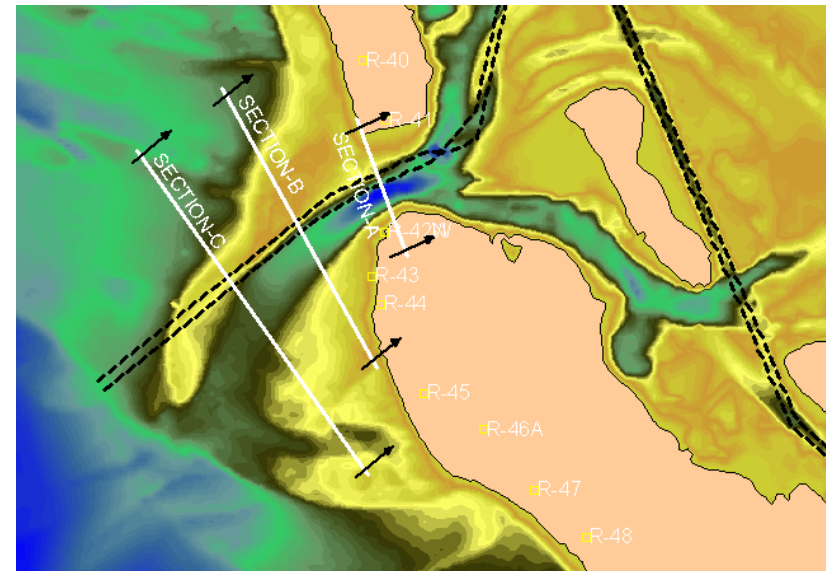
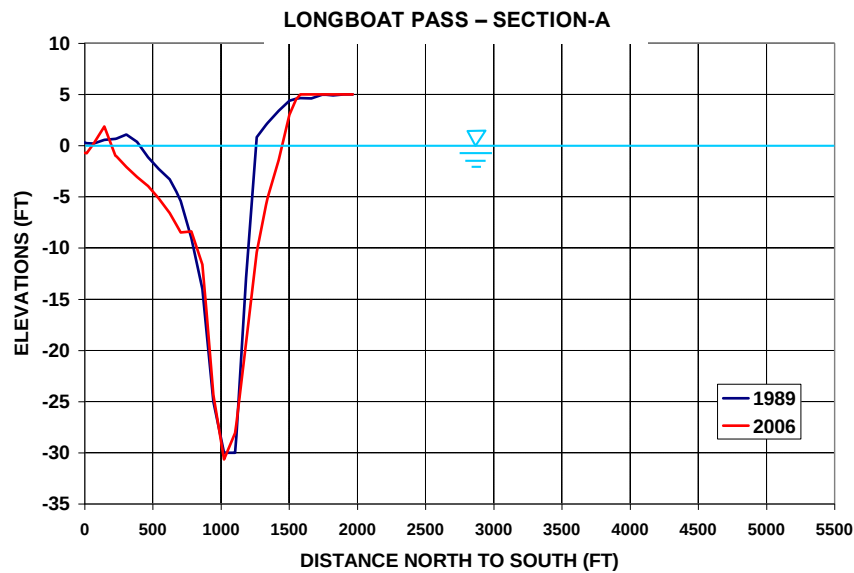
The historical aerial photographs and bathymetric data are important to the modeling effort because they are the input used to establish model grids. Additionally, large scale morphological changes must be considered in the setup of modeling procedures for different time intervals. Since 1880 when Longboat Pass opened, two major events changed inlet dynamics and produced significant morphological responses. These events were the construction of the north jetty in 1957, and the 1993 dredging of over 2 million cubic yards from the ebb shoal for beach nourishment. The results of the data analysis and modeling for Longboat Pass show the effects these two events had on the overall inlet evolution from

1880's to the present. Based on analysis of historical information and modeling results, the following is a discussion of the significant events in the inlet evolution process.

- The opening of the inlet in 1880 north of the previous inlet location resulted in erosion of the south end of Anna Maria Island to form the new ebb shoal and the onshore migration of the original ebb shoal caused accretion south of the inlet and formation of the sand spit at the north end of Longboat Key which became known as Beer Can Island.
- The jetty construction and the improvements of navigation waterways in the 1950's resulted in an increase in tidal prism and growth of the ebb shoal. The increased capacity for sand deposition in the jetty impoundment and ebb shoal interrupted natural bypassing to the downdrift side of the inlet in the 1960's. This resulted in erosion of the north part of Longboat Key and the breaching of the Beer Can Island spit near the location of the old inlet.
- Sand bypassing was gradually reestablished, and the Beer Can Island spit reattached to Longboat Key by 1970.
- Maintenance dredging of the federal channel, which began in 1977, limited the growth of the ebb shoal with the volume apparently stabilized slightly under its equilibrium volume. It should be noted that the dredging was relatively infrequent for coastal inlets with an interval between dredging events of typically more than 5 years, and the volume dredged was relatively small.
- The large scale dredging of over 2 million cubic yards from the ebb shoal in 1993 interrupted the natural balance between sand transport induced by wave and tidal flow circulation. Immediately following the dredging, the shoal features were dominated by waves which caused severe erosion of the downdrift shoals and shoreline. The erosion of the Beer Can Island spit occurred as the channel migrated to the south. The seaward extent of the ebb tidal plume and the seaward extent of the ebb shoal were both reduced, and the sand bypass attachment bar on the south side of the inlet formed further north than the pre dredging attachment location. Although this provided wider beach at an erosion hot spot along Beer Can Island, the inlet continued to migrate south and the ebb shoal bar migrated further south. This re-exposed the previous erosion hot spot to a new period of critical erosion.

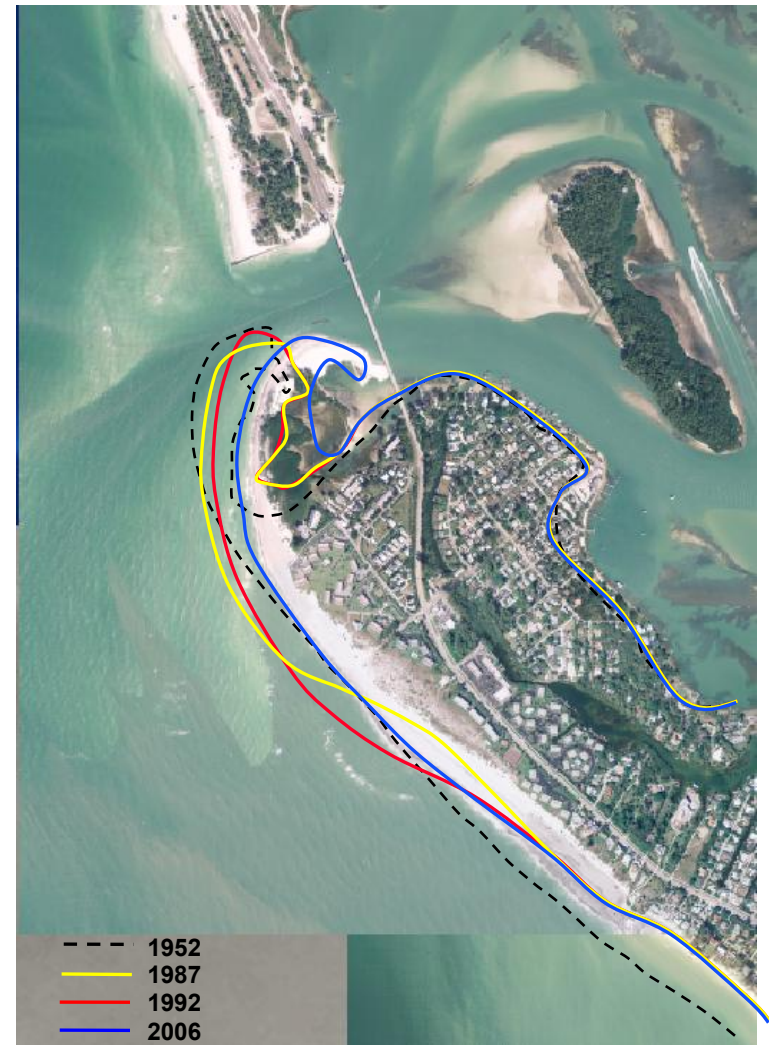
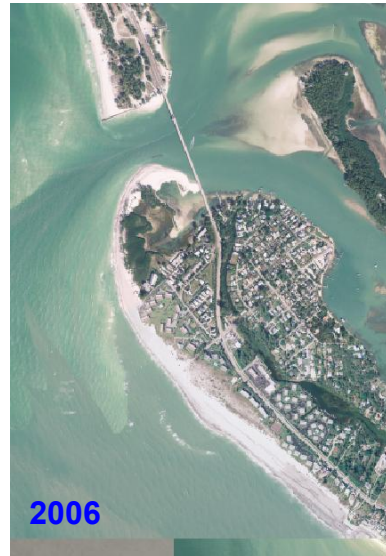
**Figures 3.29 and 3.30** illustrate two important points related to the evolution of Beer Can Island.

**Figure 3.29** shows the present condition (2006) of Longboat Pass and three profiles across the ebb shoal channel from the inlet throat to the seaward limit of the channel. The inlet cross sections show erosion on the south side of the channel near the throat, the south migration of the inlet, and the large volume loss



**Figure 3.29. Longboat Pass Cross Sections 1989 and 2006**





**Figure 3.30. Beer Can Island Shoreline Change AND North End of Longboat Key**

from the two shoals adjacent to the channel. The figure also indicates shoaling of the seaward extent of the channel as the ebb shoal migrated closer to shore.

**Figure 3-30** shows the shoreline position along Beer Can Island at four different times from 1952 to 2006. Although the sand spit was breached and reattached in the 1960's, the spit location with respect to the inlet throat did not change significantly, although the shoreline has generally eroded to a more southerly location.

Analysis of historic changes, available data, and modeling of coastal processes indicate minor recovery in total ebb shoal volume has occurred. However, because of the altered channel orientation and position closer to shore, the authorized federal channel no longer follows the natural tidal channel. This has reduced the ability of tidal currents to scour material from the navigation channel. Qualitatively, this could potentially increase maintenance dredging requirements.

### 3.4.2 Recommendations

The following recommendations are made based on historical data analysis and modeling of Longboat Pass evolution.

#### Federal Channel

As discussed above, the authorized channel location no longer follows the natural tidal channel alignment. It is therefore recommended that the alignment of the authorized channel be modified to conform more closely to the natural tidal channel alignment. This could potentially reduce maintenance dredging requirements and associated costs, and allow the shoals to further recover from the 1993 dredging. It may also potentially contribute to improved navigation safety.

#### Use of ebb shoal as a sand source for beach nourishment.

Since the inlet channel is under an ongoing maintenance dredging program, beach compatible material dredged from the channel should continue to be used for beach restoration. However, the shoal is still recovering from the dredging of more than 2,000,000 cubic yards of sand in 1993. Beyond maintenance dredging, the use of the ebb shoal as a source of sand for large scale beach restoration is not recommended because of potential adverse impacts to adjacent beaches. If ongoing monitoring shows continued recovery of the ebb shoal, selective dredging of additional sand for beach restoration may become an option in the future. It should, however, be anticipated that quantities would be limited.

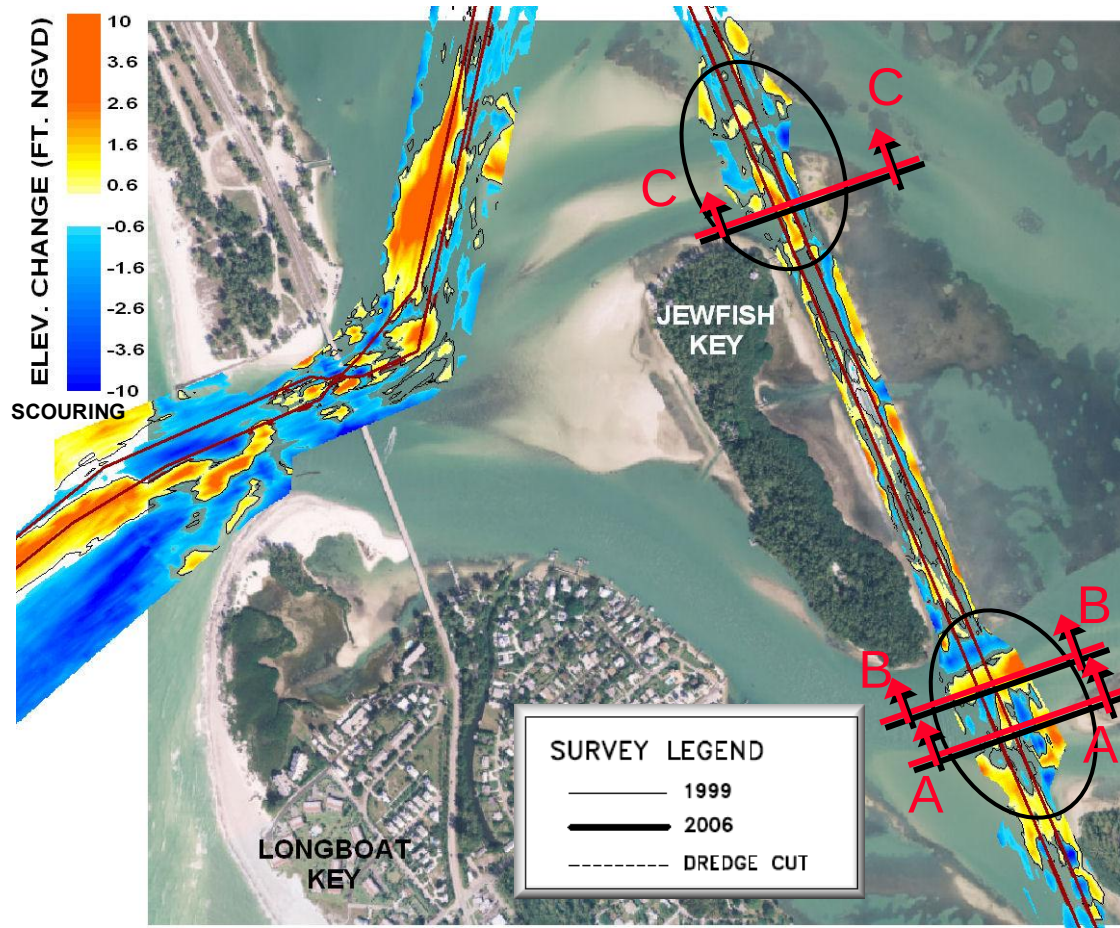
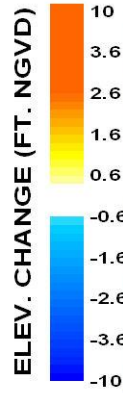
#### Maintenance of the ICW and flood shoal as sand source

Some sand which is carried into the inlet by flood tidal currents may be carried back out on a subsequent ebb flow, and by this process some of that sand eventually bypasses the inlet. However, flood shoals are not subject to high wave energy to which ebb shoals are exposed, and it is that wave action on the ebb shoals that is responsible for most sand bypassing of inlets. Furthermore, expenditure of wave energy in bypassing sand on the ebb shoal provides some protection to the shoreline in the lee of the shoal. Dredging of flood shoals will therefore not have as pronounced an effect on adjacent shorelines and on inlet transport processes as dredging of ebb shoals does, particularly if the dredging of the flood shoals is relatively minor, so that it does not result in a large increase in the rate at which the flood shoals trap sand.

Model results and available data indicated increase of shoaling in specific areas of the ICW may be expected to occur as the result of beach nourishment activities near the inlet. It is therefore recommended that the maintenance dredging of the ICW in the vicinity of the two shoaling problem areas identified in **Figure 3-31** and **Figure 3.32** be modified to include an appropriate amount of advance dredging.



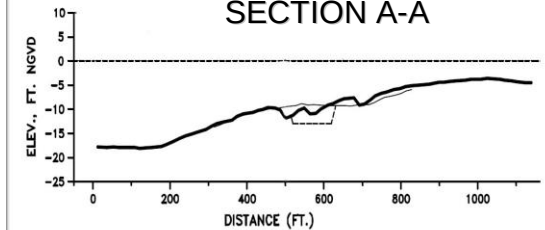
SHOALING



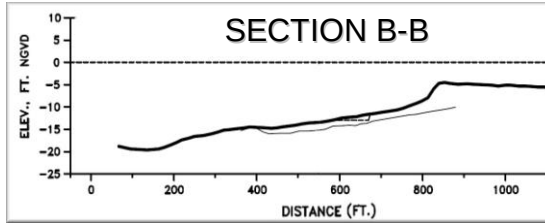
SURVEY LEGEND

- 1999
- 2006
- - - DREDGE CUT

SECTION A-A



SECTION B-B



SECTION C-C

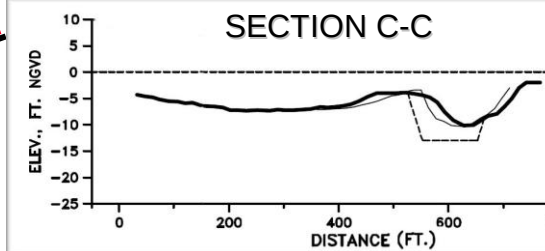
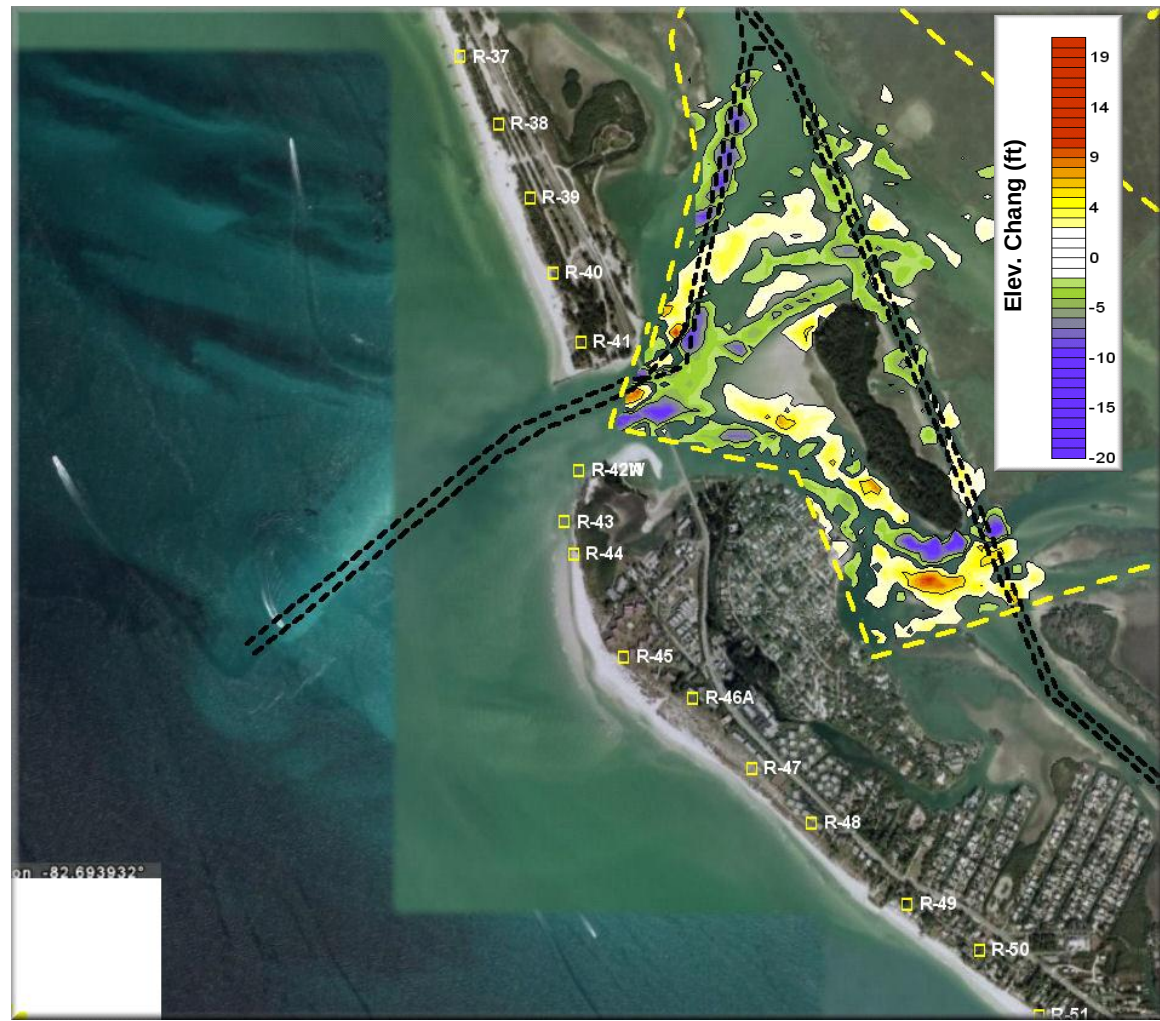
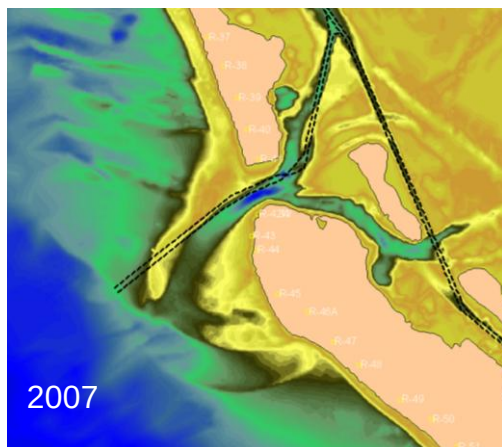
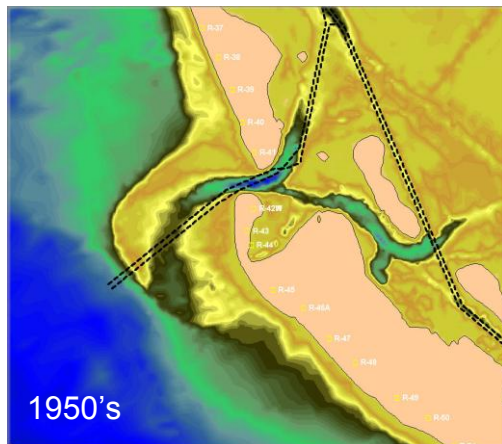


Figure 3.31. Longboat Pass Federal Channel Morphology Change 1999 to 2006



**Figure 3.32. Longboat Pass Flood Shoal 1950's to 2007 Volume Change**

This could be accomplished by increasing the channel width along those reaches where shoaling is a problem, so that material could accumulate there for a longer period of time before becoming a problem to navigation. This would result in dredging less frequently, and each dredging operation would remove larger quantities of material that would potentially make beach disposal more economical.

#### Erosion control of Beer Can Island at the north end of Longboat Key

Beer Can Island shoreline and its shoal have lost significant volumes of sand since the 1993 dredging of the ebb shoal. Terminal structures could be designed to stabilize this eroding shoreline. Furthermore, structures that are designed to stabilize the shoreline would reduce sand transport into the inlet and therefore may also be beneficial in reducing long term dredging costs. Transport processes in the dynamic area adjacent to an inlet are complex in an area where tidal currents, a deep channel, and wave action all play a significant role. There are, therefore, a variety of terminal structures that may be considered, and the design needs to be site specific in order to optimally achieve project goals.

Recommended alternatives to manage erosion hot spots along Beer Can Island include:

- Periodic nourishment using dredged material from the ICW and federal channel maintenance
- Design of local permeable erosion control structures where needed.

Further modeling and analysis is necessary to design a specific approach to addressing erosion control at Beer Can Island.

#### Restoration of the terminal structures north of Longboat Pass on the south end of Anna Maria Island

The 50-year old jetty on the north side of the inlet on the south end of Anna Maria Island may require restoration to tighten the structure and restore its function to capacity. **Figure 3.33** shows a recent photo of the jetty indicating that it is somewhat permeable. Sand tightening of the jetty is recommended to reduce erosion along the south end of Anna Maria Island and reduce sand transport into the inlet.

The regional modeling completed for this study, in conjunction with the detailed modeling procedures applied to Longboat Pass, can be applied to provide future analysis of alternatives and design optimization at other inlets within the study area.





## **4. VENICE INLET EVOLUTION MODELING AND ANALYSIS**

### **4.1 Background**

Venice Inlet, formerly known as Casey's Pass, is located between Venice Beach to the south and Casey Key to the north. This inlet is one of several tidal connections between the Gulf of Mexico and the Intracoastal Waterway (ICW), providing gulf access for the vicinity of Lyons Bay, Dona Bay, Roberts Bay, and Little Sarasota Bay. **Figure 4.1** shows the present waterway configuration, including the location of the Federal Navigation Channel, the ICW, and inter-connected bays in the vicinity of Venice Inlet. The figure also shows the regional and detailed model domains.

The present study compiled recent and historic surveys, aerial photographs, and other data to document the morphologic evolution of the inlet and its system of channels and shoals. This information is also used to set up numerical models that simulate the inlet tidal hydraulics and coastal processes which have driven the inlet morphological changes at various stages in that evolution. This analysis, performed for the period of time for which records are available from the 1880's to present, proved valuable in evaluation of changes which have occurred in the distribution of the tidal prism flowing from the inter-connected bay system through the various tidal inlets which connect the bays to the Gulf of Mexico. Quantification of the changes in this tidal prism distribution over time helps to explain the resulting morphological changes.

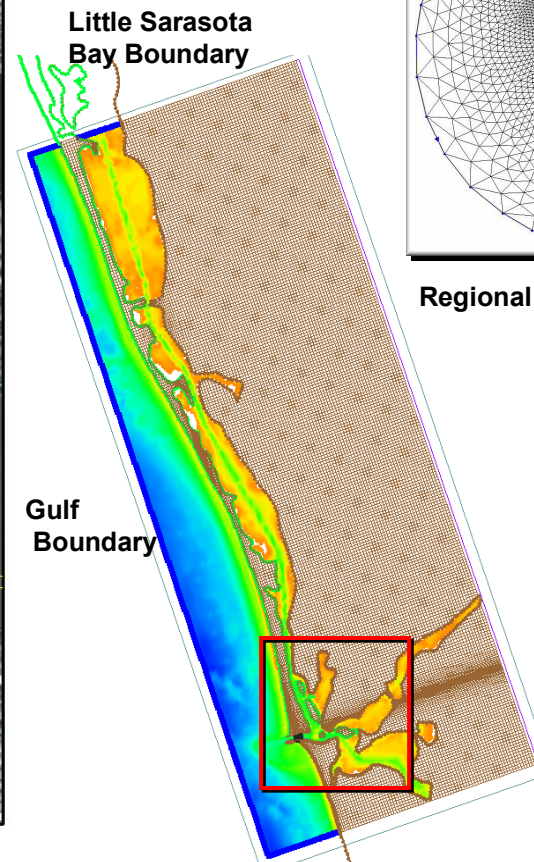
The modeling effort consisted of two basic parts. The regional model discussed in **Section 2** provided tidal driven current velocities and water level boundary conditions needed for input to the more detailed localized model grid for Venice Inlet. The detailed models for Venice Inlet include wave and sediment transport modeling with the Coastal Modeling System (CMS, Buttolph et al. 2006), and long-term morphology evolution with the Inlet Reservoir Model (IRM, Kraus 2000a, 2000b).

The combination of the CMS 2D flow/sediment transport model with the simple long-term morphology of the IRM provides a practical application tool to help identify sediment transport pathways across the dynamic inlet shoals, and how those patterns of sand movement have led to the evolution of morphologic features. The results of the analysis include

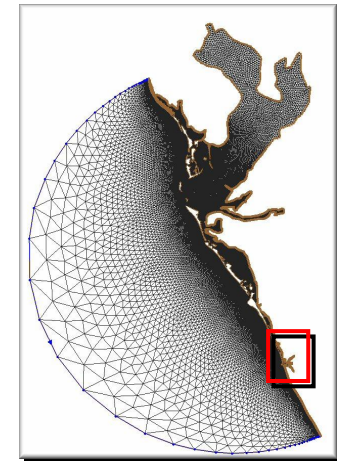
- Describing natural conditions which existed before any dredging or inlet modifications;
- Describing how present conditions evolved and how they are influenced by ongoing processes, and;
- Evaluating potential alternative inlet management strategies to provide a basis for management policy decisions.



Venice Inlet Aerial Photo (Present conditions)



Venice Inlet CMS grid (Present conditions)



Regional ADCIRC mesh

Figure 4.1. Venice Inlet (location and model coverage)



## 4.2 Inlet Evolution

The evolution of Venice Inlet over the period of record is separated into three time intervals characterized by distinct differences in processes which were occurring during each interval. The 1880's to 1920's interval covers a period of natural inlet evolution. The 1930's to the 1950's period includes the jetty construction in 1937 and the dredging which began in the 1940's for the federally authorized navigation channel and the ICW improvements. The time period from the 1960's to present is distinguished by the long-term effects of additional improvements to the ICW in 1963. This period also includes effects of the 1983 closure of Midnight Pass which changed the tidal prism distribution among inlets connected to Little Sarasota Bay.

Little Sarasota Bay has the largest bay area of all the bays contributing to the tidal prism of Venice Inlet. However, the tidal prism for Venice Inlet is also drawn from Lyons Bay, Dona Bay, and Roberts Bay because of their close proximity to the inlet. Little Sarasota Bay tidal prism has been distributed through multiple inlets as follows:

**Table 4.1** Inlets of Little Sarasota Bay

| Period       | Inlets sharing the tidal prism of Little Sarasota Bay                                                                     |
|--------------|---------------------------------------------------------------------------------------------------------------------------|
| 1880-1921    | <ul style="list-style-type: none"><li>- Big Sarasota Pass</li><li>- Little Sarasota Pass</li><li>- Casey's Pass</li></ul> |
| 1921-1983    | <ul style="list-style-type: none"><li>- Big Sarasota Pass</li><li>- Midnight Pass</li><li>- Venice Inlet</li></ul>        |
| 1984-Present | <ul style="list-style-type: none"><li>- Big Sarasota Pass</li><li>- Venice inlet</li></ul>                                |

The discussion of Venice Inlet evolution therefore includes the historical regional changes in Little Sarasota Bay and Midnight Pass, and how those changes affected Venice Inlet. **Appendix 4A** includes available aerial photos for Venice Inlet.

### 4.2.1 1880's to 1920's

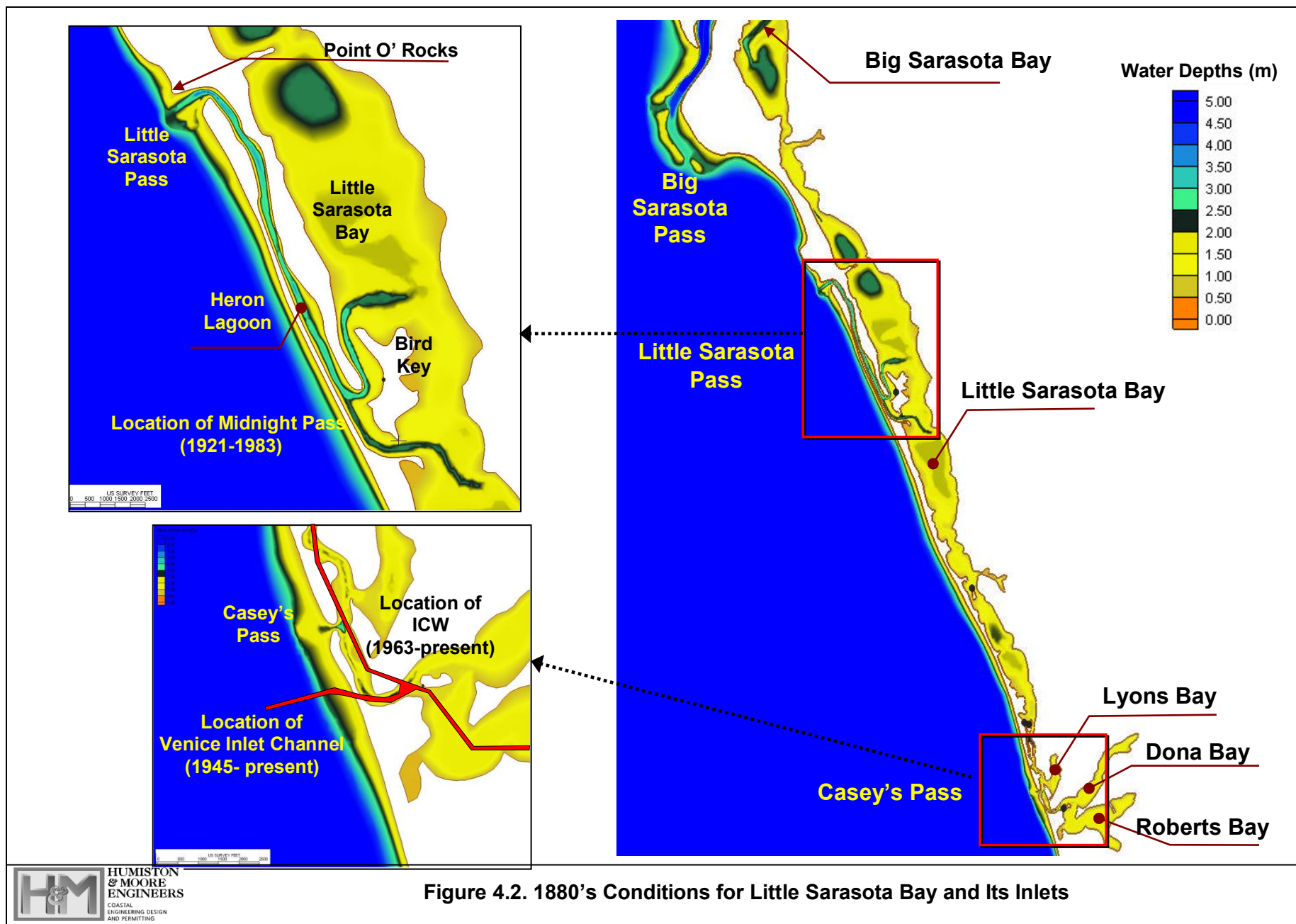
Early hydrographic maps of 1880's show that Casey's Pass was located approximately 1700 feet north of the present location of Venice Inlet. **Figure 4.2** shows the 1883 conditions. Water depths are illustrated according to the legend. The unimproved inlet was subject to migration along the coast as illustrated in

**Figure 4.2.** The figure shows the regional conditions of Casey's Pass and the bay system of Lyons Bay, Dona Bay, Roberts Bay, Little Sarasota Bay, and Big Sarasota Bay. The largest bay in this system which had significant influence on Casey's Pass is Little Sarasota Bay because Big Sarasota Bay is more than 10 miles distant and is also connected to the gulf through other inlets. Due to these multiple hydrodynamic connections, modeling the regional system was necessary to accurately simulate each inlet tidal prism share and flow dynamics.

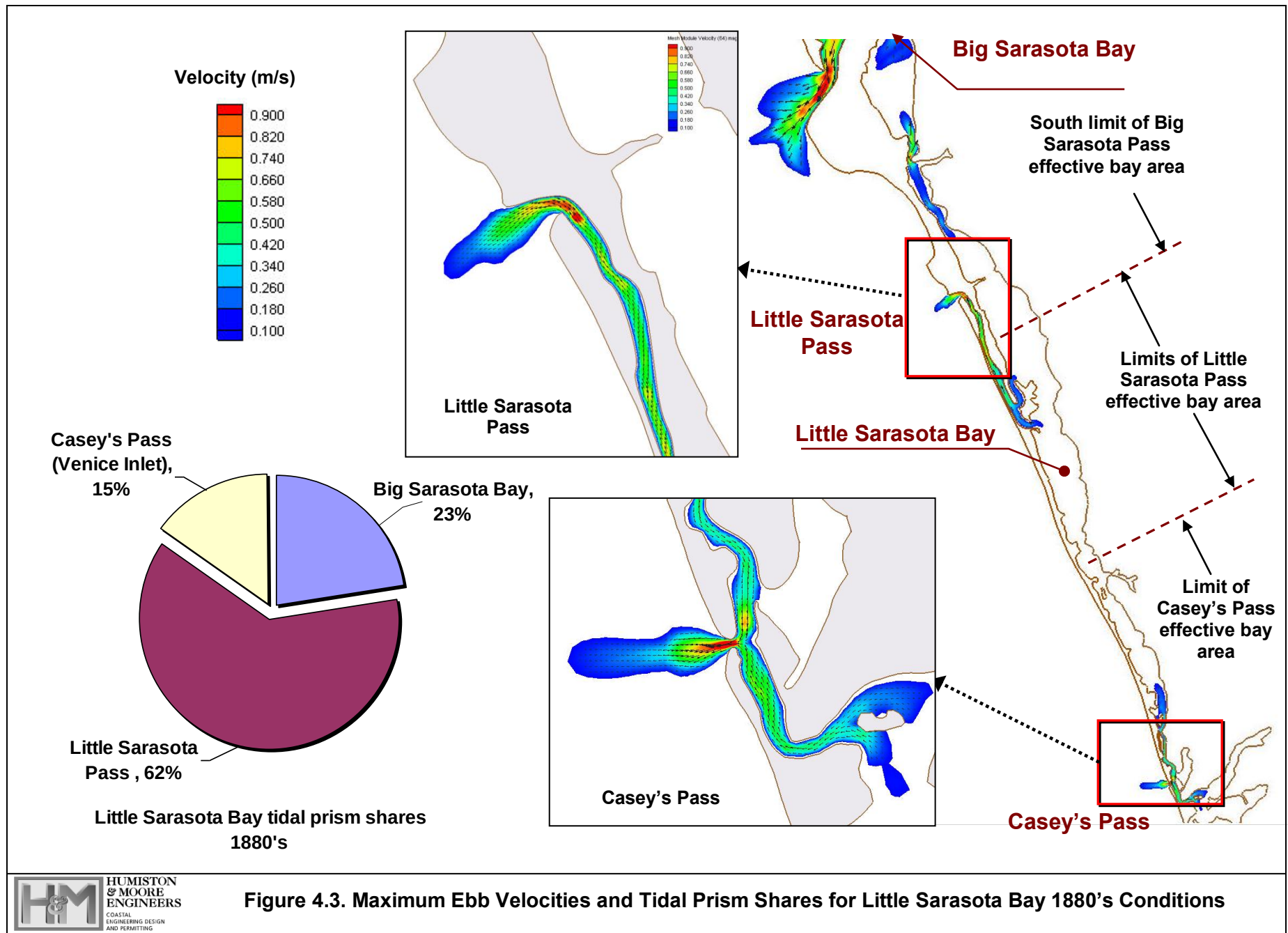
#### Regional Hydrodynamics

Modeling the regional hydrodynamics for the 1880's conditions was done to assess the natural dynamics of Little Sarasota Bay and its inlets prior to the 20<sup>th</sup> century development. **Figure 4.3** shows the 1880's maximum ebb currents for Little Sarasota Bay with details at Little Sarasota Pass and Casey's Pass. The figure indicates the velocity where magnitudes are above 0.1 meters per second, flow directions, and extents of areas of flow velocities that are strong enough to result in active sand transport. Red-colored areas indicate velocities greater than the critical velocity for sediment movement. The figure also indicates the approximate limits of the effective bay area which contributes to the tidal prism distribution to each inlet. For the purpose of the local analysis, the connection between Big Sarasota Bay and Little Sarasota Bay is treated as if it was another inlet to Little Sarasota Bay.

The figure also shows the approximate distribution of the tidal prism of Little Sarasota Bay among the three inlets. Little Sarasota Pass carried more than 60% of the tidal prism from Little Sarasota Bay while Casey's Pass carried approximately 15%.







#### 4.2.2 1930's to 1960's

The 1930's to the 1950's period included the jetty construction in 1937 and the dredging, which began in the 1940's for the federally authorized navigation channel and the ICW improvements.

##### Venice Inlet Jetties Construction

In 1937, Casey's Pass was stabilized with two jetties in their present location and the U.S. Army Corps of Engineers authorized a Federal Navigation Project, which has been maintained since 1945. The pass became known as Venice Inlet.

**Figure 4.4** shows the 1880's shoreline superimposed on the aerial photos of 1943. The figure shows the jetties a few years after their construction and the effects they had on the adjacent shorelines. The 1943 aerial shows the jetty impoundment process at the north side and the downdrift erosion at the south side of the inlet. The figure also shows the early development of the ICW connecting Lyons Bay to Dona Bay and Roberts Bay east of Turner Key.

**Figure 4.5** shows the 1950's inlet and waterway configuration which was used as representative of the conditions between 1930's to 1960's for the purposes of setting the regional modeling for that period. When the hurricane of 1921 opened Midnight Pass approximately 4 miles south of Little Sarasota Pass, Midnight Pass provided a more hydraulically efficient waterway than the long narrow channel that connected Little Sarasota Pass to Little Sarasota Bay. As a result, Little Sarasota Pass closed, and Midnight Pass carried the major share of the Little Sarasota Bay tidal prism.

**Figure 4.6** shows the morphologic changes which occurred from the 1880's to the 1950's. The figure shows the effect of the jetties at Venice inlet, which created a shoreline offset by impounding sand on the north side of the inlet and causing downdrift erosion on the south side. The figure also shows the formation of the ebb shoal seaward of the jetties as the inlet improvements were conducive to the growth of the ebb tidal shoal. The figure does not show any indication of a well developed attachment bar formation downdrift of the inlet. This indicates that the jetty impoundment and the formation of the ebb shoal was still holding more sand than bypassing of sand to the downdrift beach resulting in downdrift erosion.

**Figure 4.7** shows the contours of the 1950's conditions superimposed on the 1960's aerial photo of Venice Inlet. The figure indicates the 1950's seaward limit of the ebb shoal to be approximately 1000 feet seaward of the ends of the jetties. The 1960's aerial shows the advance of the shoreline at the north side of the inlet due to jetty impoundment. The figure also indicates downdrift erosion of approximately 250 feet from a baseline based on the approximate 1880 mean high water line position.



**Figure 4.4. Aerial Photo of 1943 and Shoreline of 1880's**



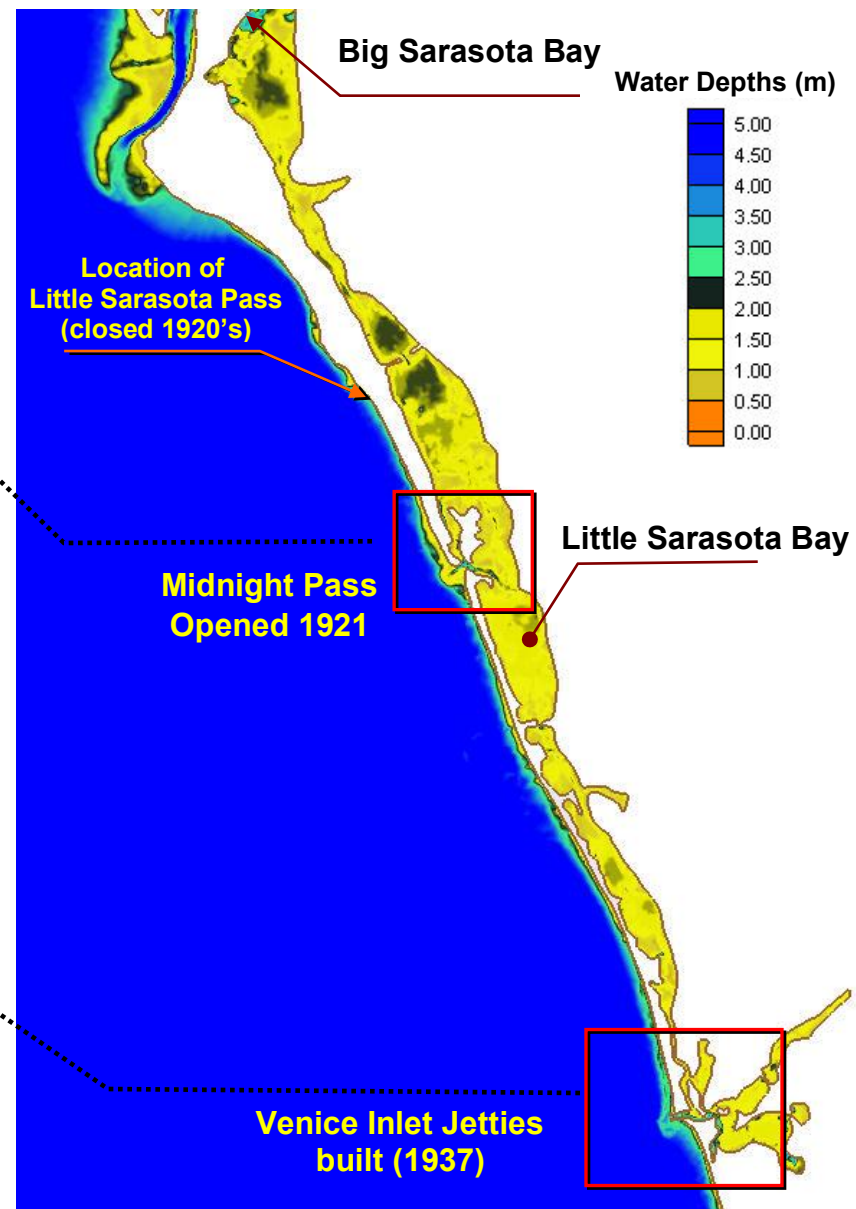
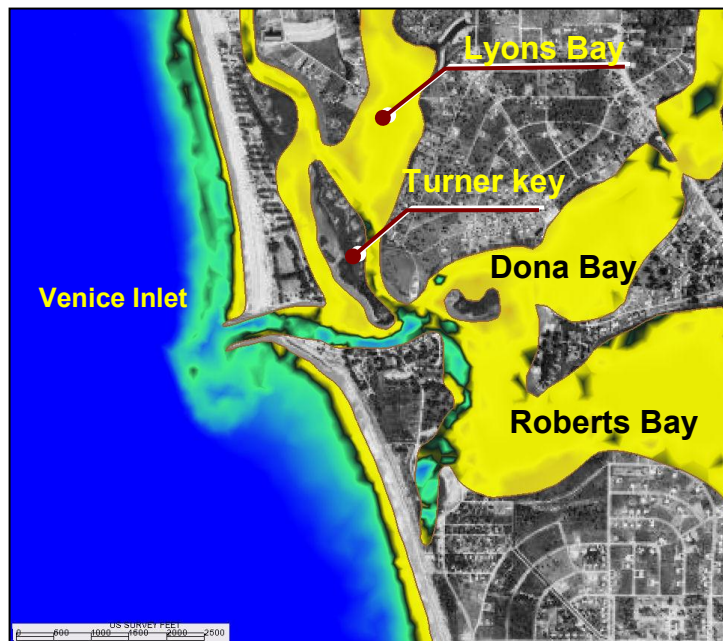
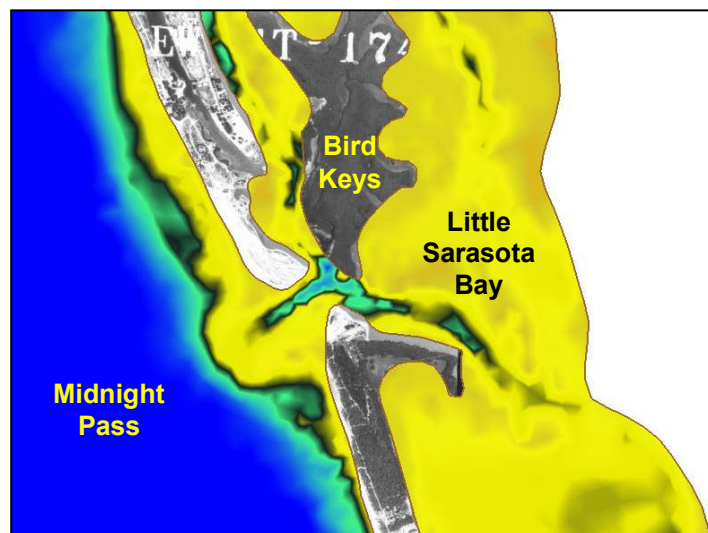
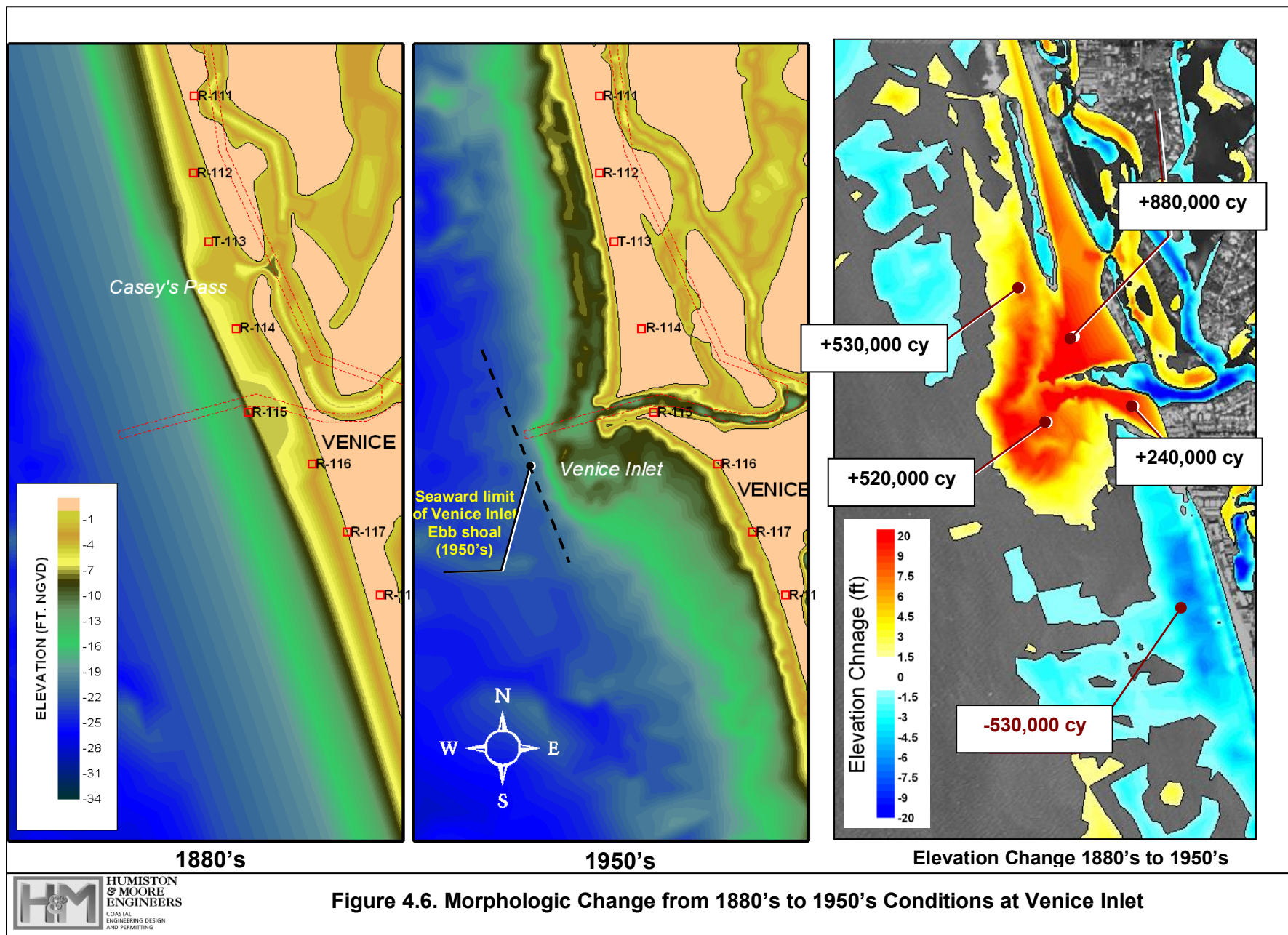
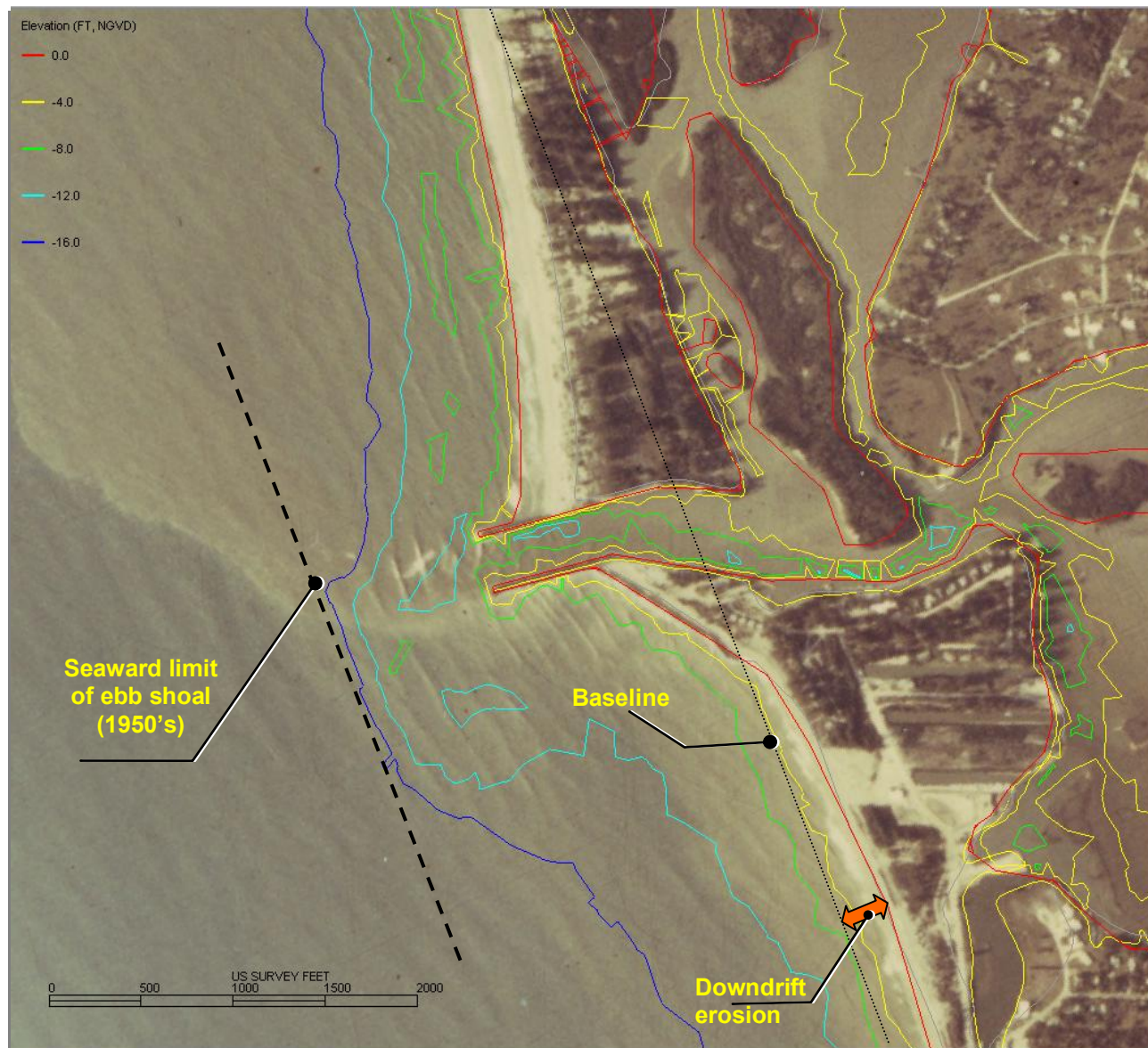


Figure 4.5. 1950's Conditions for Little Sarasota Bay and its Inlets







**Figure 4.7. Aerial Photo of 1960 and Depth Contours of the 1950's Conditions at Venice Inlet**



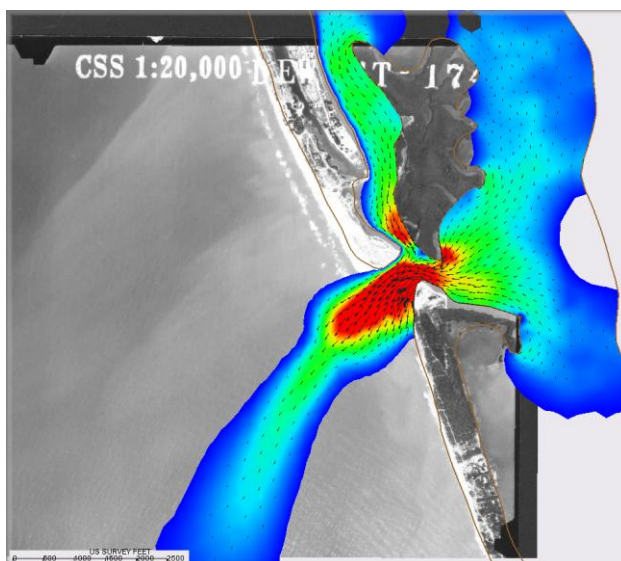
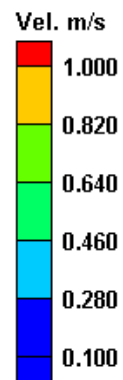
## Regional Hydrodynamics

Modeling the regional hydrodynamics for the 1950's conditions was done to assess the effects of the initial improvements to the ICW and other developments within Little Sarasota Bay, including the closure of Little Sarasota Pass and opening of Midnight Pass.

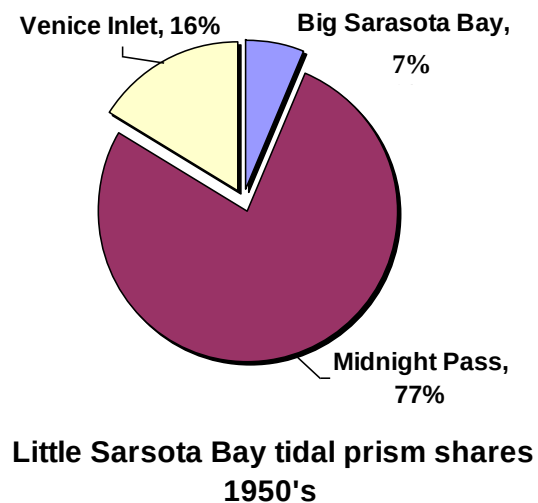
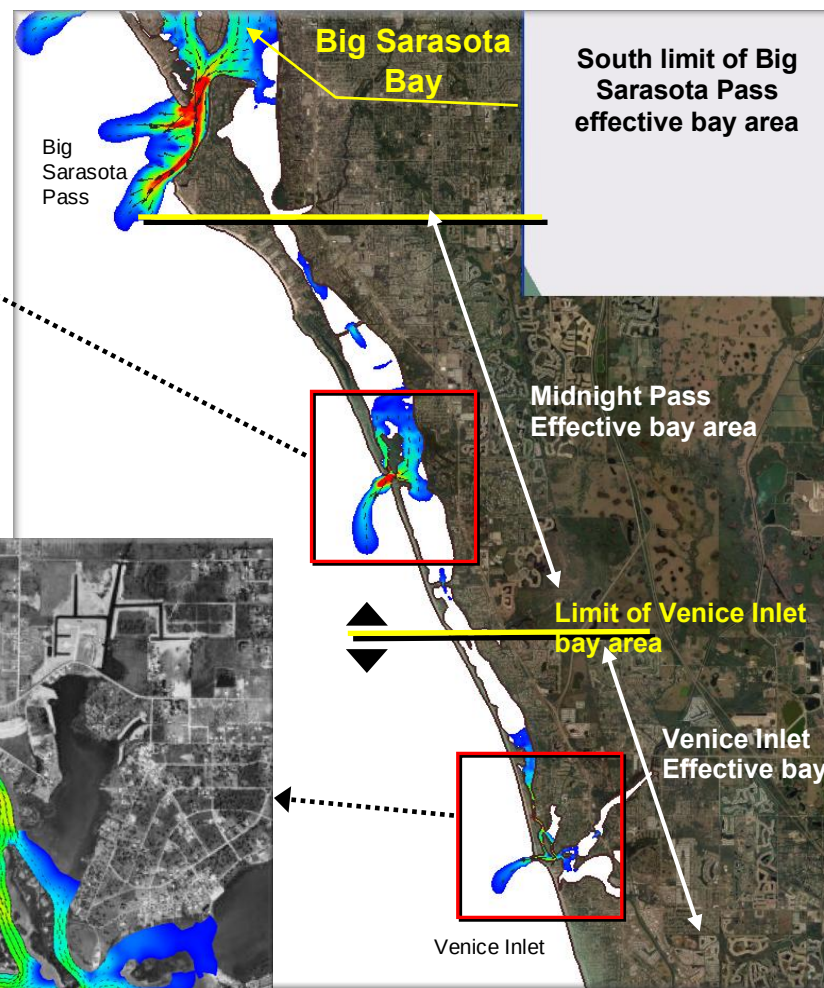
**Figure 4.8** shows the 1950's maximum ebb currents for Little Sarasota Bay with details at Midnight Pass and Venice Inlet. As indicated in Section 4.2.1, the connection between Big Sarasota Bay and Little Sarasota Bay is treated as if it was an inlet to Little Sarasota Bay. The figure indicates the approximate limits of the effective bay area governing the portion of the tidal prism distribution to each inlet. The figure also shows the distribution of the tidal prism of Little Sarasota Bay among the three inlets. The opening of Midnight Pass and waterway development increased the tidal prism of Midnight Pass over that which had previously flowed through Little Sarasota Pass before it closed. On the other hand, the tidal prism flowing north to Big Sarasota Bay was reduced.

In the 1950's Midnight Pass carried the majority of Little Sarasota Bay tidal prism, approximately 77%, while Venice Inlet carried approximately 16%. The share of the Little Sarasota Bay tidal prism flowing through Venice Inlet remained essentially unchanged because although Midnight Pass was more efficient than the previously existing Little Sarasota Pass. Additionally, Venice Inlet, with its jetties and maintained navigation channel, was also more efficient, and the changes balanced with each other.

The opening of Midnight Pass and increase of its tidal prism share therefore extended the northern limit of its effective bay area within Little Sarasota Bay. This reduced the prism flowing through the connection between Little Sarasota Bay and Big Sarasota Bay. The tidal prism share of Little Sarasota Bay that flowed through the connection to Big Sarasota Bay was reduced from the 23% share during the 1880's to approximately 7% during the 1950's. The changes in tidal flows and effects of typical wave and storm conditions resulted in the morphological changes documented by comparing the bottom elevations of the 1880's and 1950's which are illustrated in **Figure 4.6**.



Midnight Pass



Venice Inlet

Figure 4.8. Maximum Ebb Velocities and Tidal Prism Shares for Little Sarasota Bay (1950's)

#### 4.2.3 1960's to Present Conditions

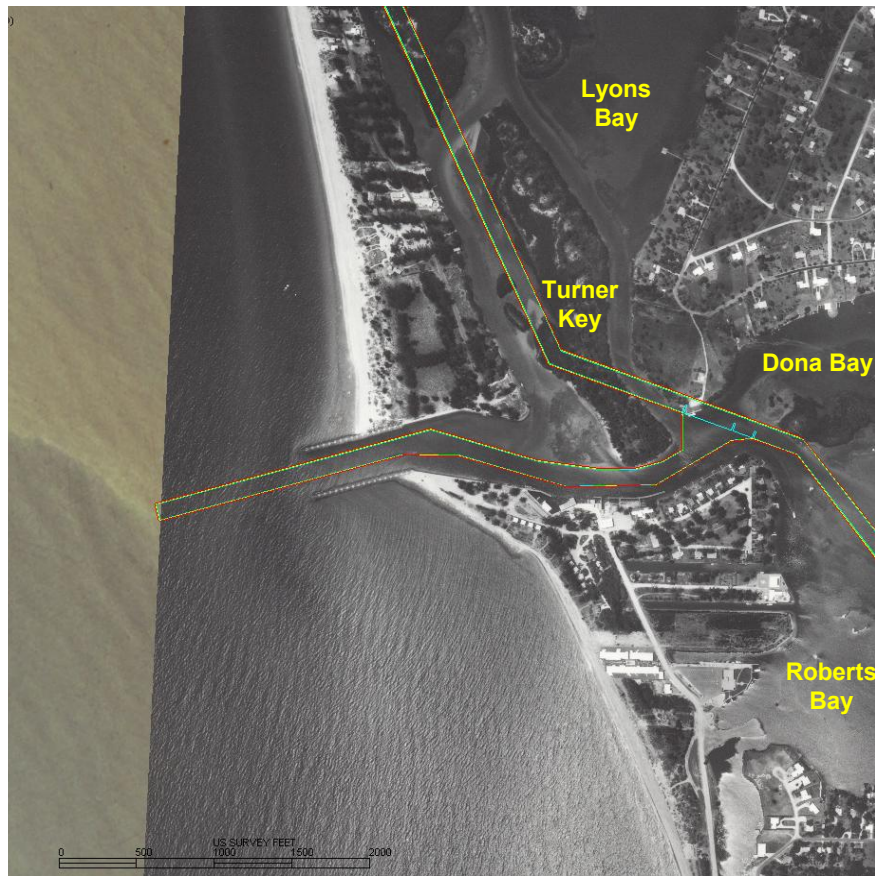
**Figure 4.1** shows the present conditions of Venice Inlet and the ICW. The improvements to the ICW were completed in the early 1960's to provide a wider and deeper navigation channel to accommodate increased traffic and for improved safety. A channel was cut across the south end of Turner Key so that the ICW channel to the north would largely be along the west side of Turner Key. The south part of Turner Key that was separated by the ICW dredging became known as Snake Island. **Figure 4.9** shows 1962 and 1969 aerial photos of Venice Inlet illustrating pre and post ICW improvement conditions. The wider and deeper ICW improved hydraulic efficiency of the connection between the Gulf of Mexico through Venice Inlet and northward to Little Sarasota Bay. This resulted in an increase in the tidal prism of Venice Inlet. The 1969 aerial appears to show less downdrift erosion on south side of the inlet than shown in the 1962 aerial; however, this is the result of placement of 68,000 cubic yards downdrift. The material placed on the downdrift side eroded rapidly returning to pre-nourishment conditions.

#### Closure of Midnight Pass

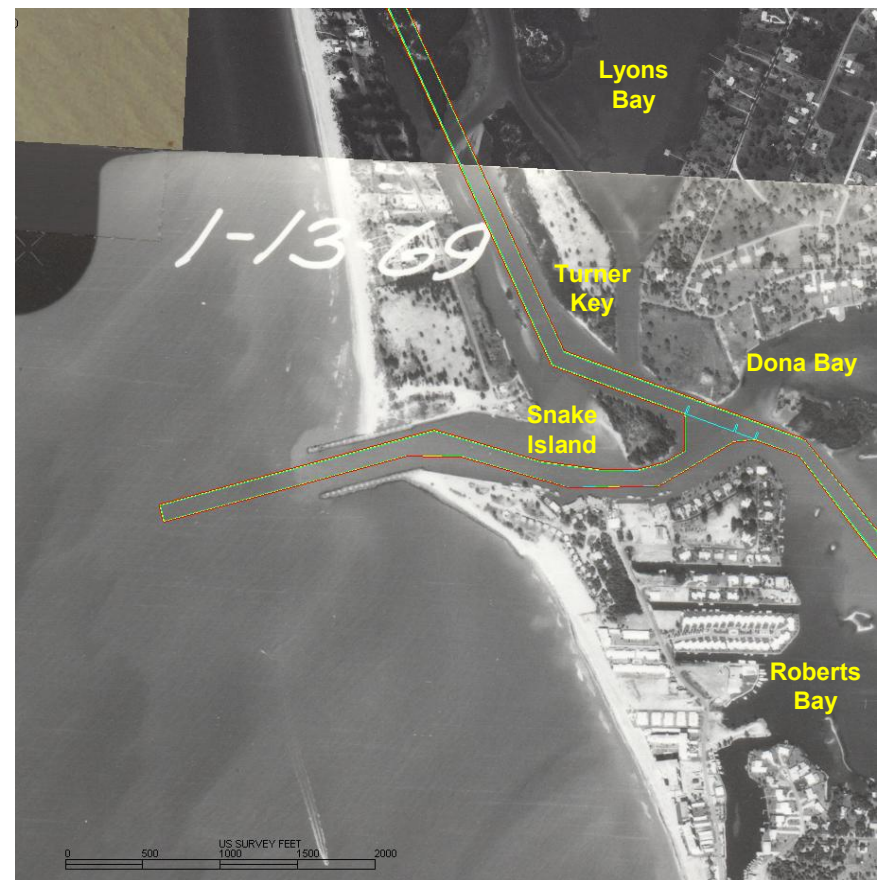
As discussed in the regional modeling section, the navigation improvements at Venice Inlet and the ICW provided a deeper shorter channel between the gulf and Little Sarasota Bay, and the phase of the tide at Venice Inlet is typically slightly ahead of Midnight Pass. This resulted in drawing an increased tidal prism through Venice Inlet and a smaller share of the tidal prism through Midnight Pass. The decrease in tidal prism could have contributed to reduced Midnight Pass stability causing sand transport on the ebb shoal to be dominated by waves rather than tides. The inlet nearly closed following the 1983 El Nino extra-tropical storms, and the unstable migration of the inlet began to threaten several homes. As a result a permit was issued to shut off the meandering and closing channel, with the stipulation that the channel be reopened at its original location. After several tries, the reopening portion of the project was unsuccessful, and abandoned.

The 1983 storms followed by Hurricane Elena and Tropical Storm Juan in 1985 may have accelerated the tendency for Midnight Pass to close, and the rapid onshore migration of its ebb shoal increased the sand supply to the area that hampered attempts to reopen the channel. The 20-year analysis of sediment transport rates discussed in the regional section and illustrated in **Figure 2.11** confirmed that there were higher than normal sediment transport potential rates associated with the storm activity that occurred during this period. It is likely that these high transport rates and the decrease in tidal prism both contributed to Midnight Pass closure.





**1962 aerial showing Venice Inlet condition  
prior to 1963 ICW improvements**



**1969 aerial showing Venice Inlet condition  
post 1963 ICW improvements**

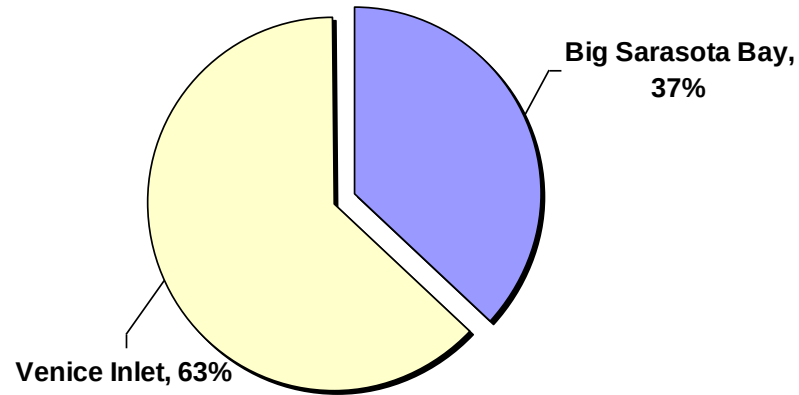
### Regional Hydrodynamics

Modeling the regional hydrodynamics for the present conditions was done to assess the effects of the 1960's improvements to the ICW and the closure of Midnight Pass in 1984. **Figure 4.10** shows the maximum ebb currents for the present condition of Little Sarasota Bay with a detail for Venice Inlet. The figure indicates the approximate limits of the effective bay area governing the tidal prism share distribution to Venice Inlet and Big Sarasota Bay. As discussed previously, the pie chart in the figure also shows the distribution of the tidal prism of Little Sarasota Bay between Venice Inlet and Big Sarasota Bay.

As mentioned above, the ICW improvements at Venice Inlet and closure of Midnight Pass resulted in an increase in the Venice Inlet tidal prism flowing from little Sarasota Bay. The model results indicate that Venice Inlet carries approximately 63% of the tidal prism of little Sarasota Bay which is significantly higher than the 16% share it carried in the 1950's.

#### 4.2.4 Discussion of Modeling Results and Morphological Changes

**Figure 4.11** shows a comparison of the relative amounts of the Venice Inlet tidal prism derived from little Sarasota Bay, and from the other bays closer to the inlet for the three stages modeled. The graph shows that as a result of the ICW development and closure of Midnight Pass, Little Sarasota Bay provides the majority of the flow through Venice Inlet at the present conditions. The total tidal prism of Venice Inlet, including the other smaller bays, was approximately doubled from the 1950's to present conditions. As a result of the increased tidal prism, higher velocities through Venice Inlet extended the ebb jet further offshore. This has resulted in growth in the volume and seaward limits of the ebb shoal as shown in **Figure 4.12** and **Figure 4.13**. The figures also show the contours of the 1992 and 2006 superimposed on the 1995 and 2004 aerial photos of Venice Inlet, and the growth of the ebb shoal as indicated by the relative position of the seaward limits of the ebb shoal.



Little Sarasota Bay tidal prism shares  
Present conditions

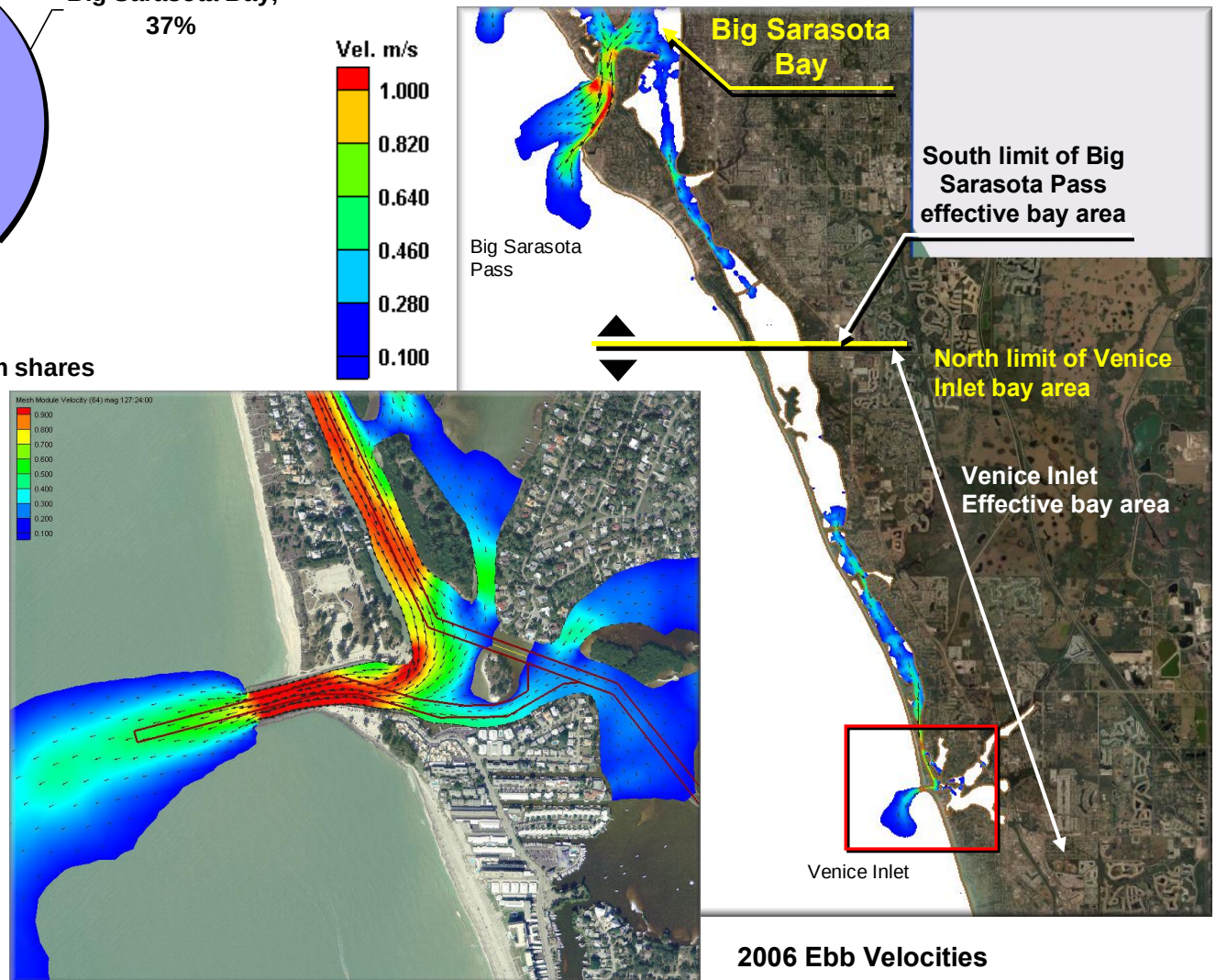
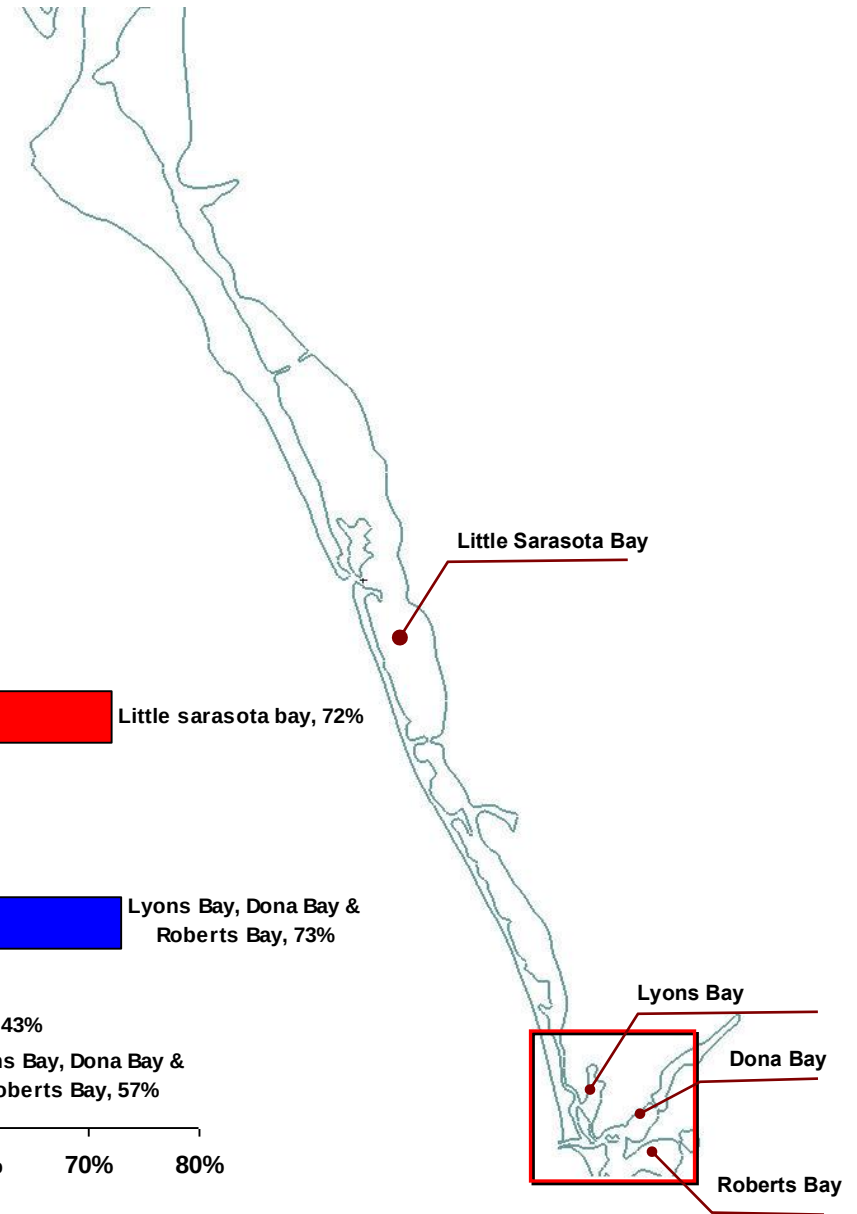
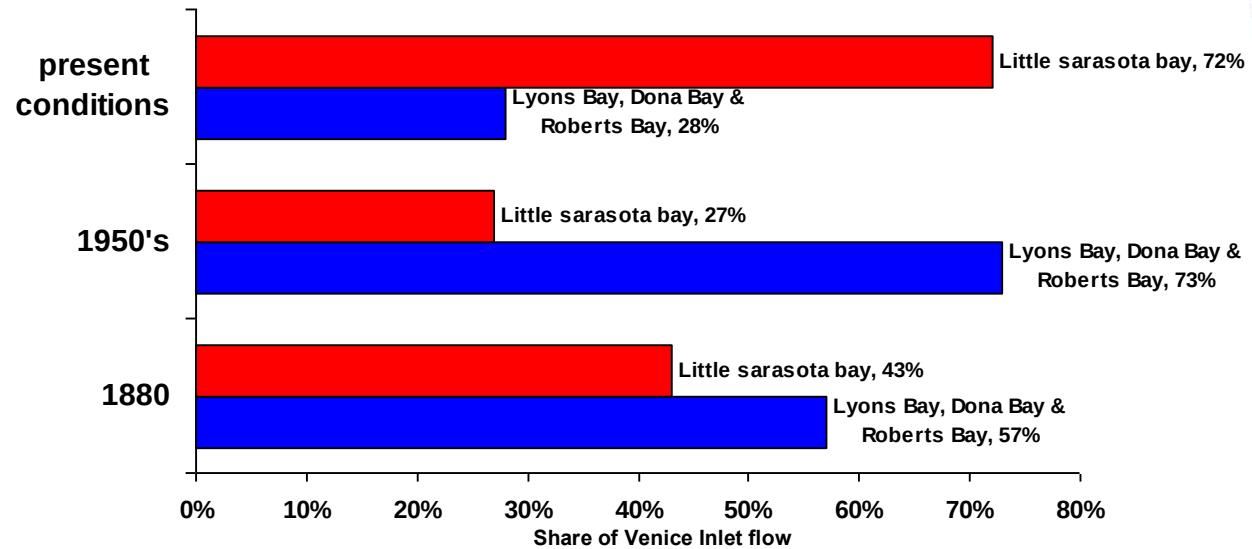


Figure 4.10. Ebb Velocities and Tidal Prism Distribution for Little Sarasota Bay (Present Conditions)

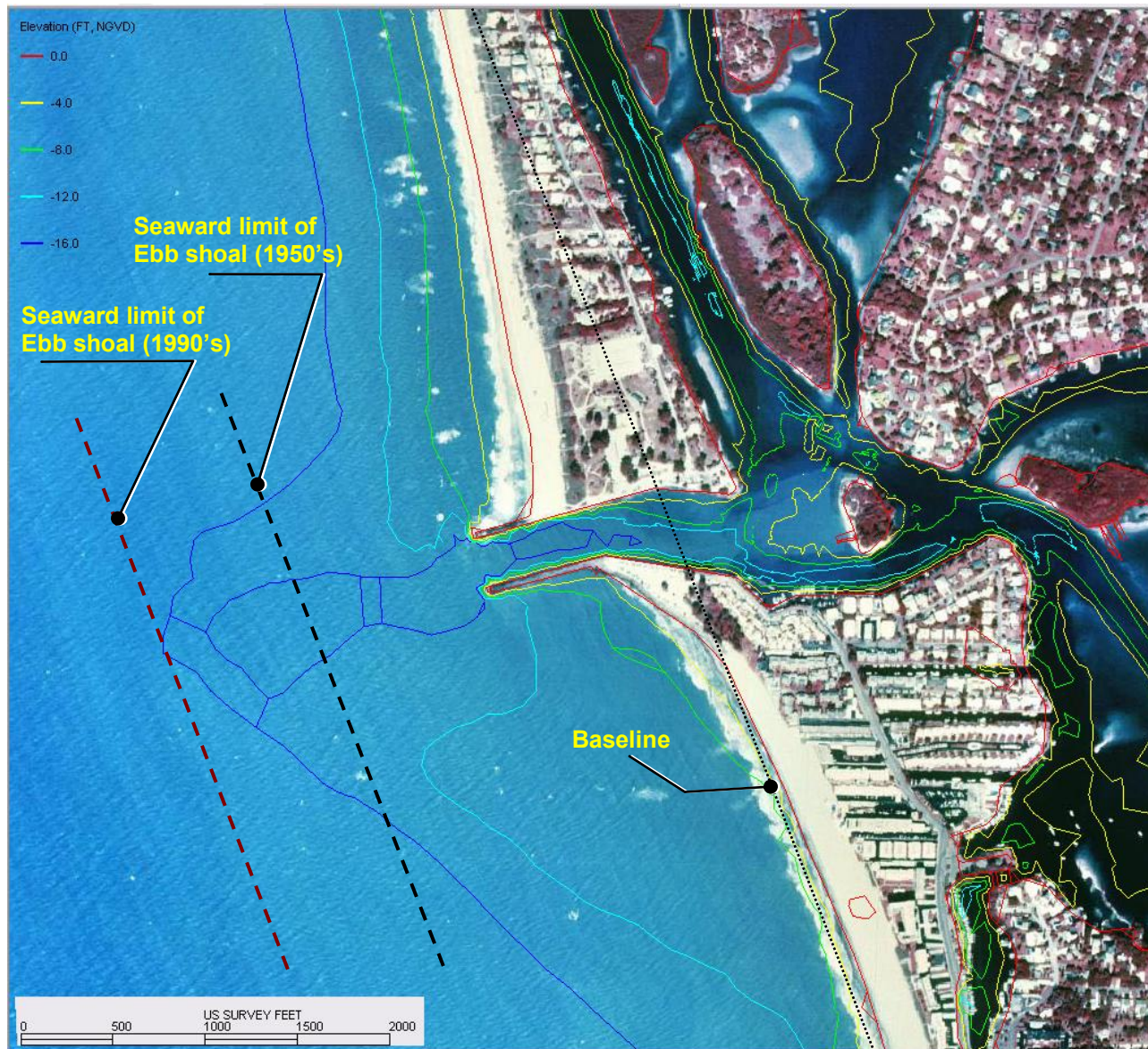




Detail of Venice Inlet

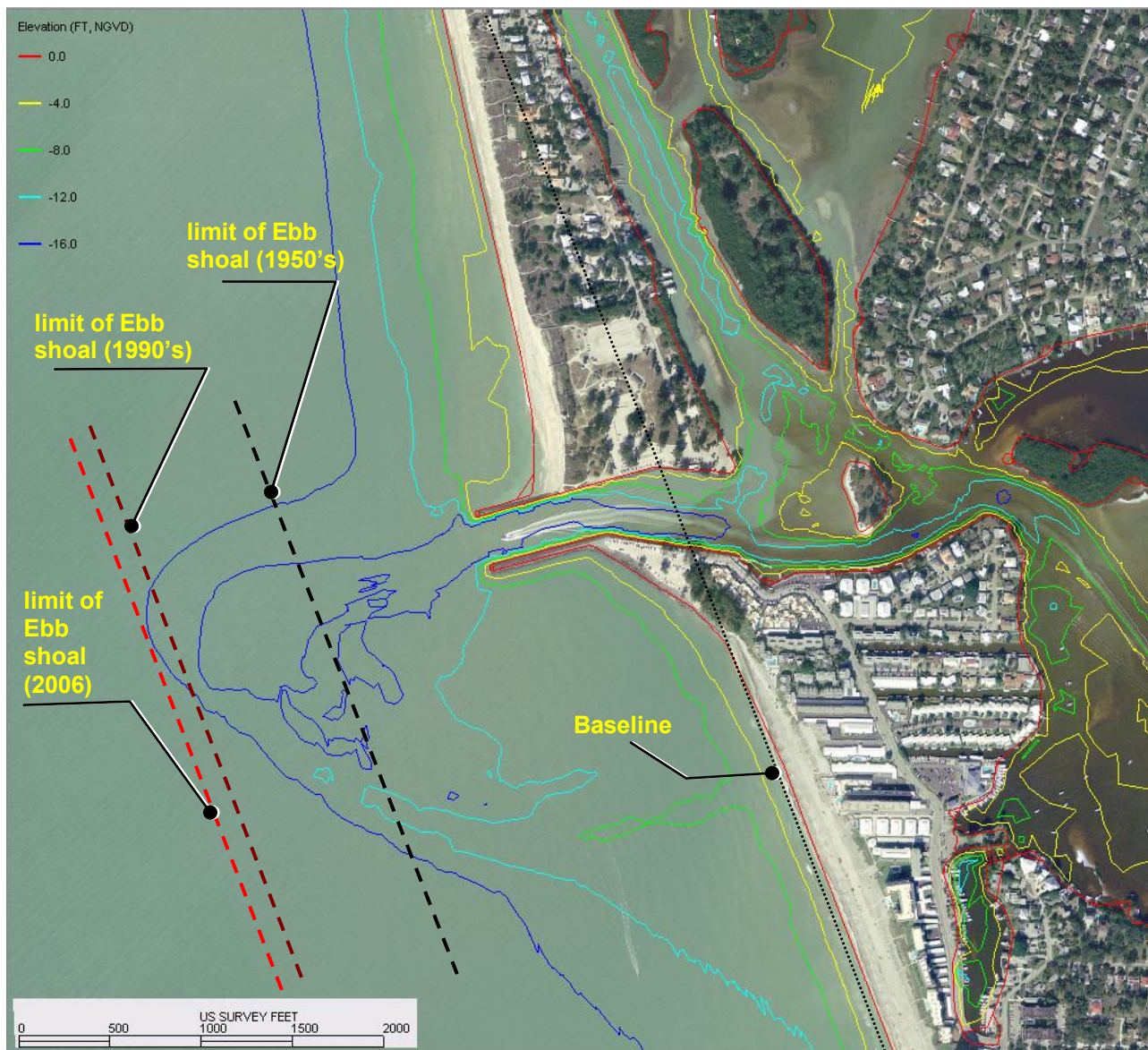


**Figure 4.11 Venice Inlet Tidal Prism contribution from Little Sarasota Bay compared to the combined contribution of Lyons Bay, Dona Bay and Roberts Bay**



**Figure 4.12. Aerial Photo (1995) and Elevation Contours of 1990's at Venice Inlet**





**Figure 4.13. Aerial Photo (2004) and Elevation Contours of Present Conditions at Venice Inlet**



## Morphology Change

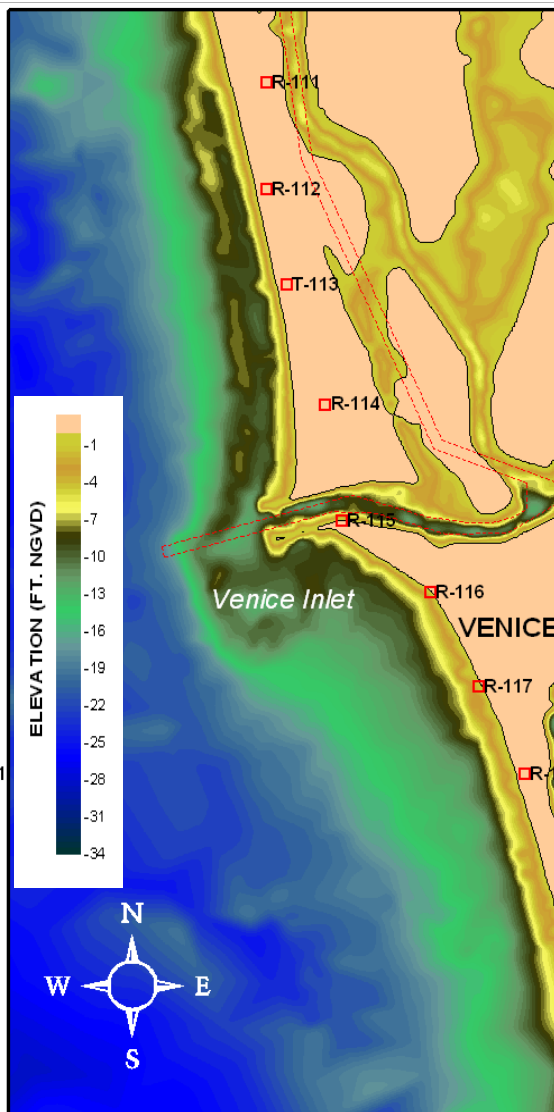
**Figure 4.14** shows the evolution of Venice Inlet through a comparison between hydrographic surveys from the 1950's, and present conditions. The figure shows the growth of Venice Inlet ebb shoal in volume and area.

The authorized navigation channel is superimposed on the 1950s and 2006 bathymetry in **Figure 4.14** to indicate the extent of the ebb shoal growth. When the channel was authorized in the 1940's, it was extended to deep water beyond the seaward limit of the ebb shoal. Present conditions show the ebb shoal has now grown to a point seaward of the original west end of the navigation channel. As the larger ebb jet extended the ebb shoal further offshore, additional sand accumulated in deeper water to extend the ebb shoal to the west, and form a broader bypassing bar extending southward from the ebb shoal.

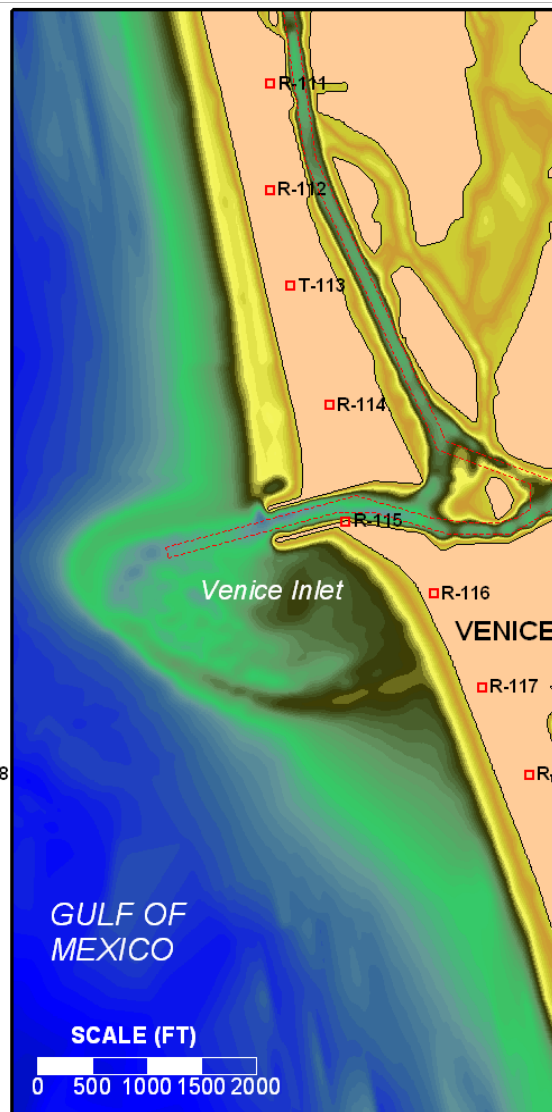
Since the inlet position was fixed with jetties in the 1930's, the increase in tidal prism and current velocities resulted in scouring the portions of the inlet ebb and flood channels close to the throat of the inlet. Sediment deposition occurred where velocities decrease as the plume spreads further from the throat of the inlet, depositing sand offshore and on interior flood shoals.

Morphology change from 1950's to present conditions indicates there was scour of approximately 350,000 cubic yards from Venice Inlet ebb and flood channels. The scour areas extended seaward of the jetties at the entrance to the inlet. The scour also extended on the flood shoal area resulting in erosion of the west side of Snake Island. The deposition areas on the ebb shoal resulted in the growth of the ebb shoal by over 1.5 million cubic yards. This extended the ebb shoal seaward. The bypassing bar which grows from the south side of the ebb shoal extended further south and attached to the beach further south than in the 1950's conditions.

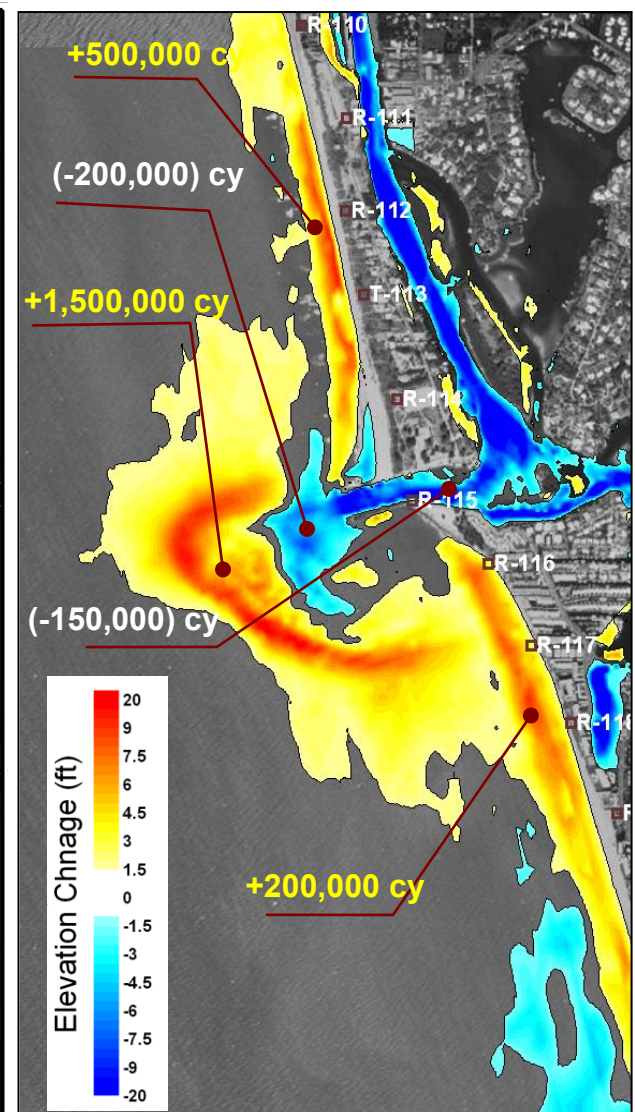
Some of the material carried by the strong tidal currents was deposited on the east side of Snake Island creating critical shoaling within the ICW. **Figure 4.15** shows the model results indicating the locations of potential shoaling. Recent surveys of 2006 and 2007 confirm model findings of areas of critical shoaling in the ICW. Comparison of present conditions and the ICW design template near the time of construction is shown in **Figure 4.16**. Of particular interest are the shoaling areas around Snake Island within the ICW which cause navigation problems. **Figure 4.17** shows the scope of the recent survey data and cross sections at some of the critical shoaling areas, which indicate significant shoaling at sections of the ICW north and east of Snake Island.



1950



2006

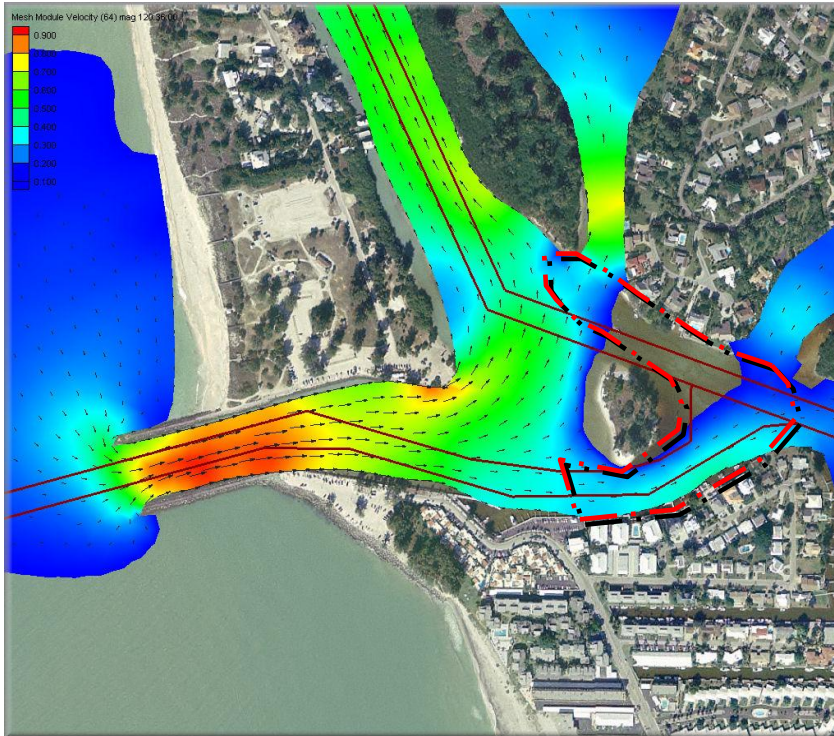


Elevation Change (1950's to 2006)

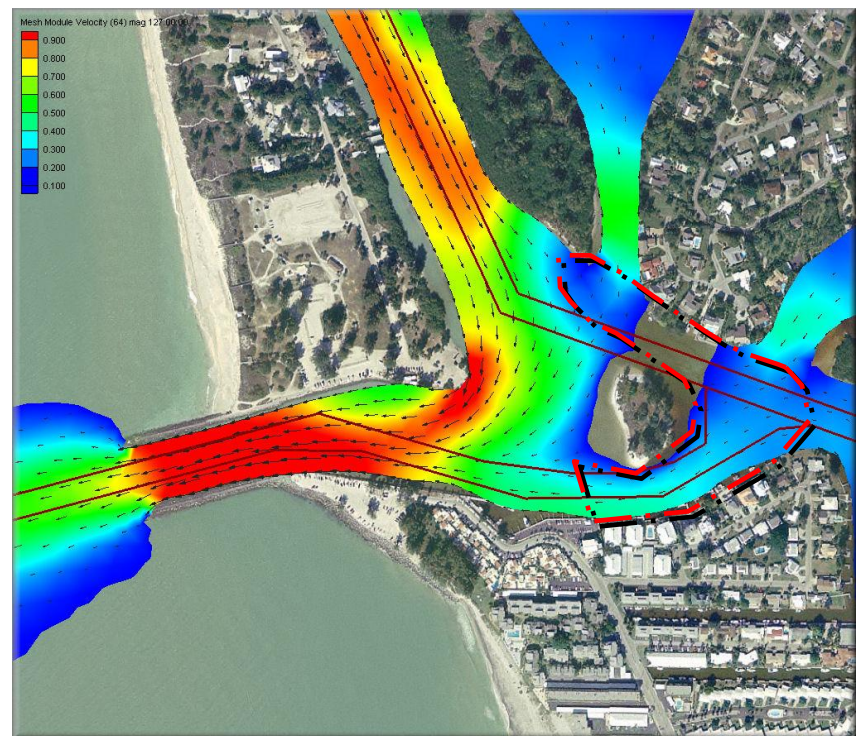
Figure 4.14. Morphologic Change from 1950's to Present Conditions at Venice Inlet



**Flood tide (Present conditions)**

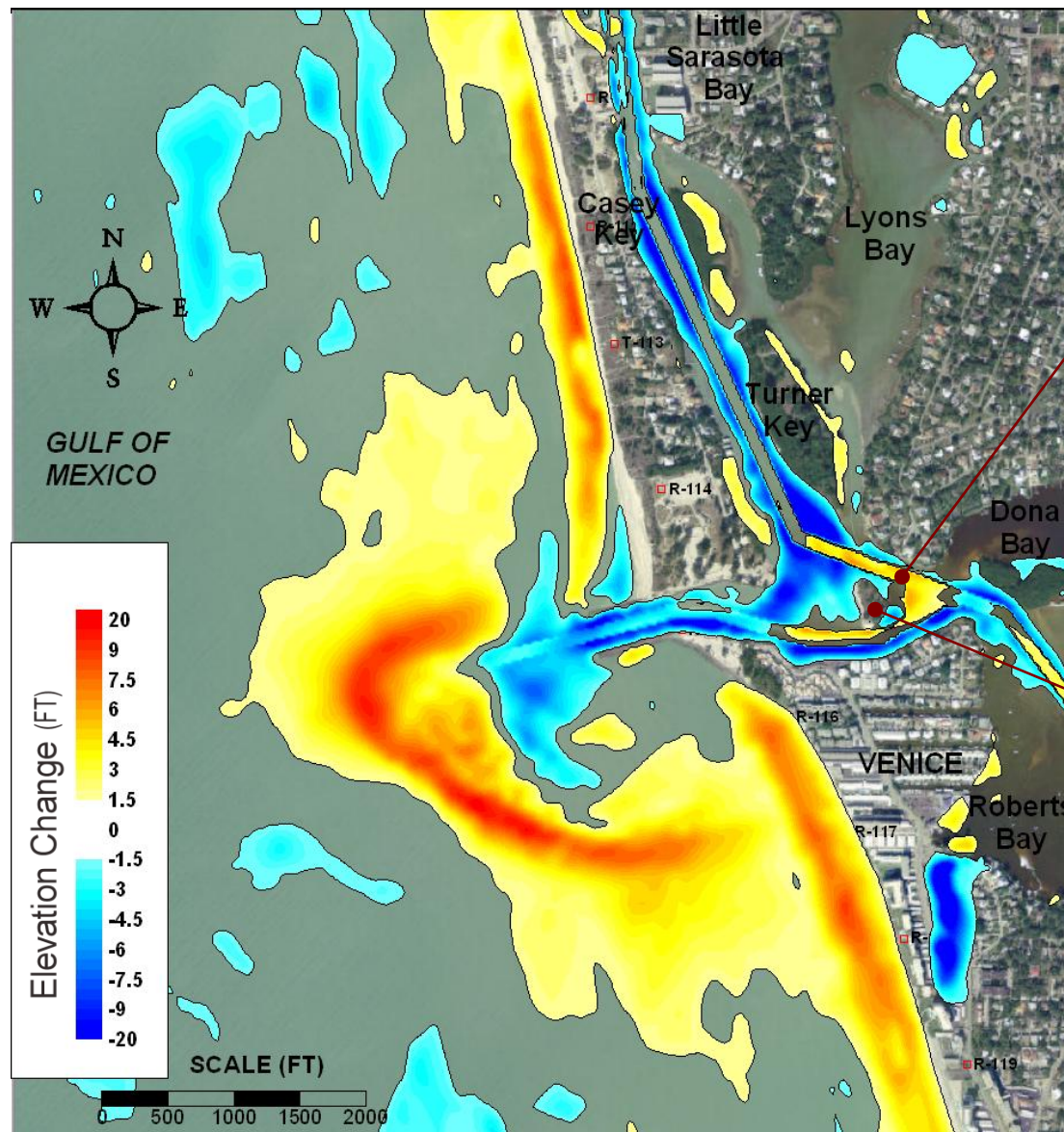


**Ebb tide (Present conditions)**



*Potential Shoaling Area*

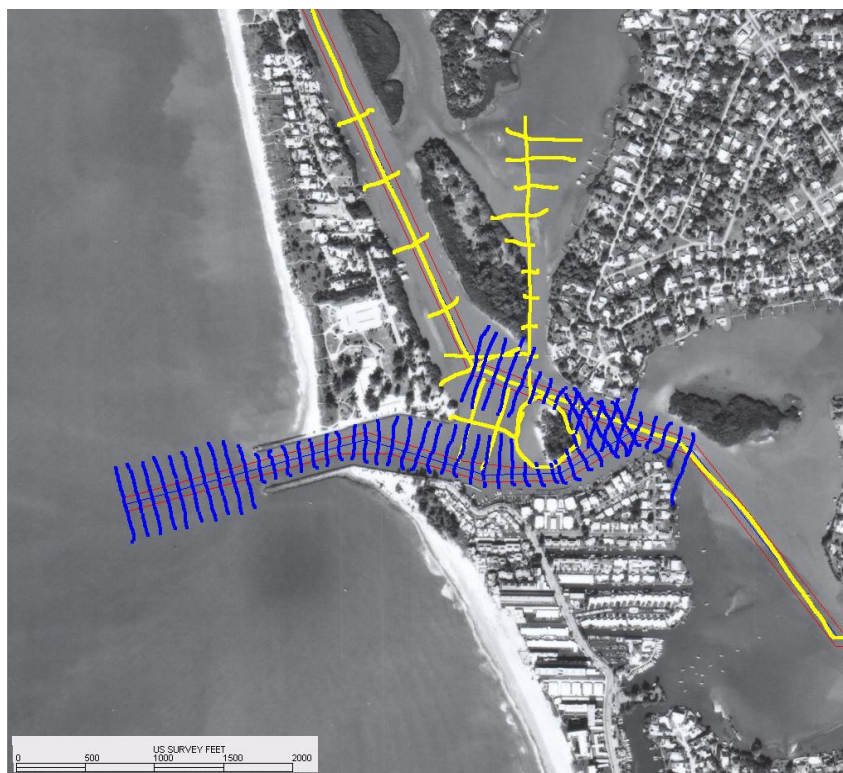




**+30,000 Cy**  
Shoaling near Snake Island in the ICW within Venice Inlet flood shoal since the construction of the ICW in 1963

**Snake Island**

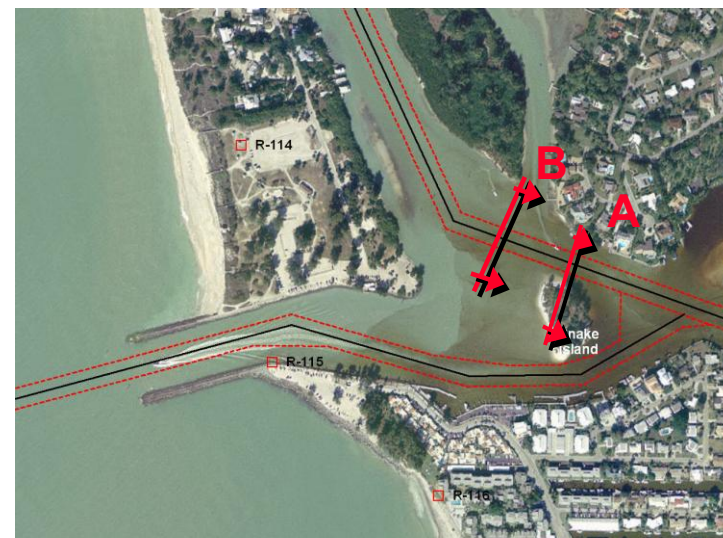
**Figure 4.16. Elevation Change from Post Dredging of the ICW to Present Conditions**



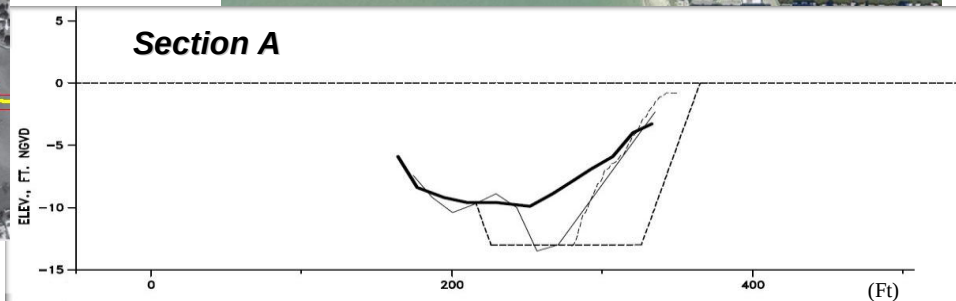
— WCIND Survey 4/26/2007  
 — USACE Survey 2/15/2006  
 — Navigation Channel

#### SURVEY LEGEND

- - - - - 2001  
 — 2003  
 — 2006  
 - - - - - DREDGE CUT



#### Section A



#### Section B

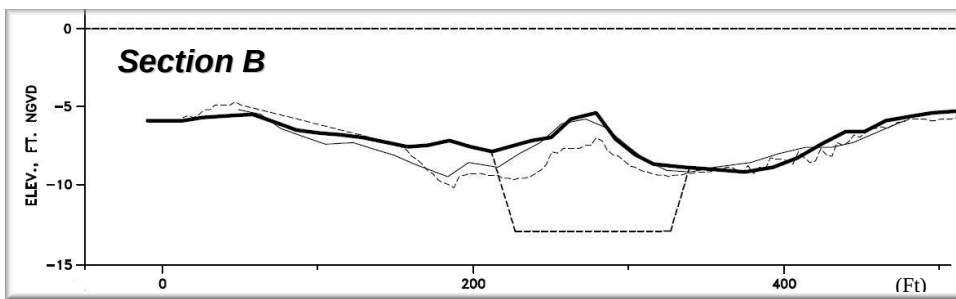


Figure 4.17. Recent Survey Data and Critical Shoaling Cross Sections

### Wave and Current Interaction

Wave and current interaction for 1950's and present conditions were simulated with the model to quantify the change in sediment exchange pattern between morphologic features. **Figures 4.18 and 4.19** show model results of the wave and current interactions for Venice Inlet for the 1950's and present conditions for flood and ebb tides, respectively. The wave input used in the selected cases shown represent storm conditions of 5-foot waves from the northwest which generate transport from north to south. The figures show the flow patterns at maximum ebb and flood tidal currents and the tidal flow interaction with wave driven currents. The figures indicate the effect the improvement of the ICW had on increased tidal prism and tidal currents and how nearshore circulation also expanded.

### Wave Driven Sediment Transport

Sediment transport along the shoreline and nearshore profile was computed for 1950's and present conditions to evaluate the effect on sediment transport from construction of inlet jetties and the resultant changes in the ebb shoal. Transport potentials were computed from breaking waves modeled for each of a series of representative wave conditions. Sediment transport potentials were calculated based on the Kamphuis (1991) formula and probability of occurrence of each case. Results of all cases were grouped to calculate annual longshore sediment transport potentials. Sediment transport computations were performed by calculating the sediment transport potentials across two elevation ranges to provide more detail of the sediment transport patterns near the inlet where the contours are not parallel to the shoreline.

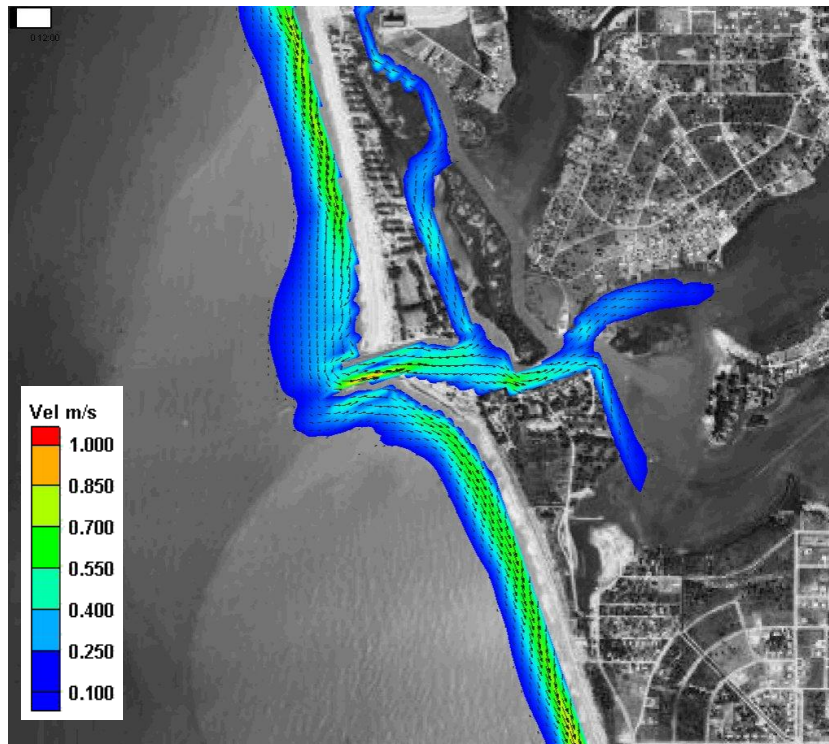
Transport was computed from the shoreline to a depth of 1.5 m, and from 1.5 m depth to seaward limit of the ebb shoal, which is estimated to be the approximate depth of closure. This procedure results in a more accurate estimate of the sediment transport circulation at the ebb shoals.

**Figure 4.20** shows the computed sediment transport potential for 1950's and present conditions. The scaled vectors in the figure indicate the magnitude and direction of the sediment transport. The 1950's results show the effects of the north jetty slowing down the nearshore transport causing sand impoundment on the north side of the inlet. Some bypassing takes place as waves and tidal currents both push sediment. However, the sediment supply downdrift is less than the wave driven downdrift transport. This results in downdrift beach erosion. These results show the effects of the jetties and ebb shoal growth. Bypassing now occurs further offshore on a larger ebb shoal in deeper water, and sand bypassing the inlet attaches to the beach further south than the 1950's conditions.

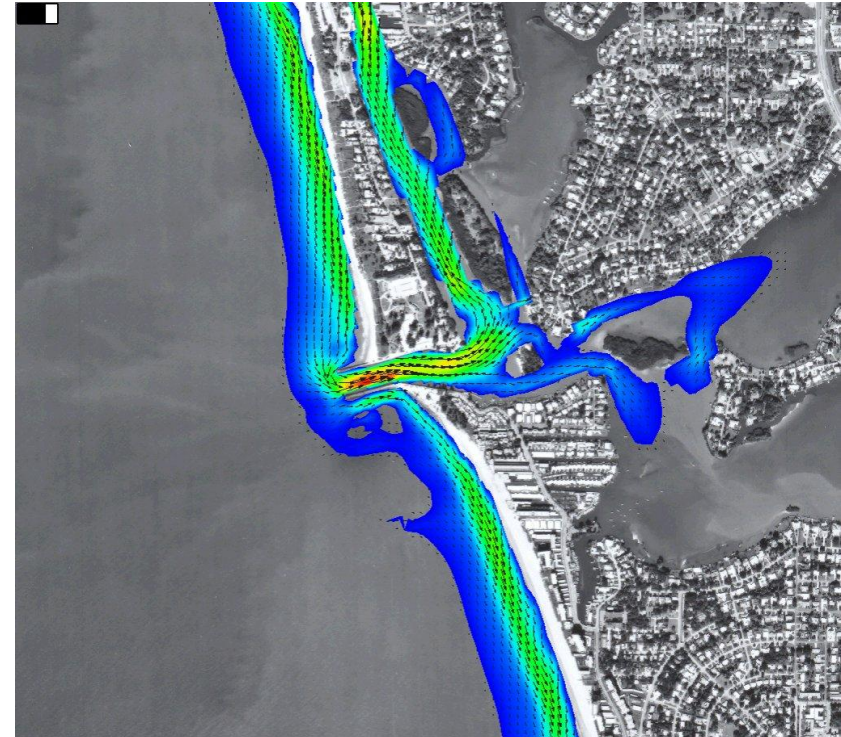
Nourishment of Venice Beach is part of Venice Inlet management to mitigate for the inlet downdrift effect. Sand dredged from the inlet channels is placed on the downdrift beach, and Venice Beach was also nourished in 1994, 1996, and 2005 with sand from an offshore borrow source.



**Current velocities of wave and tidal current interaction at Venice Inlet  
Flood tide condition**



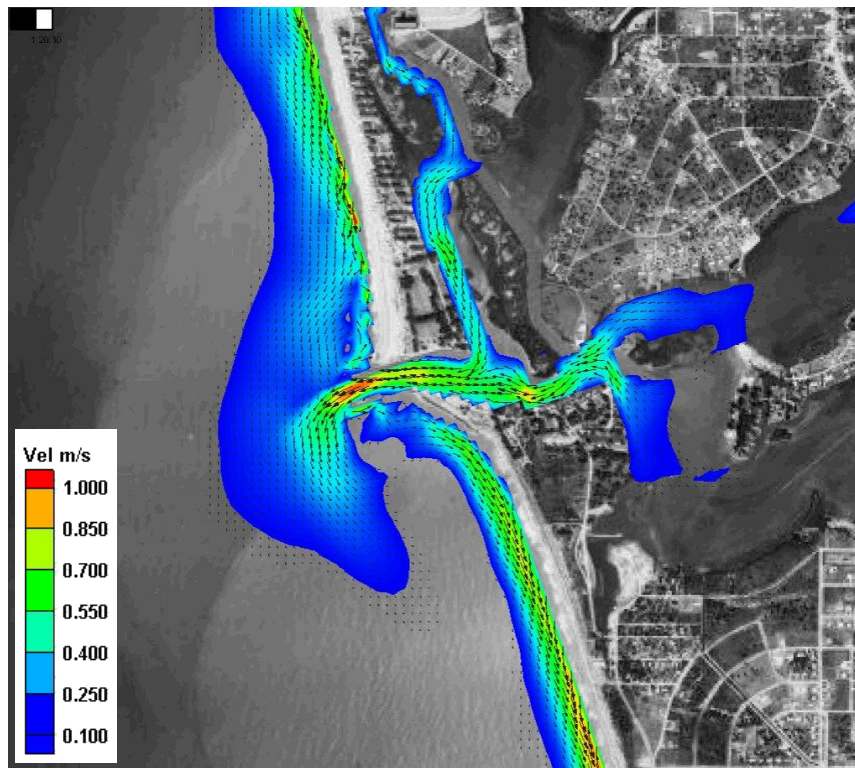
**1950's**



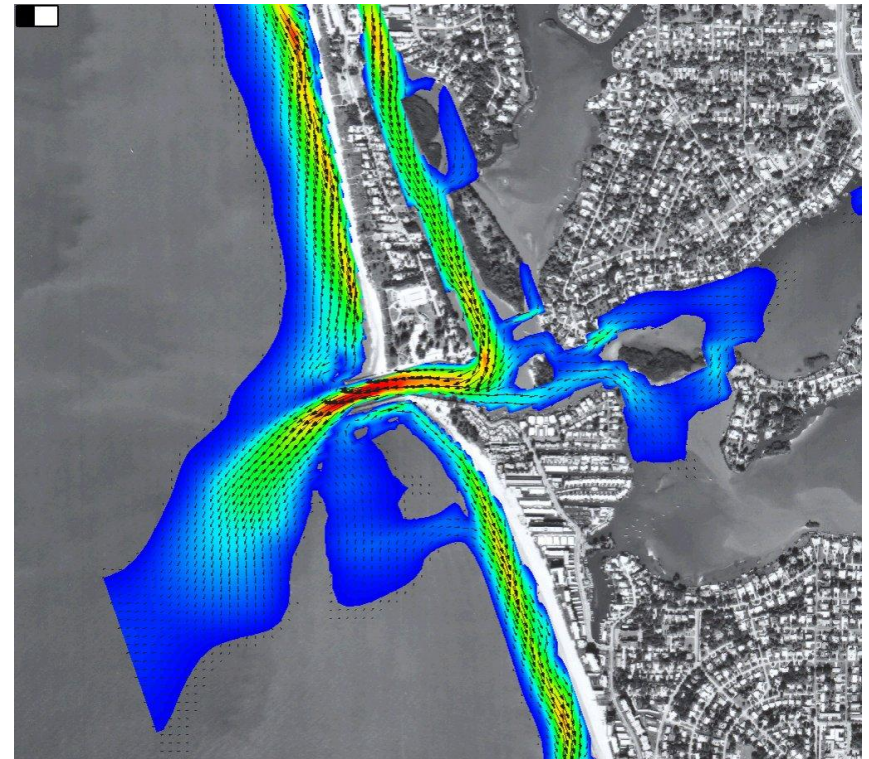
**Present condition**

**Figure 4.18. Model Results of Wave and Current Interaction at Venice Inlet at Flood Tide**

**Current velocities of wave and tidal current interaction at Venice Inlet  
Ebb tide condition**



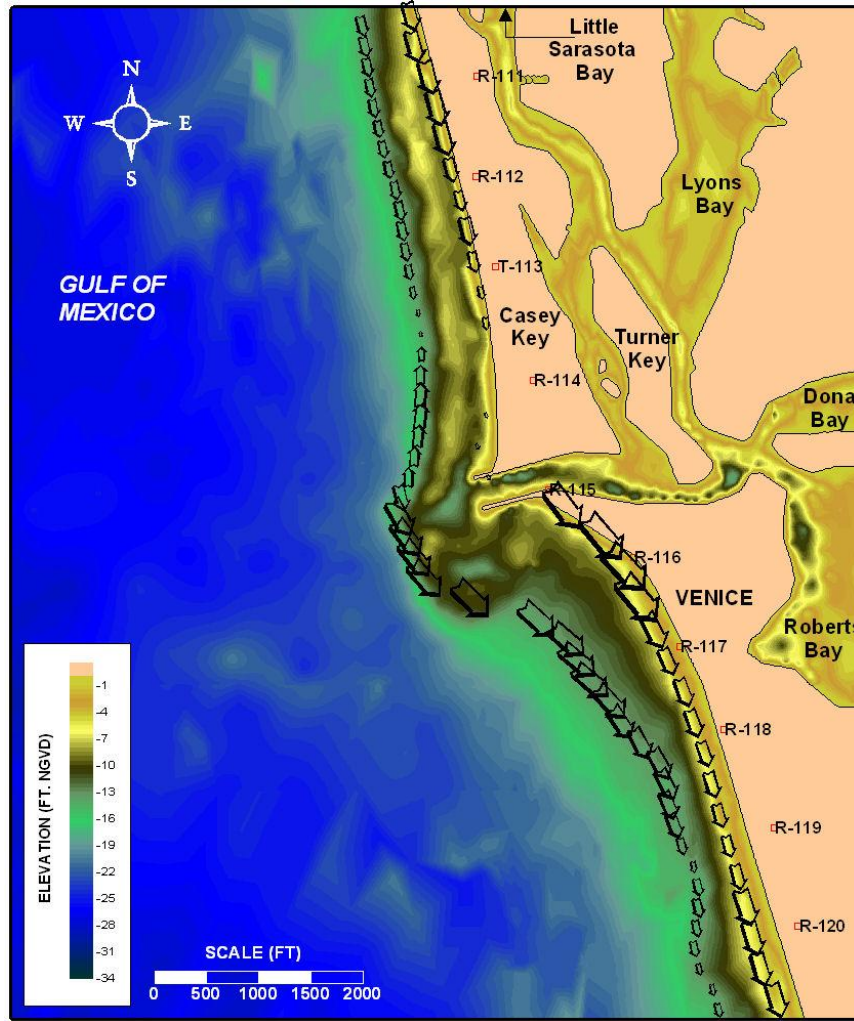
**1950's**



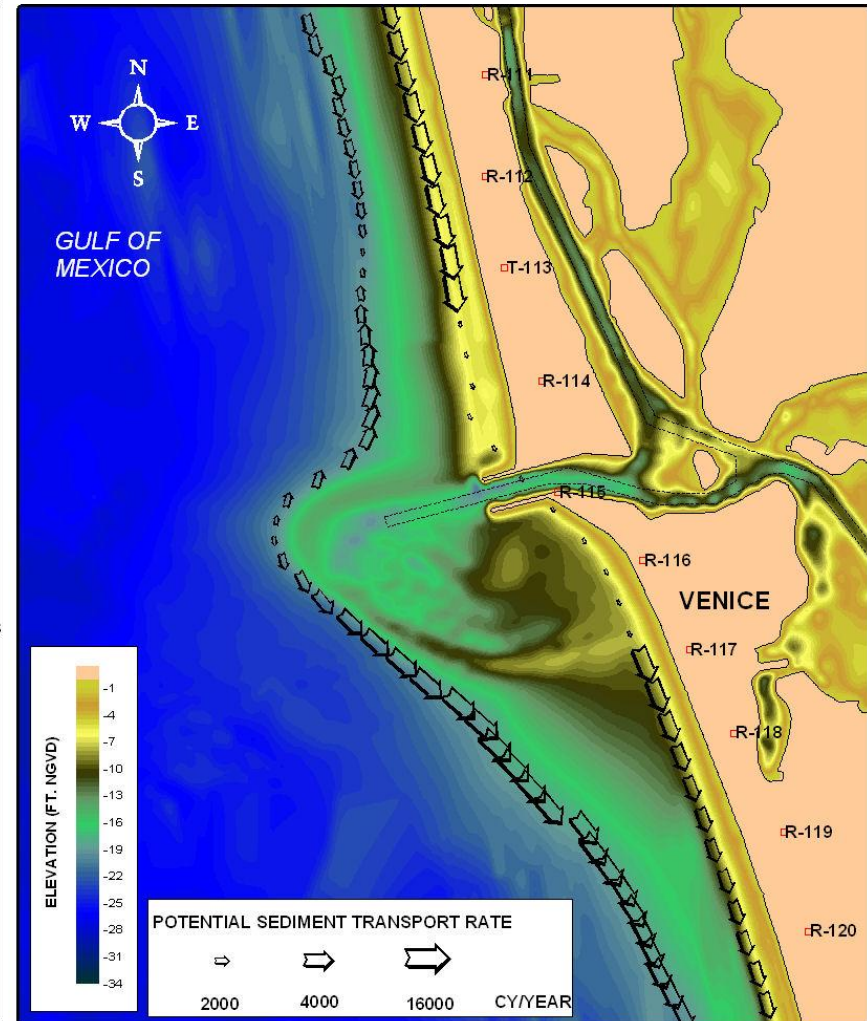
**Present condition**

**Figure 4.19. Model Results of Wave and Current Interaction at Venice Inlet at Ebb Tide**





1950's



Present condition

Figure 4.20. Model Results of Wave Driven sediment Transport Potential at Venice Inlet



### 4.3 Inlet Reservoir Model Analysis for Venice Inlet

The Inlet Reservoir Model calculates sediment transport rates and volume change of identified morphologic features and bypassing rates for an inlet. It is applied here for the Venice Inlet tidal shoal complex. The first step is to identify sediment pathways across the ebb and flood distinct morphologic features that form the shoal complex. In a typical wave-dominated inlet, there would be three distinct ocean-side features: an ebb shoal, bypassing bar, and an attachment bar.

The concept of the Reservoir Model is based on the assumption that each feature has a maximum equilibrium sand-retention capacity that cannot be exceeded. The equilibrium capacity is primarily a function of tidal prism and potential sediment transport to the inlet; however it may also be influenced by inlet geometric changes such as those brought about by construction of jetties.

Once a feature has reached equilibrium capacity, all additional sediment transport to that feature will bypass to the next feature(s), until sediment eventually arrives at the downdrift side of the inlet, or is deposited in another location such as the channel or flood shoal. If a morphologic feature is partially full, it still provides partial bypassing, and the degree to which bypass occurs is a function of how close the feature is to its equilibrium size.

The Inlet Reservoir Model therefore calculates growth of the shoals as a function of the littoral drift and equilibrium volumes of the shoals. It accounts for the long timescales of large morphologic feature changes and time delays in exchange of material between the features. It may therefore be used to estimate how dredging of an inlet shoal may affect bypassing, and how long it will take for a shoal to reform after dredging. Further information on the Inlet Reservoir Model can be found in Kraus (2000a, 2000b, 2002).

#### 4.3.1 Inlet Reservoir Model Setup

The Venice Inlet ebb and flood shoal system has a history that is more complex than that of a typical inlet. The complexity is the result of changes in tidal prism over time, and the resulting changes in the equilibrium volume for the various shoal features. This complicates the analysis because the Reservoir Model assumes constant equilibrium volumes for each feature. To overcome this limitation, the modeling was divided into two stages corresponding to different periods and corresponding tidal prisms. The first stage, 1937-1963, is the period starting with the stabilization of the inlet with the construction of the jetties in 1937. The second stage, 1964-2040, is following the 1963 ICW improvement which significantly increased the tidal prism and ebb shoal volume.

The wave data, sediment transport and tidal hydrodynamic modeling, in addition to the bathymetric data, were evaluated to define sediment pathways for each stage of Venice Inlet evolution. Based on the CMS modeling results and documented

elevation change, the sediment pathways and morphological features are represented as illustrated in **Figures 4.21 and 4.22** for each of the two temporal stages. Sediment pathways for the both north and south transport direction were included in the model to account for all sediment inputs to the inlet system.

Sediment transport inputs for both directions were calculated with the ONELINE model (Dabees and Kamphuis 1998) using the 20 years (1980-1999) of wave data from WIS station 277. Annual average potential transport rates were computed for the 20-year record. Additionally, high and low potential sediment transport rates were computed based on the 20-year average rates and standard deviations to account for sediment transport variability. The model was run using the three input rates for each temporal stage.

The bathymetric data considered together with the modeling results defined the distinct morphologic features in the system. For both temporal stages of the inlet evolution, the following features have been present: jetty impoundment, an ebb shoal, flood shoal, bypassing bars north and south of the inlet, and downdrift shoal or attachment bar on the south side of the inlet.

The ebb shoal was divided in two features in the second stage to simulate the shoal migration offshore as the tidal prism increase created a stronger ebb jet pushing sand further offshore. In addition, the flood shoal was divided into multiple features for the second stage. Flood shoal features included ICW channel, shoals around and including Snake Island, and Little Sarasota Bay channel as shown in **Figure 4.22**. The multiple features of the flood shoal allow for evaluating alternatives for dredging the ICW.

The equilibrium volume of each feature was determined based on comparisons of available surveys and calculated volumes and rates of change for each feature. Although the features have varied somewhat in shape, location and size, they have been distinct in all available surveys and aeriels. The input sediment transport rates were specified based on the sediment transport computations for each time period.

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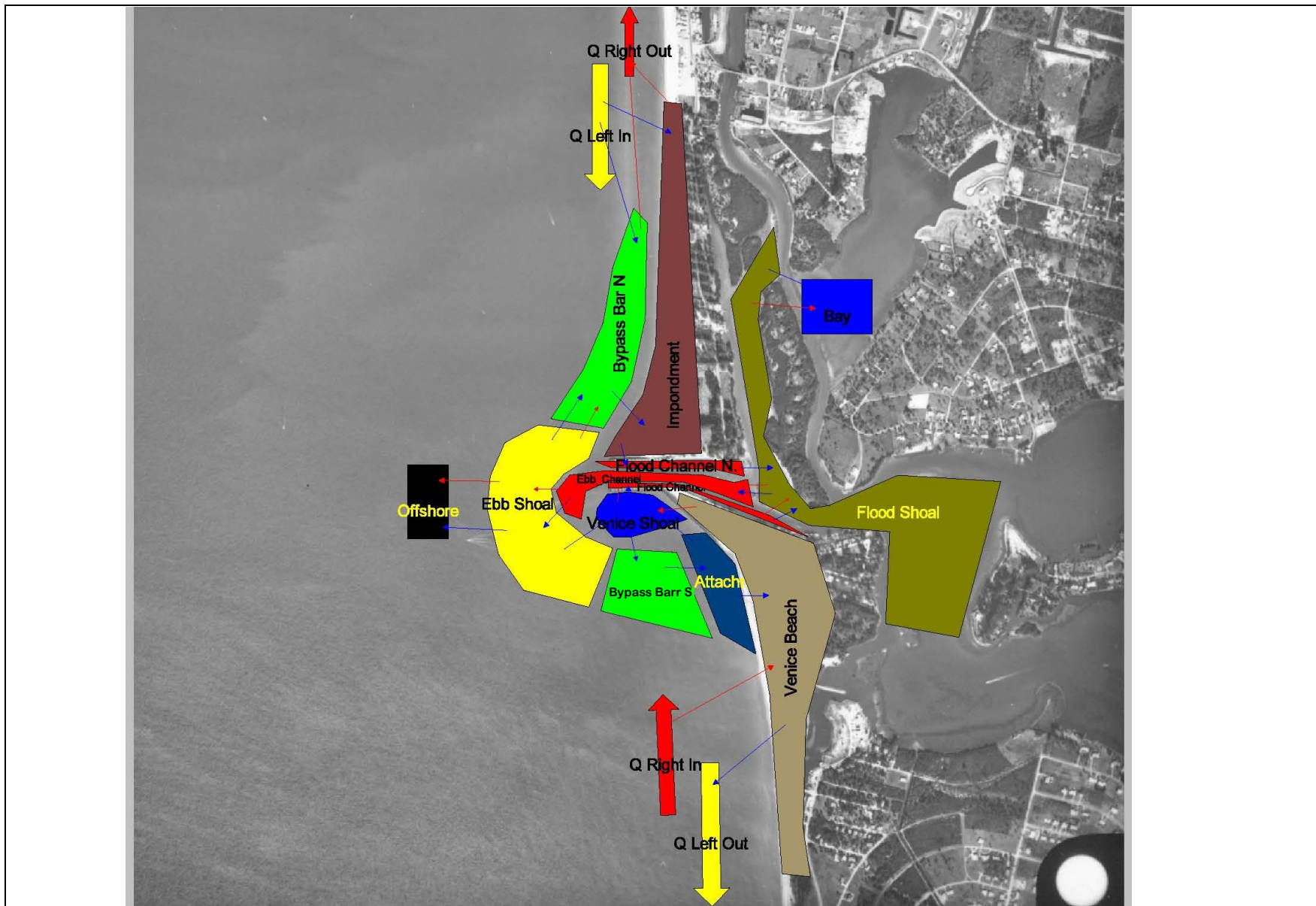
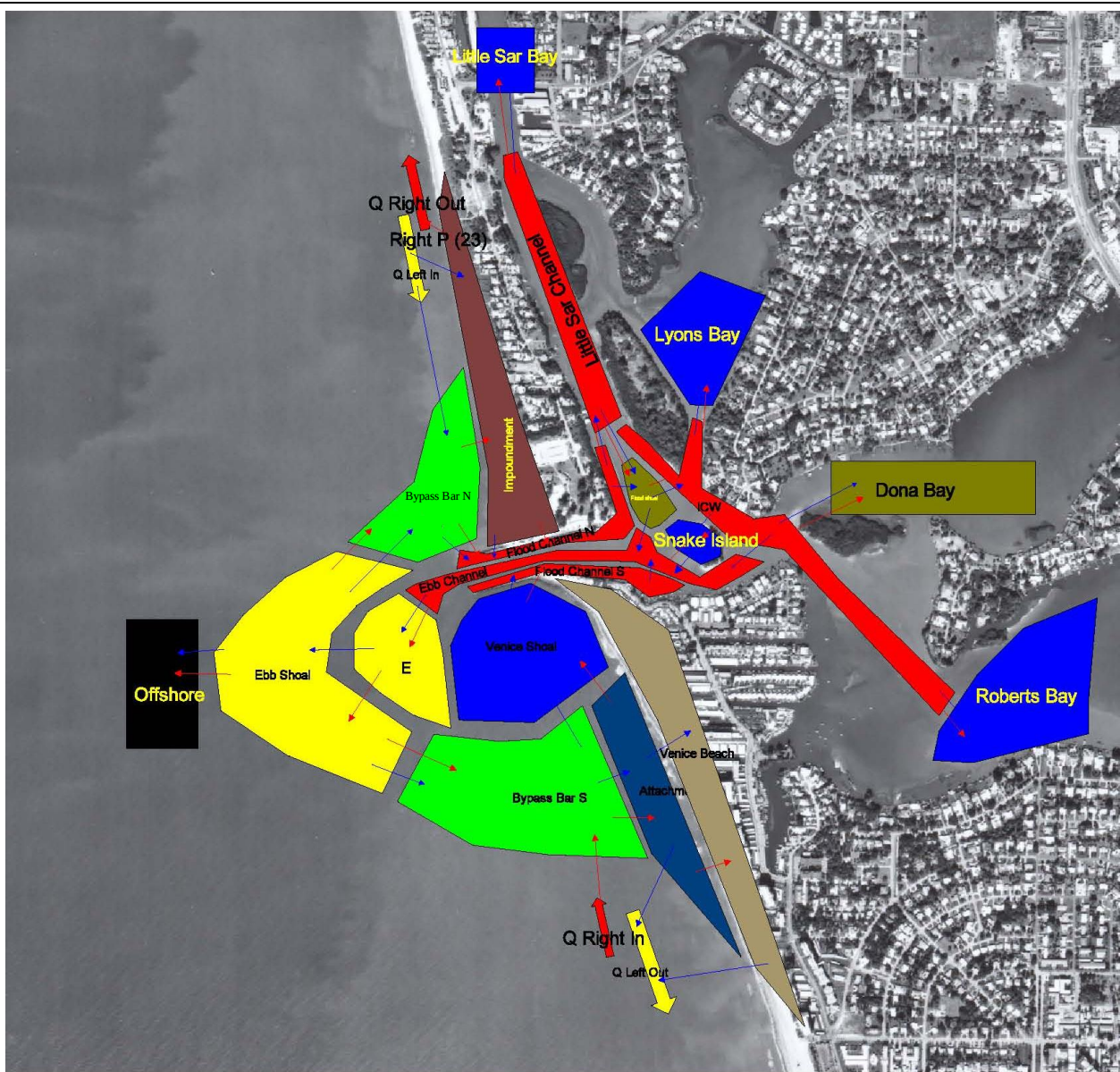


Figure 4.21. Inlet Reservoir Model Setup 1937-1963





**Figure 4.22. Inlet Reservoir Model setup 1964-2060**

#### 4.3.2 Inlet Reservoir Model Results

**Appendix 4.B** contains figures showing model results for each of the morphologic features. The results show the calculated volume for each feature for average, maximum and minimum potential sediment transport rates. The figures also show the actual measured volume at times when data was available. Calculated volumes show good agreement with the observed and measured volumes and trends. The results describe the variation in volumetric change in response to the change in tidal prism after the ICW improvements of 1963.

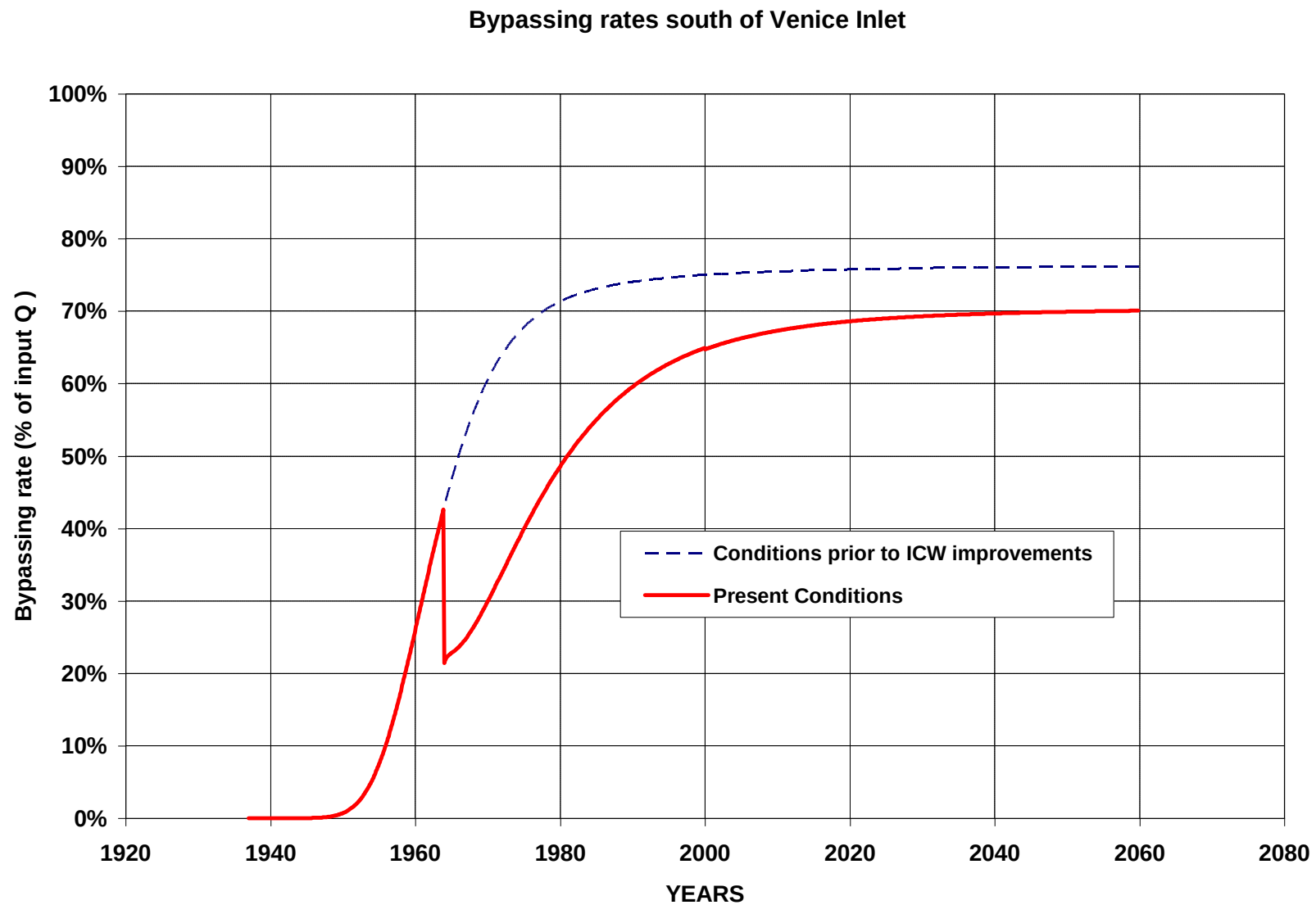
##### Venice Inlet Bypassing

**Figure 4.23** shows the model results for sediment transport bypassing to the south side of Venice Inlet. The figure shows the bypassing rates relative to the average southward sediment transport reaching the inlet from the north. **Figure 4.23** also illustrates the effects of the 1963 ICW improvements on bypassing through a comparison of model results with a projection of what would have occurred had the conditions prior to the 1960's development persisted. The model results indicate the time lag in bypassing as the rates did not reach 10% of sediment input until after 1955, 18 years after the jetty construction. The sand deficit during the early decades after the jetty construction resulted in erosion downdrift of the inlet.

As the ebb shoal was developing, the bypassing rates gradually increased. Prior to the 1960's ICW development, as the ebb shoal was reaching its equilibrium to the tidal prism of the 1950's, sand bypassing to the downdrift was approximately 43% of the average littoral drift input from the north. Following the ICW development in 1963, the ebb shoal capacity to hold sand increased as a result of the increased tidal prism. Consequently the bypassing rate dropped to approximately 22% of average input. This resulted in an increased sand deficit to the Venice Beach. The bypassing rate then increased gradually as the ebb shoal growth resumed.

**Figure 4.23** indicates that at present time (year 2008), as the ebb shoal approaches its equilibrium volume the bypassing rates are near 67% of average littoral drift input from the north. Although the leveling of the ebb shoal growth volume indicates that it is near equilibrium, the bypassing does not level to 100%. The bypassing deficit after the ebb shoal reaches equilibrium is due to losses offshore and flood shoal areas, including the ICW. The figure also indicates decrease in the sand bypassing rate at equilibrium compared for conditions prior to the ICW development. The increase in offshore and bay sediment deposition results in the decrease in the maximum level of sand bypassing shown in the figure.

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**Figure 4.23. Inlet Reservoir Model Results of Bypassing Rates for Southward transport at Venice Inlet**



### Venice Inlet Ebb Shoal

**Figure 4.24** shows the model results for total ebb shoal volume, including all of the shoal features that make up the ebb delta. The figure shows the volume of the ebb delta from 1937, when the Venice Inlet was stabilized by two jetties, through the increase of tidal prism in 1960's, present conditions, and projection of future trends. The result indicates reasonably good model agreement with measurement from available surveys, including the increase in ebb shoal volume after the 1960's ICW development. The model results also show the minimum and maximum limits of the ebb shoal volume at any point of time given the documented variability in sediment transport input.

### Venice Beach

**Figure 4.25** shows the model results for Venice Beach on the downdrift side of the inlet. The figure illustrates the high erosion rate of Venice Beach following the construction of the jetties as the ebb shoal was forming. The results also show the effect of the beach fill from major nourishment projects in 1994 and 2005, and show that the model results are in agreement with measurements from available surveys. The figure also indicates the correlation between the erosion rates on Venice Beach and the bypassing rates illustrated in Figure 4.20. The Inlet Reservoir Model results confirm there is a need for periodic beach nourishment at Venice beach to compensate for the deficit in Venice Inlet sand bypassing.

### 4.3.3 Evaluation of Dredging Alternative

The Inlet Reservoir Model was used to evaluate dredging sections of the ICW within the Venice Inlet flood shoal that are subject to high shoaling rates. The proposed alternative evaluated dredging 30,000 cubic yards from the shoaling areas identified in the analysis and shown in **Figures 4.15 to 4.17**. The proposed dredging was introduced in the reservoir model run at year 2008, and the model was then run to evaluate the effects on inlet bypassing rates and time frame of shoaling recurrence.

The model results indicated no significant effect on inlet bypassing rates as a result of the dredging of the shoaling section of the ICW. The shoaling sections are located in areas in the shadow of Snake Island and where small volumes of sand deposit over long periods. The model results shown in **Figure 4.26** indicate that to maintain the ICW with less than 20,000 cubic yards of shoaling in this area, the dredging interval would be between 4 and 10 years.

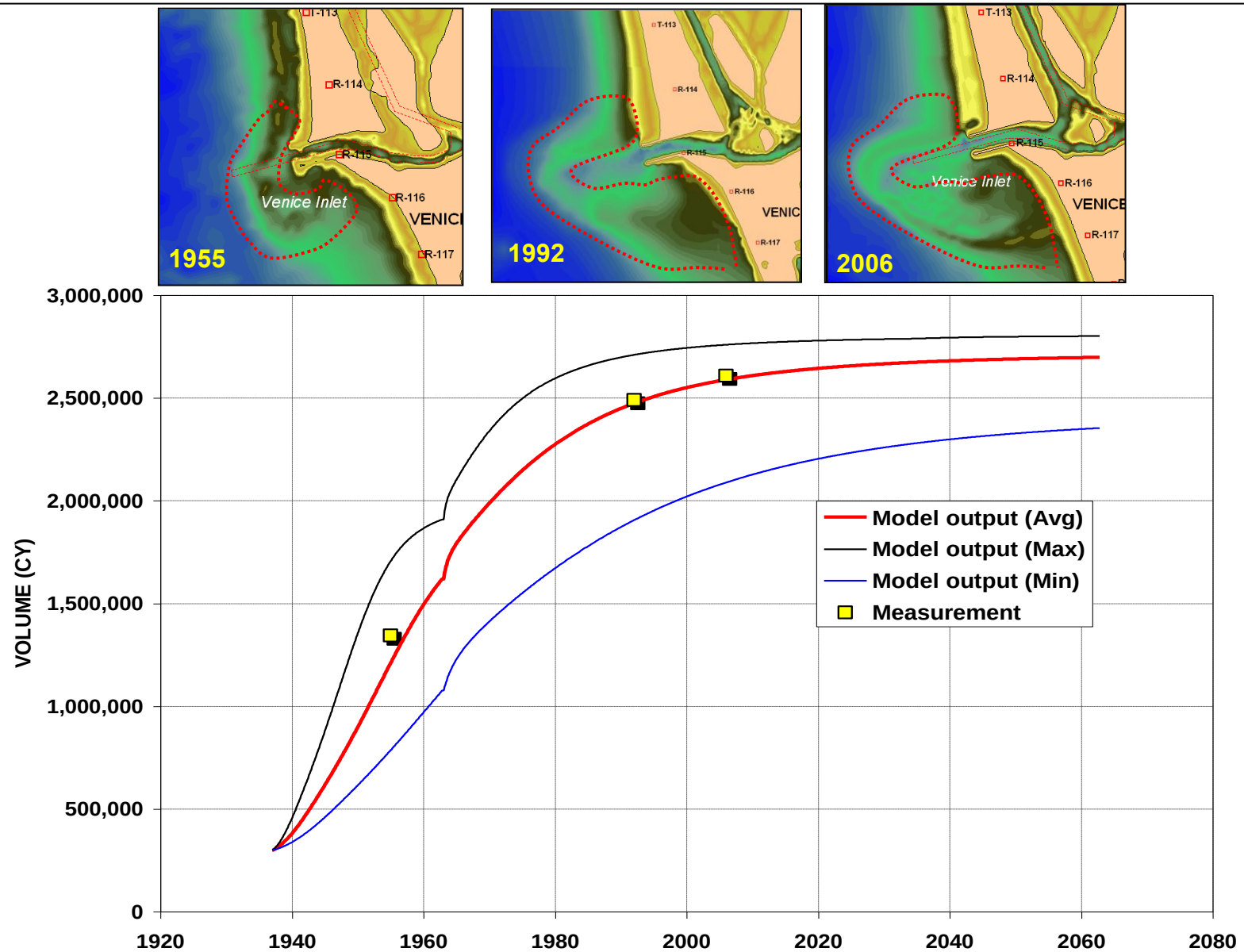
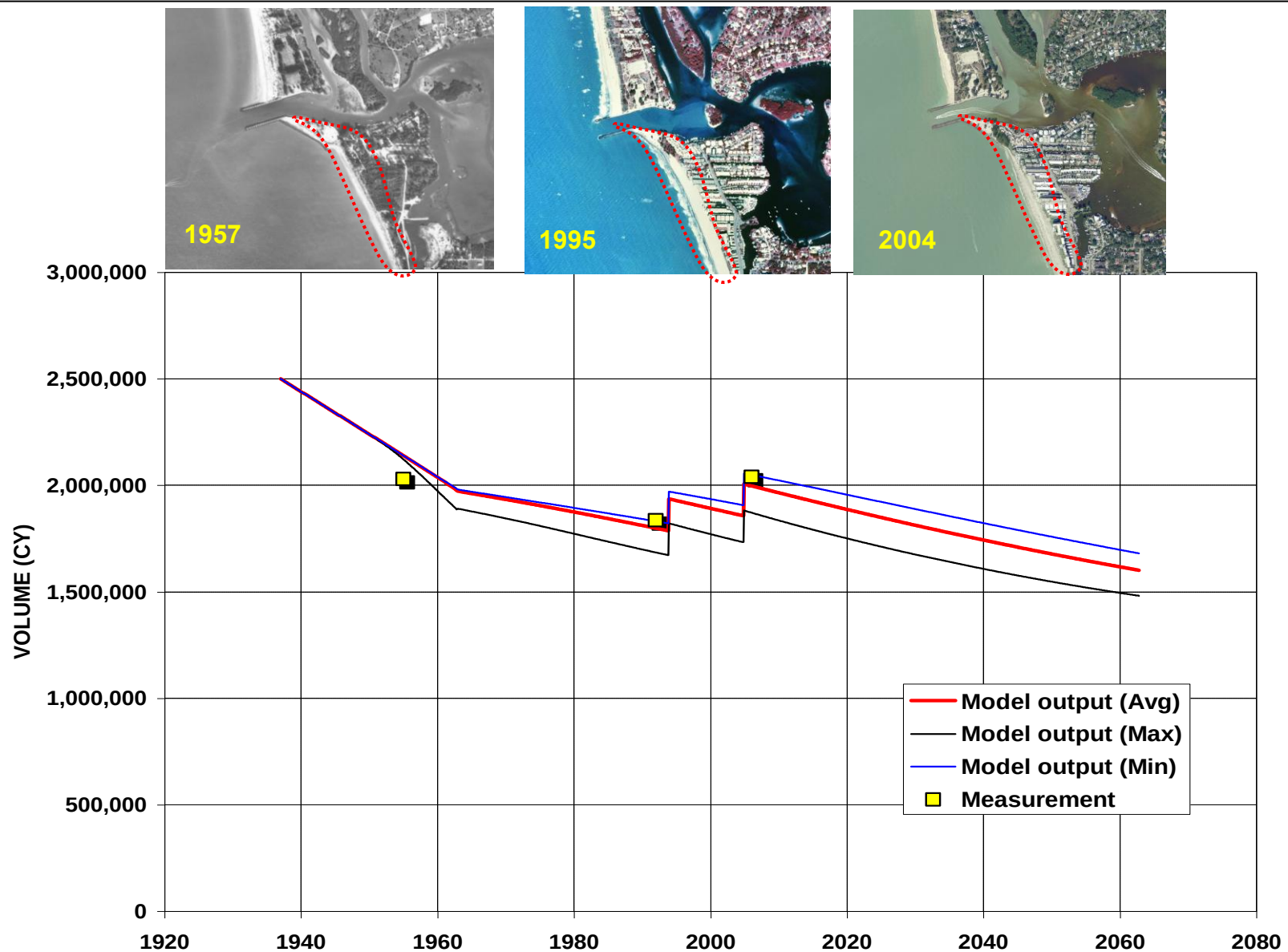
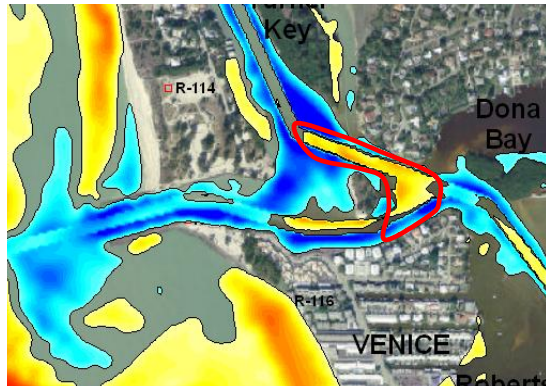


Figure 4.24. Inlet Reservoir Model Results of Total Ebb Shoal Volume for Venice Inlet



**Figure 4.25. Inlet Reservoir Model Results of Venice Beach Downdrift of Venice Inlet**





Venice Inlet Reservoir Model predictions  
shoaling rates post dredging 30,000 cy from critical shoaling areas of the ICW

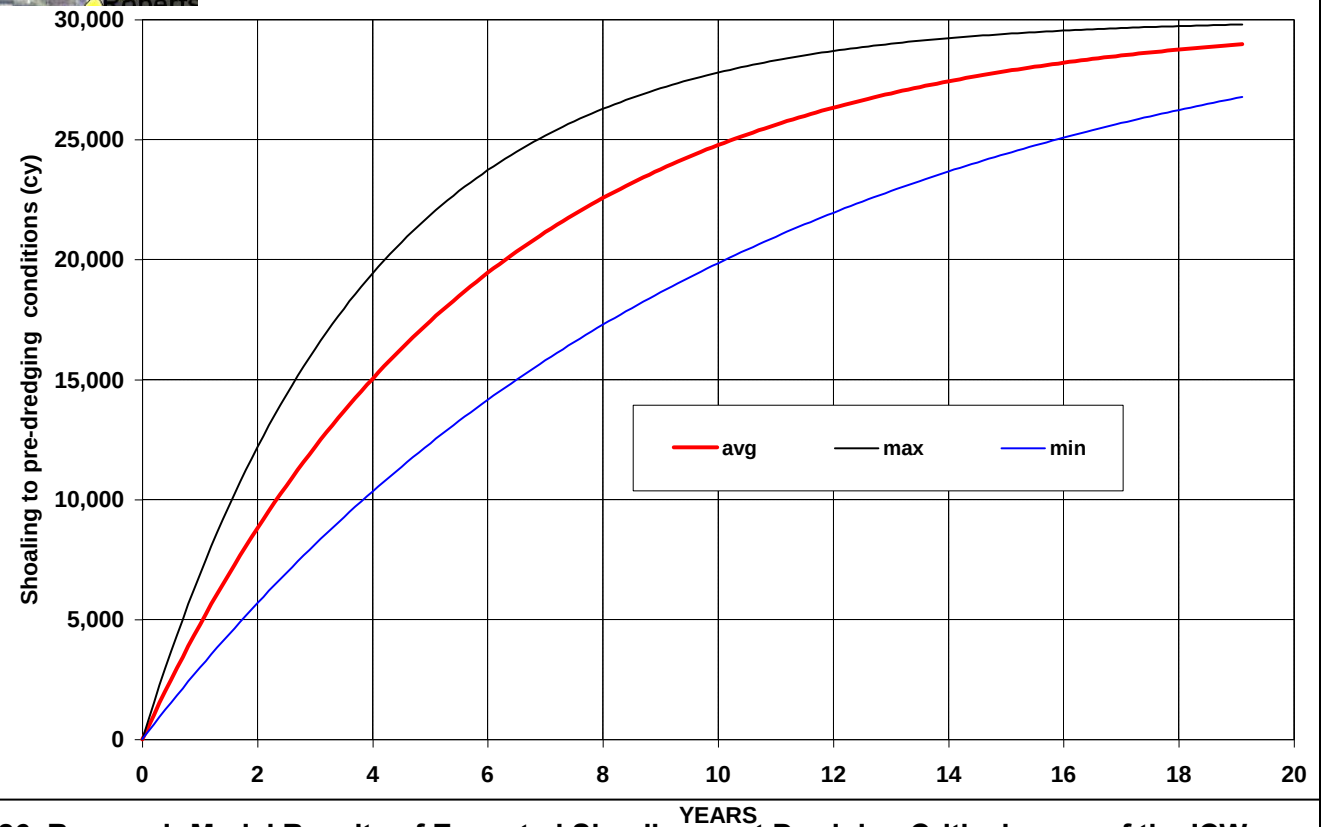


Figure 4.26. Reservoir Model Results of Expected Shoaling post Dredging Critical areas of the ICW

## 4.4 Summary and Recommendations

### 4.4.1 Summary of Model Results

The regional model evaluated tidal circulation over the broad interconnected bay area described in **Section 2.2** and illustrated in **Figure 2.1**. Detailed modeling and analysis of Little Sarasota Bay and Venice Inlet were discussed in this section to evaluate the long-term evolution of the inlet. The modeling was run for historic and existing conditions to evaluate how tidal circulation and inlet dynamics were influenced by major events which changed inlet and waterway geometry, such as completion of the ICW and closure of Midnight Pass. **Figure 4.27** summarizes the changes of the total Sarasota Bay system tidal prism distribution between its inlets from 1880 to present. The regional model provided local boundary conditions at individual inlets, assuring that those local boundary conditions are consistent with flow through the broad interconnected system.

Results of the modeling and data analysis for conditions which existed in the 1950's, in comparison to present conditions, illustrate how the ICW dredging changed the relative amount of the Sarasota Bay tidal prism which flows through various inlets, and how this has influenced subsequent dynamic inlet shoal changes. The modeling indicates the ICW and closure of Midnight Pass resulted in an increase in the tidal prism and current velocities through Venice Inlet. This increase resulted in inlet channel scour, growth of the ebb shoal volume, and shoaling of interior flood channels including the ICW.

The model results identified shoaling problem areas within the ICW which could be critical for navigation safety. Recent survey data confirmed the study findings. The surveys indicate significant shoaling at sections of the ICW east of Snake Island. The model results also indicate that the increases in tidal prism and inlet currents contributed to higher erosion rates on beaches adjacent to the inlet and on Snake Island.

### 4.4.2 Recommendations

The following recommendations are made based on historical data analysis and modeling of Venice Inlet.

- Field investigations

The Venice Inlet flood shoal was surveyed as part of this study. The survey was completed in April 2007 and confirmed the model findings with respect to the location of rapid shoaling areas. It is recommended that geotechnical investigations to examine sediment quality be conducted in conjunction with environmental field investigations to map natural resources. These studies

should be conducted in the rapidly shoaling areas and other areas which may be dredged to serve as sedimentation basins. This approach may improve the management of the waterway for navigation purposes, and at the same time potentially provide valuable sand for beach management.

- Maintenance dredging

Until such time as the geotechnical and environmental studies recommended above can be completed, maintenance dredging of the high shoaling areas should be continued on an as needed basis. To the extent that the dredged material is beach compatible, it should be used for beach nourishment.

- Beach nourishment

The study findings and model results indicate the need for periodic beach nourishment at Venice Beach to compensate for the sand deficit in Venice Inlet bypassing. Beach compatible material dredged from the ICW should be used to re-nourish critically eroding beach areas along Venice Beach or Snake Island. Due to the ongoing deficiency in sand bypassing at Venice Inlet, it is recommended that sand be placed on the beach south of the inlet. Supplemental sand sources should be investigated to make up for any deficit in sand on the beach south of the inlet.

- Snake Island

**Figure 4.28** shows the shoreline changes that have occurred at Snake Island. The increased tidal prism and current velocities as indicated from data and model analysis appear to have resulted in the eastward migration of the island and encroachment into the ICW channel. This migration is due to erosion of the west shoreline of Snake Island and accretion of the east side. It is therefore recommended that the feasibility of erosion control alternatives be considered as a means of stabilizing Snake Island. The purpose of an erosion control project on Snake Island would be to reduce shoaling rates of the critical sections of the ICW at the Northeast side of the island, and at the same time to stabilize the island to improve it as a recreational resource.



Anna Maria Sound

Longboat Pass

Big Sarasota Bay

New  
Pass

Big  
Sarasota  
Pass

Little  
Sarasota  
Bay

Midnight Pass  
(closed 1984)

Venice Inlet

Sarasota Bay tidal prism share %

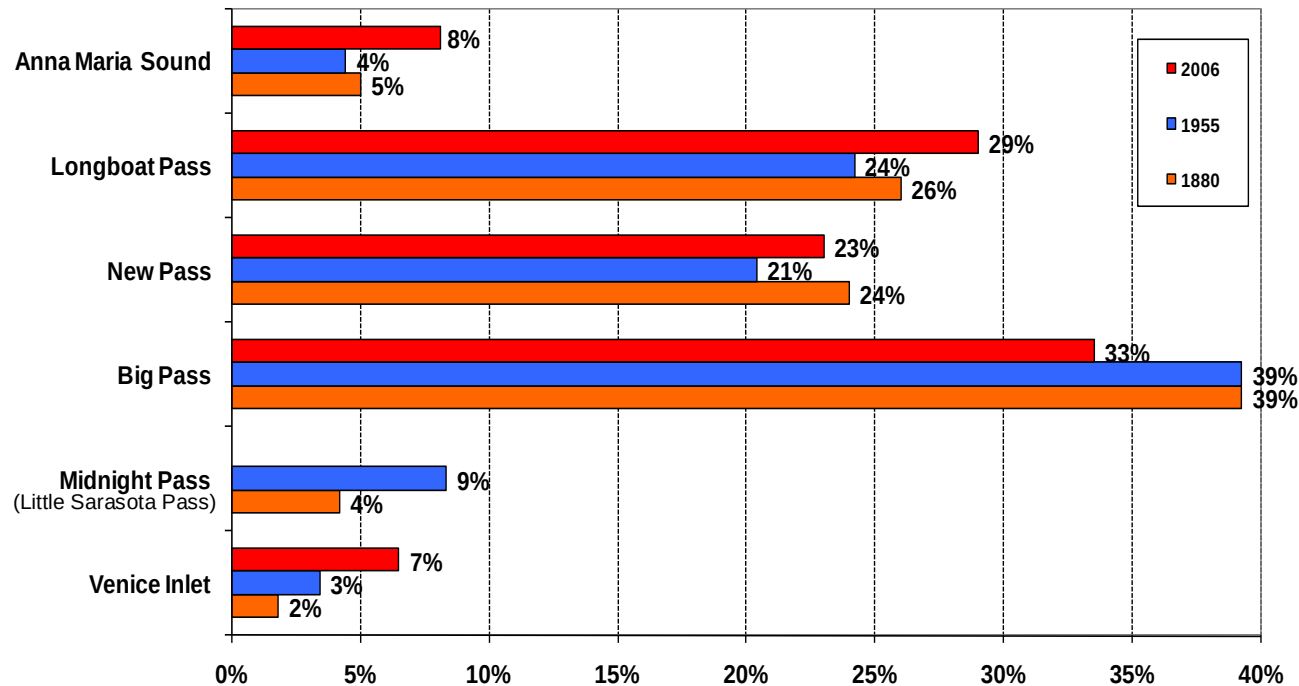
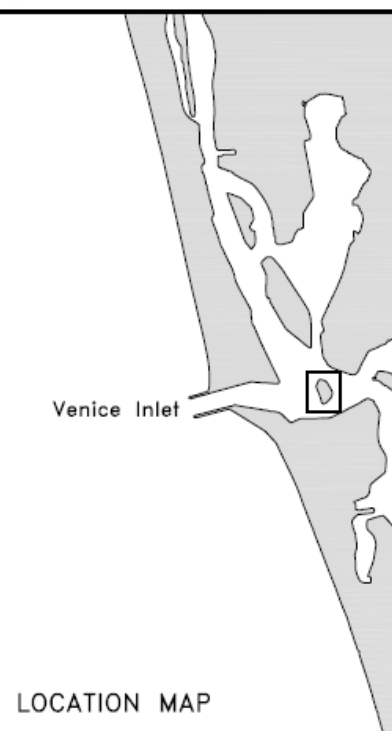
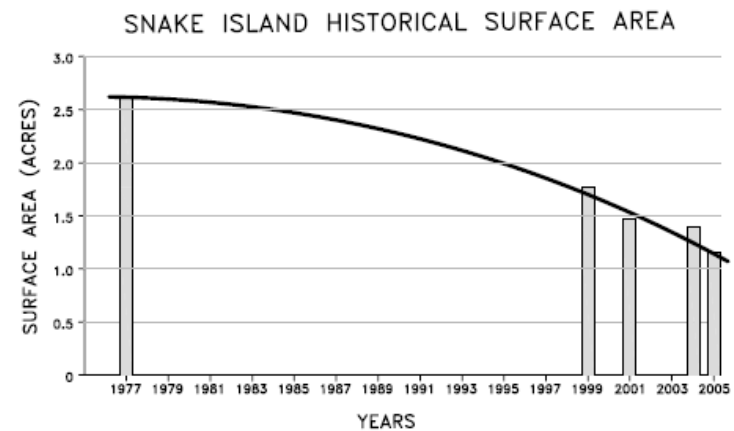
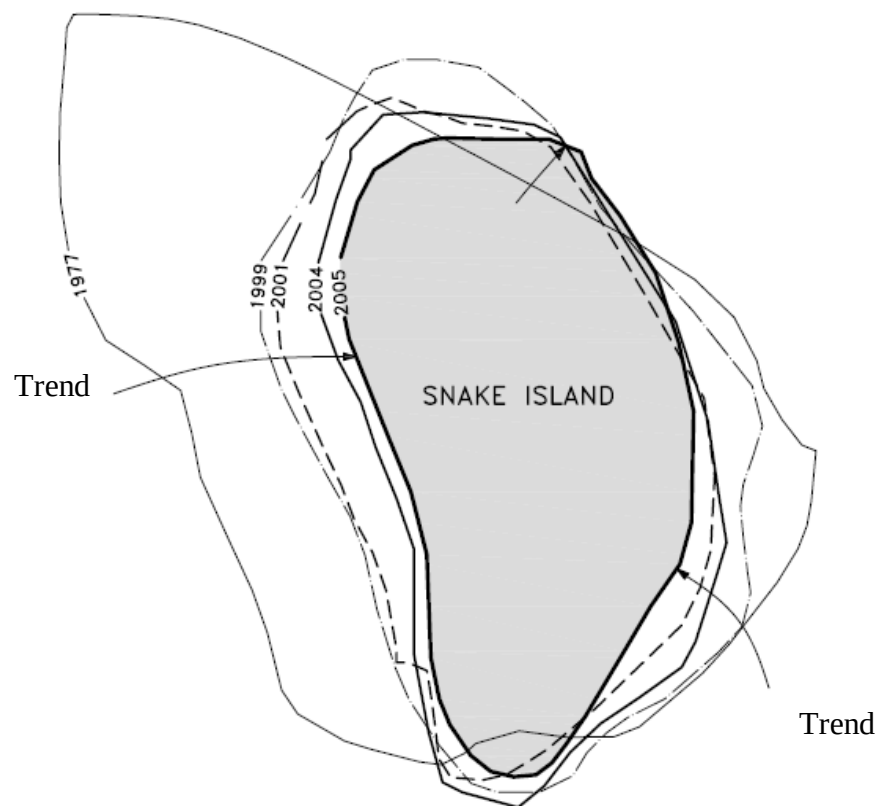


Figure 4.27. Tidal Prism Distribution between Sarasota Bay Inlets (1880's to Present Conditions)



**Figure 4.28. Snake Island Shoreline and Surface Area Change (1977-2005)**

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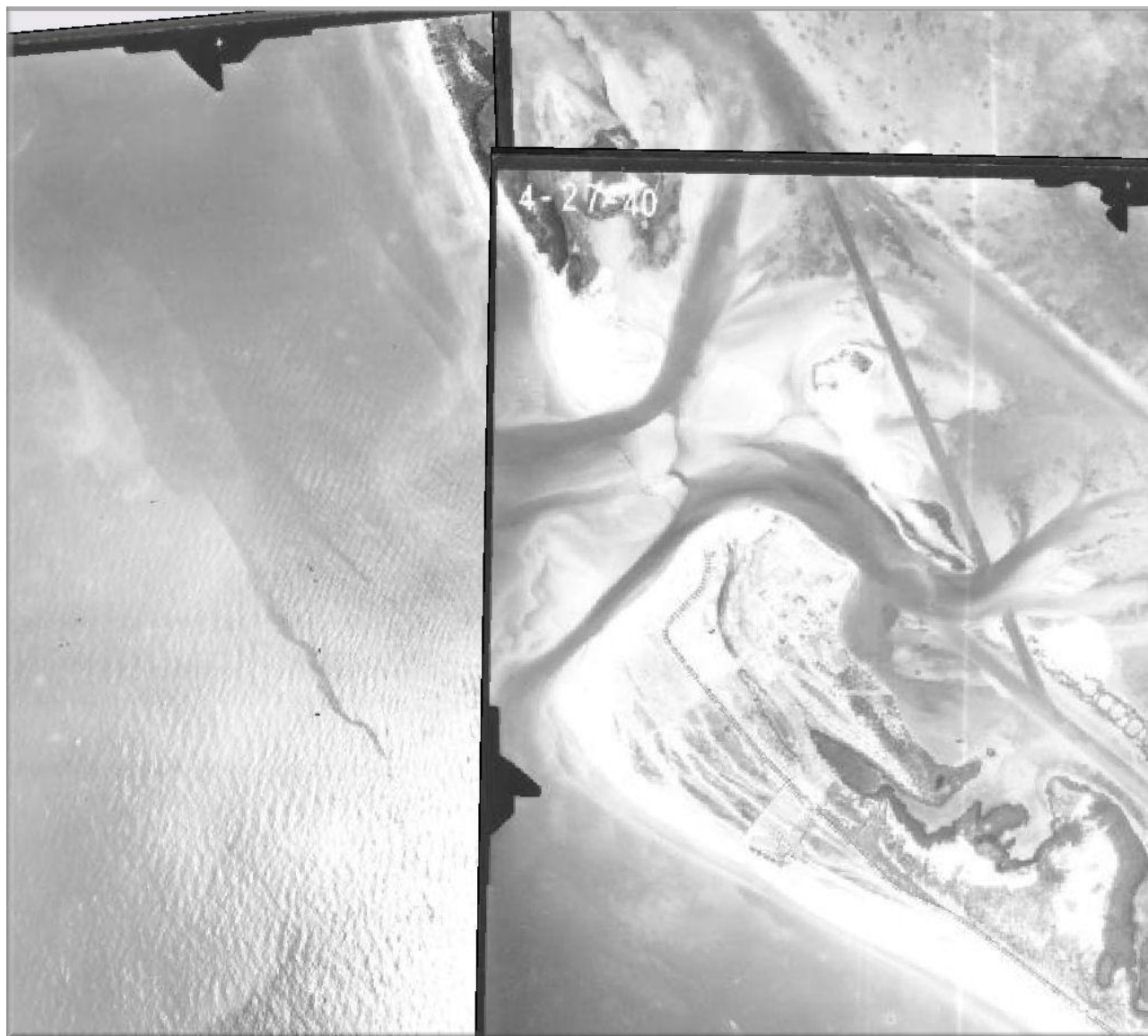
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US Army Corps of Engineers, Jacksonville District, 1975, "Detailed Project Report on Longboat Pass, Florida".

## **Appendix 3A**

### **Longboat Pass Aerial Photos**

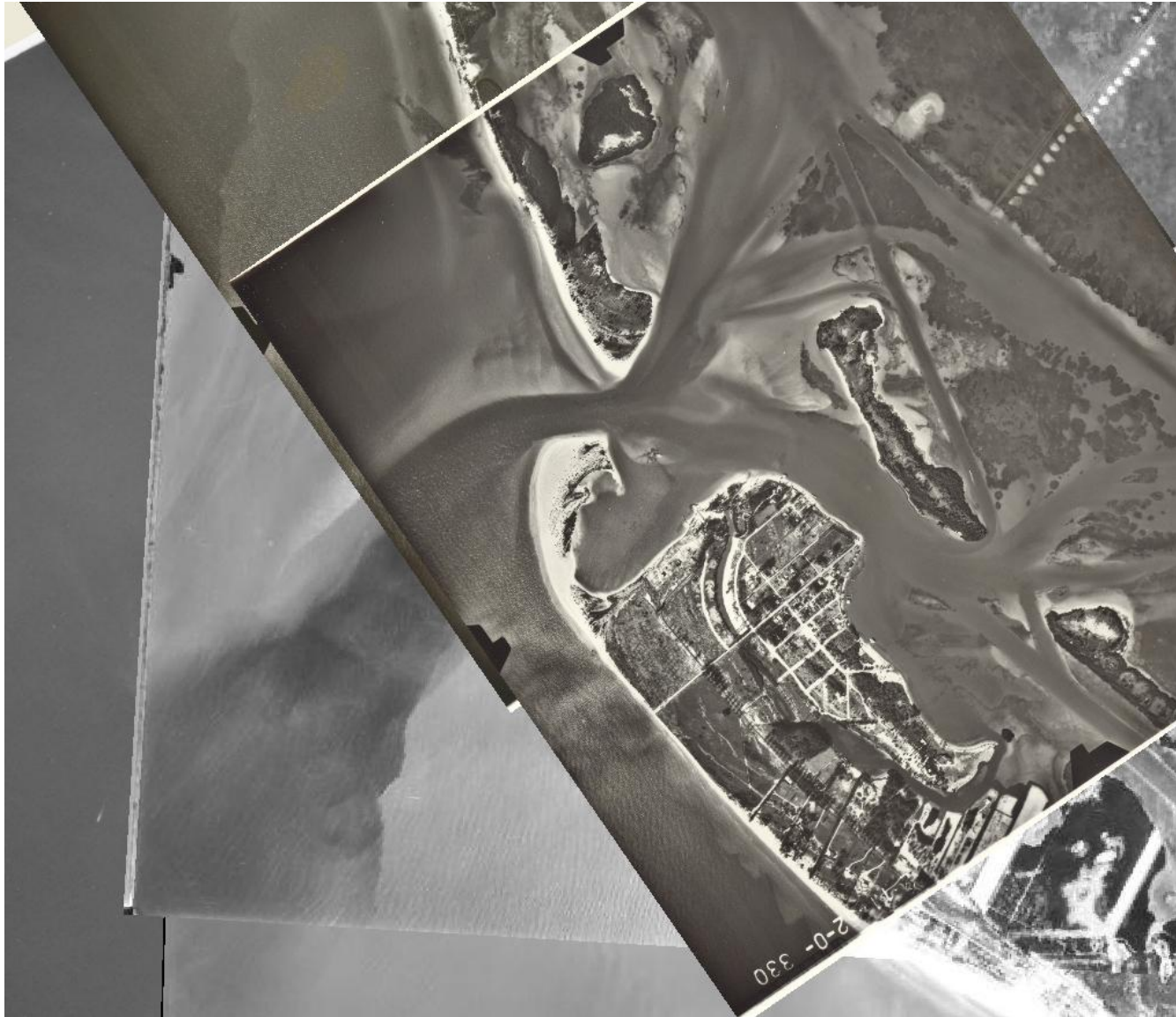


**Figure 3A-1. Longboat Pass 1940 Aerial**





**Figure 3A-2. Longboat Pass 1951 Aerial**

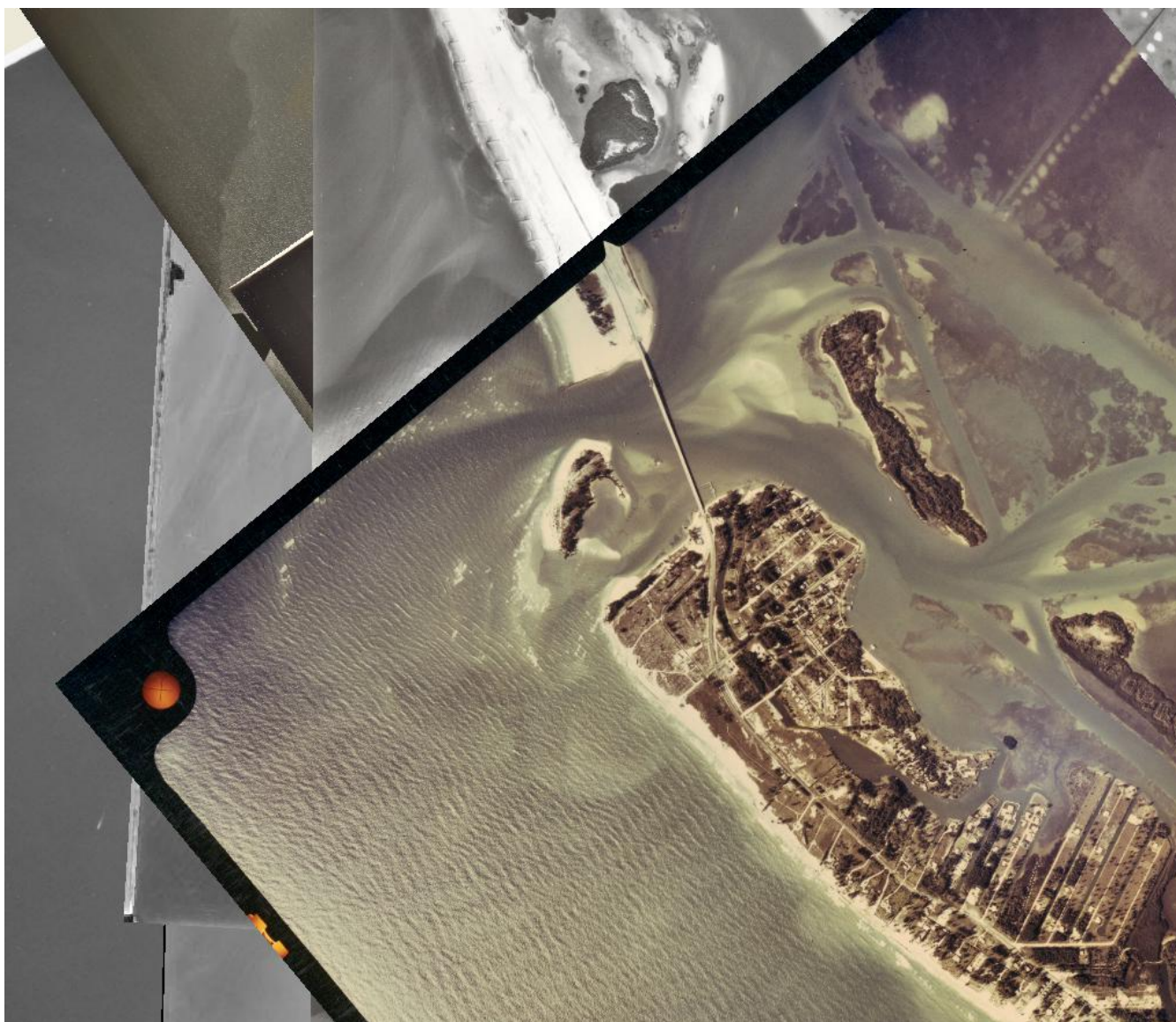


**Figure 3A-3. Longboat Pass 1952 Aerial**



**Figure 3A-4. Longboat Pass 1957 Aerial**





**Figure 3A-5. Longboat Pass 1961 Aerial**





**Figure 3A-6. Longboat Pass 1962 Aerial**



**Figure 3A-7. Longboat Pass 1963 Aerial**



**Figure 3A-8. Longboat Pass 1965 Aerial**





**Figure 3A-9. Longboat Pass 1969 Aerial**



**Figure 3A-10. Longboat Pass 1970 Aerial**

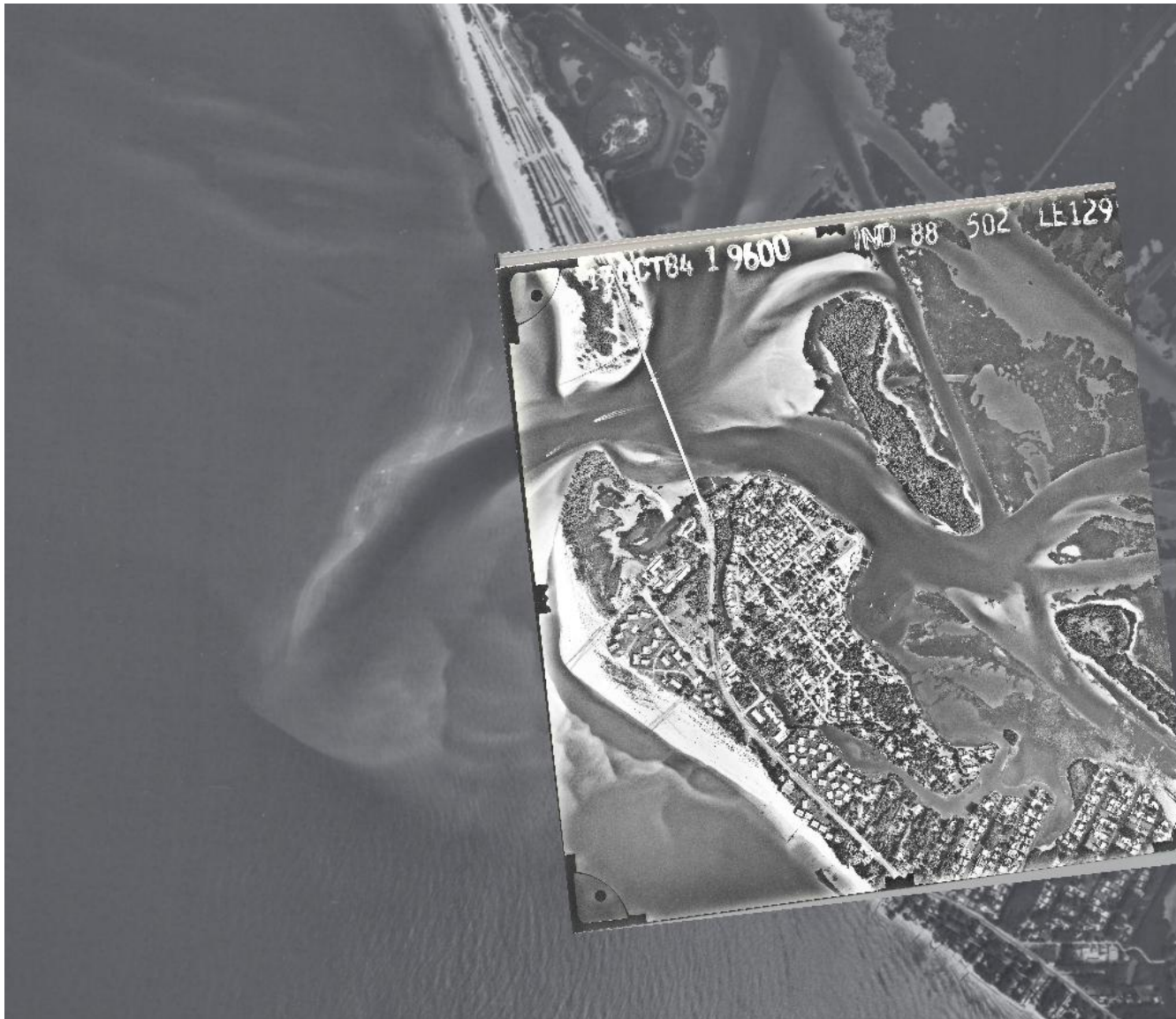


**Figure 3A-11. Longboat Pass 1977 Aerial**





**Figure 3A-12. Longboat Pass 1980 Aerial**

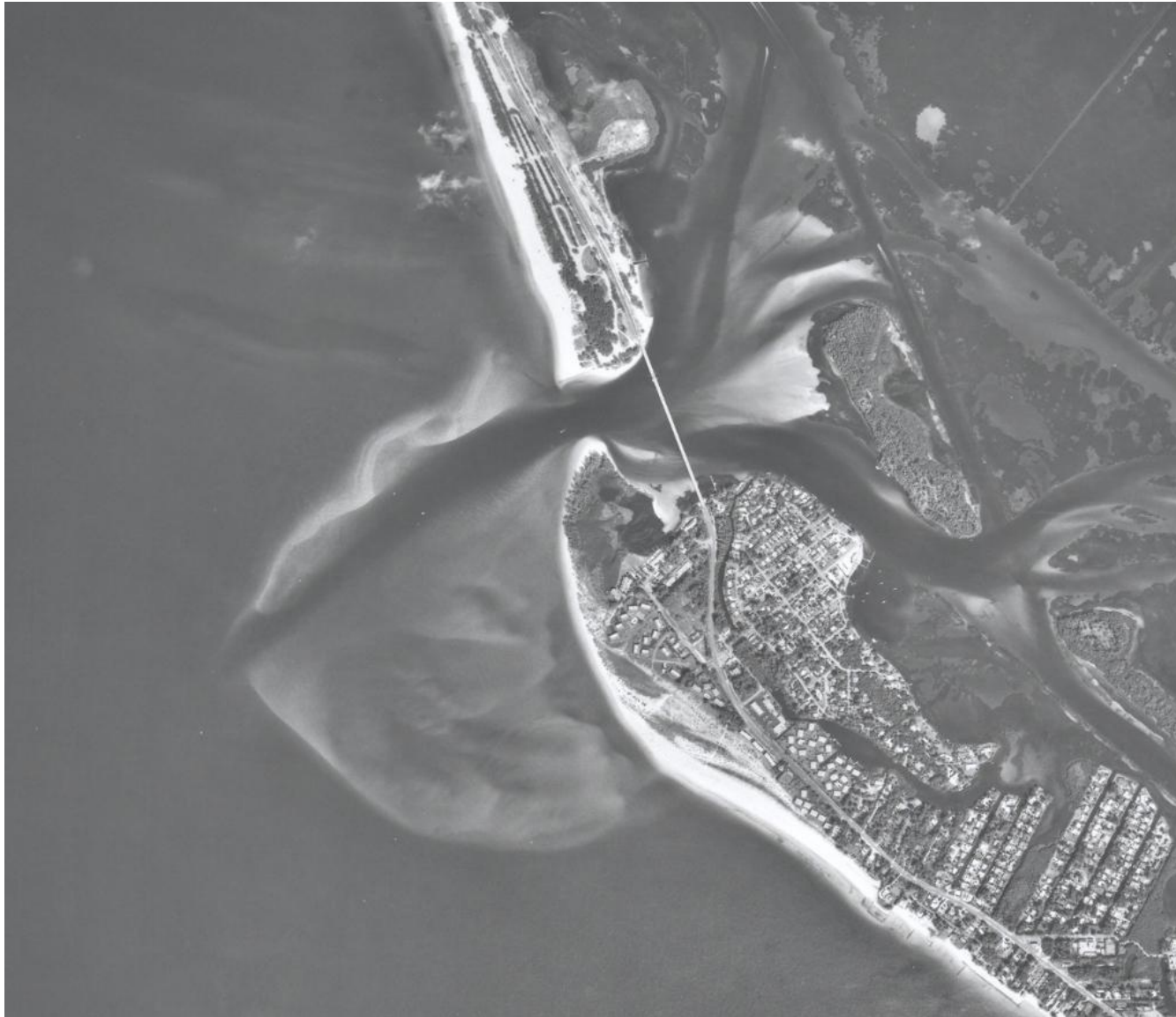


**Figure 3A-13. Longboat Pass 1984 Aerial**



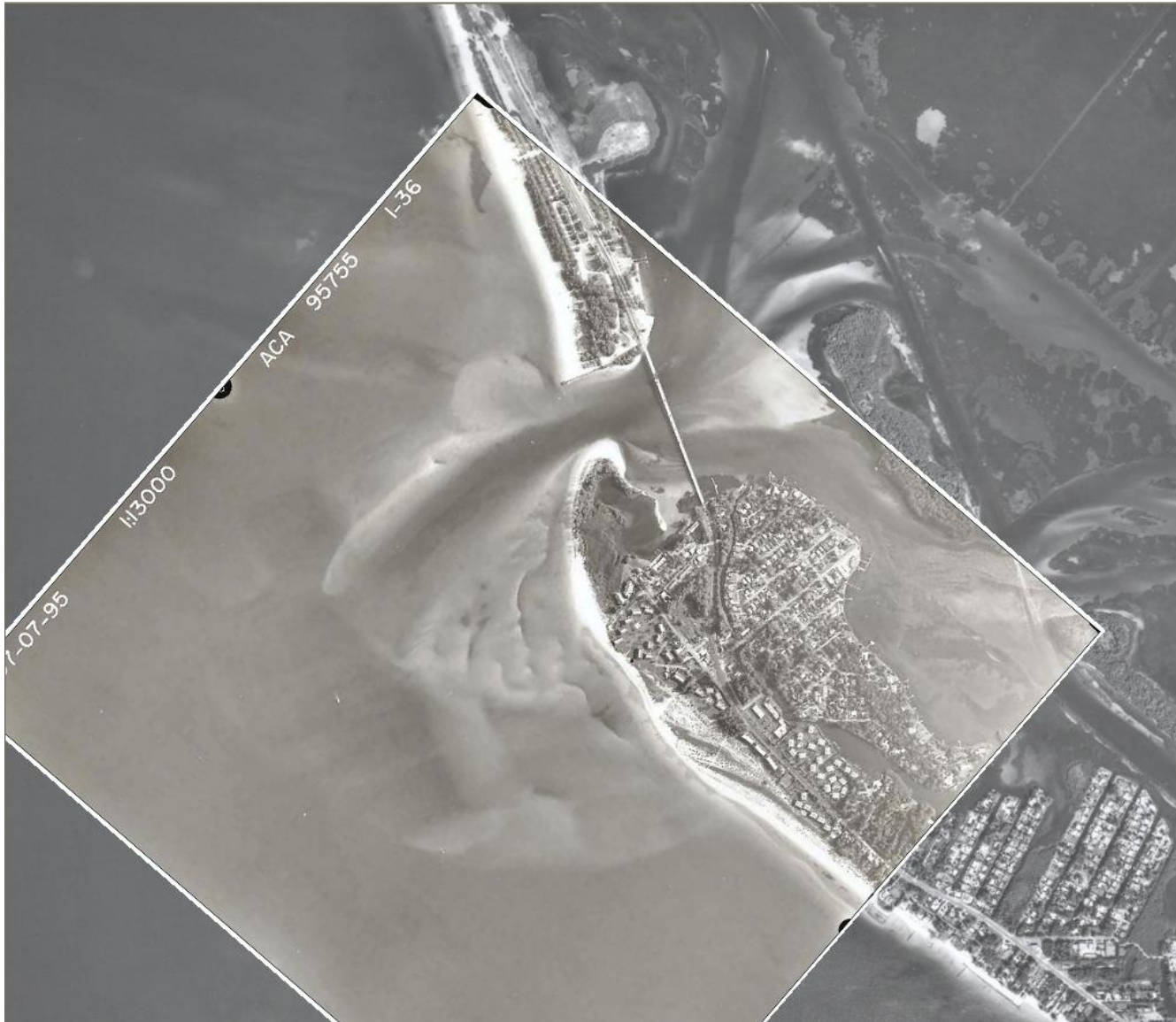
**Figure 3A-14. Longboat Pass 1987 Aerial**





**Figure 3A-15. Longboat Pass 1991 Aerial**





**Figure 3A-16. Longboat Pass 1995 Aerial**



**Figure 3A-17. Longboat Pass 1997 Aerial**



**Figure 3A-18. Longboat Pass 2001 Aerial**



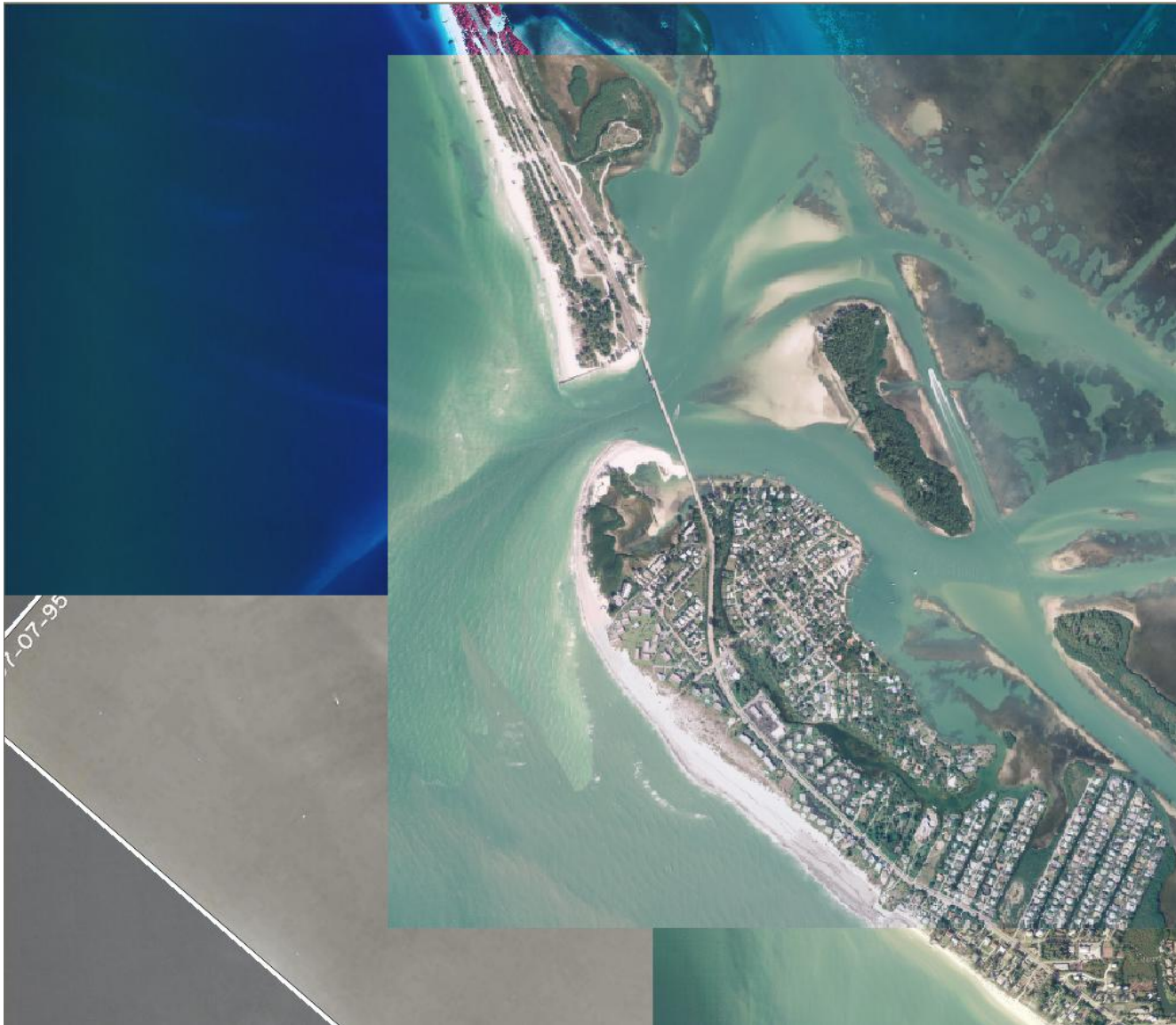


**Figure 3A-19. Longboat Pass 2003 Aerial**





**Figure 3A-20. Longboat Pass 2004 Aerial**

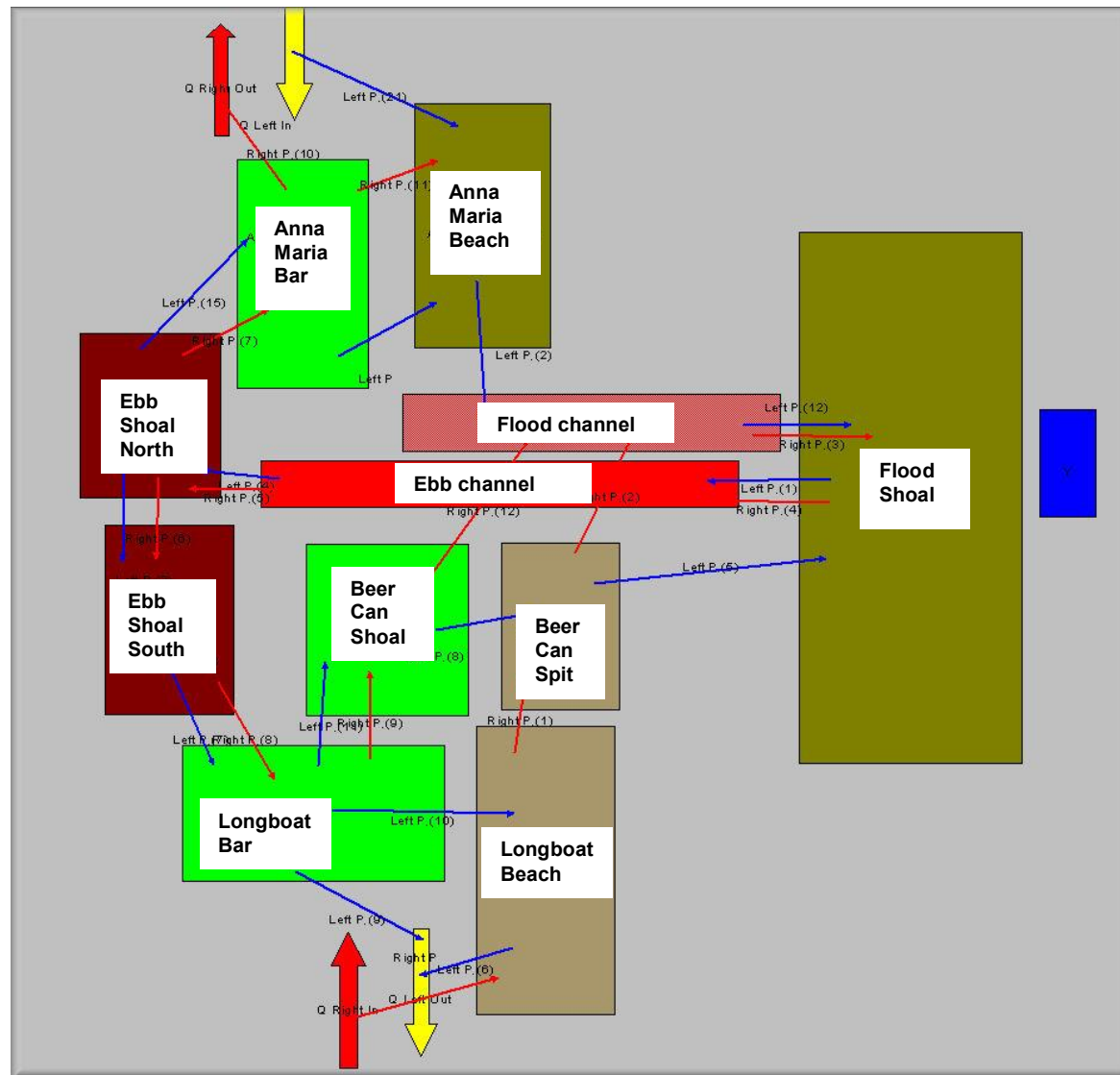


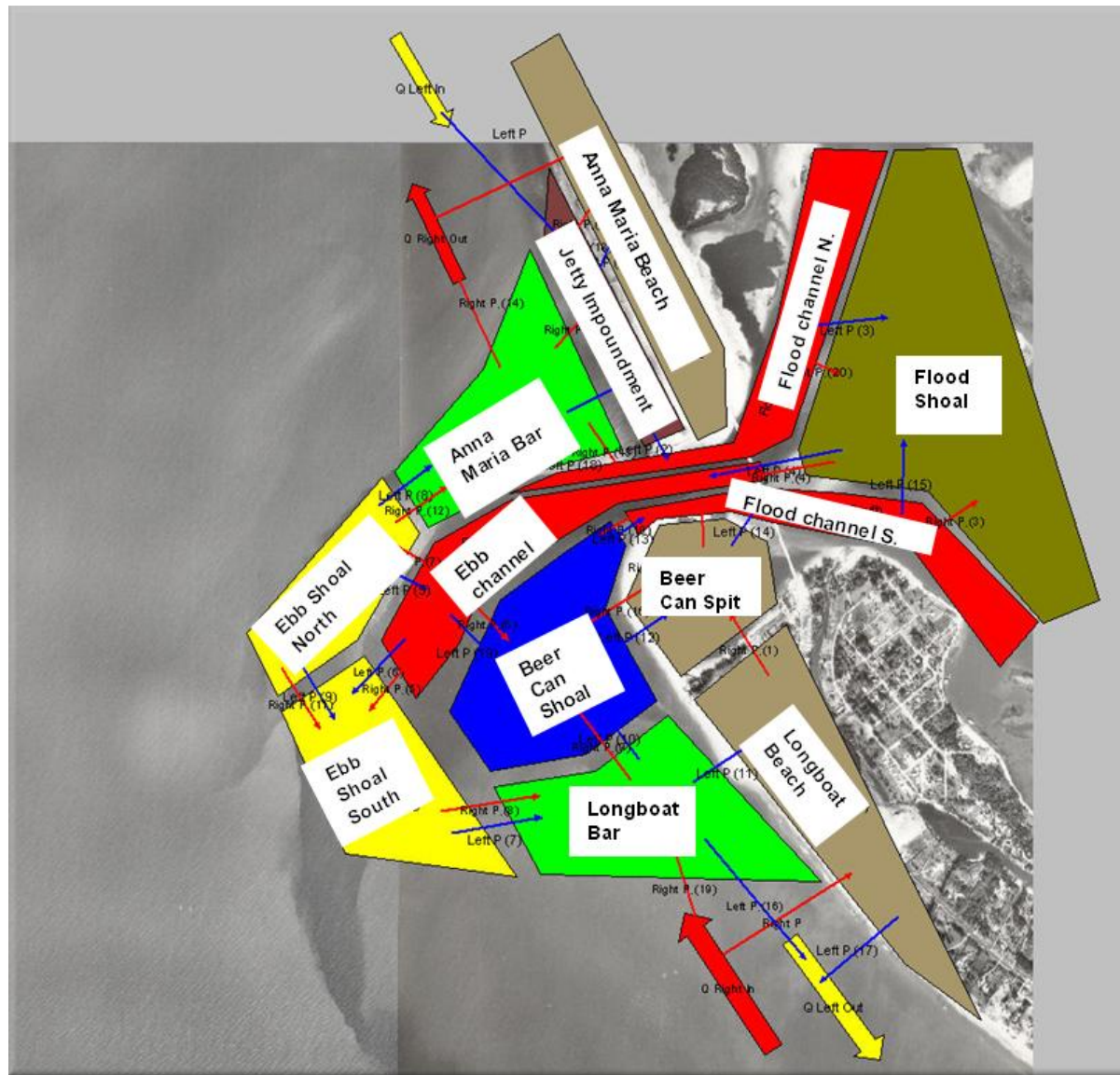
**Figure 3A-21. Longboat Pass 2006 Aerial**

## **Appendix 3B**

### **Longboat Pass Inlet Reservoir Model Results**

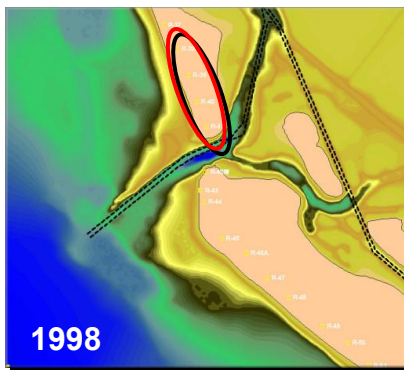
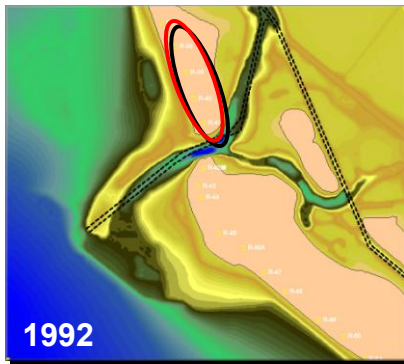
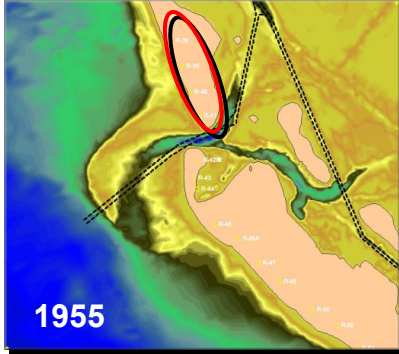












### ANNA MARIA BEACH RESERVOIR MODEL OUTPUT

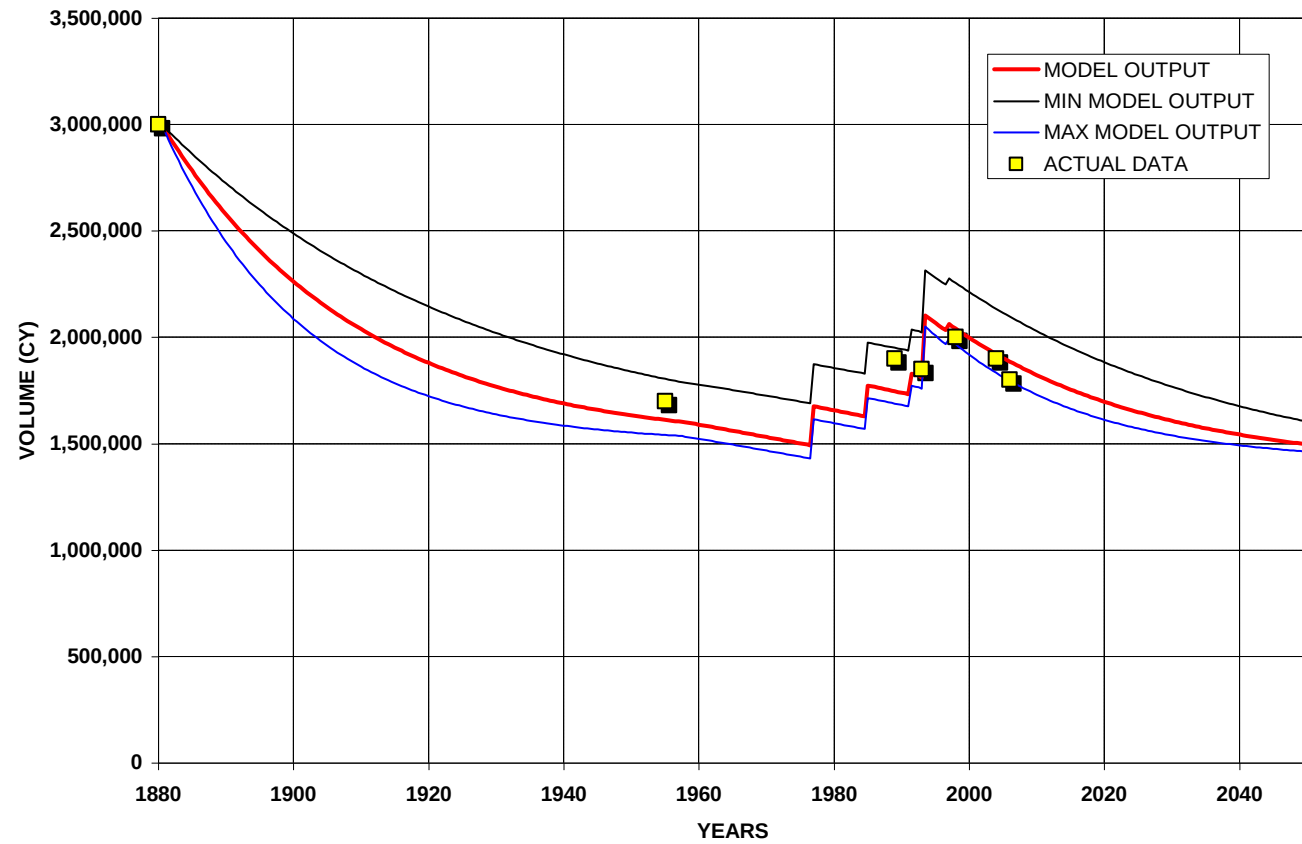
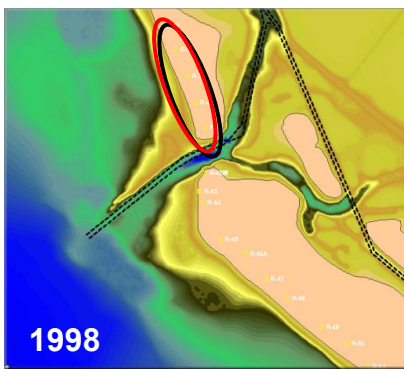
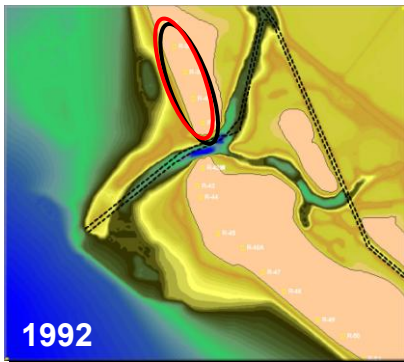
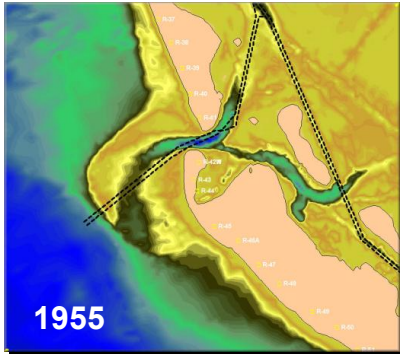
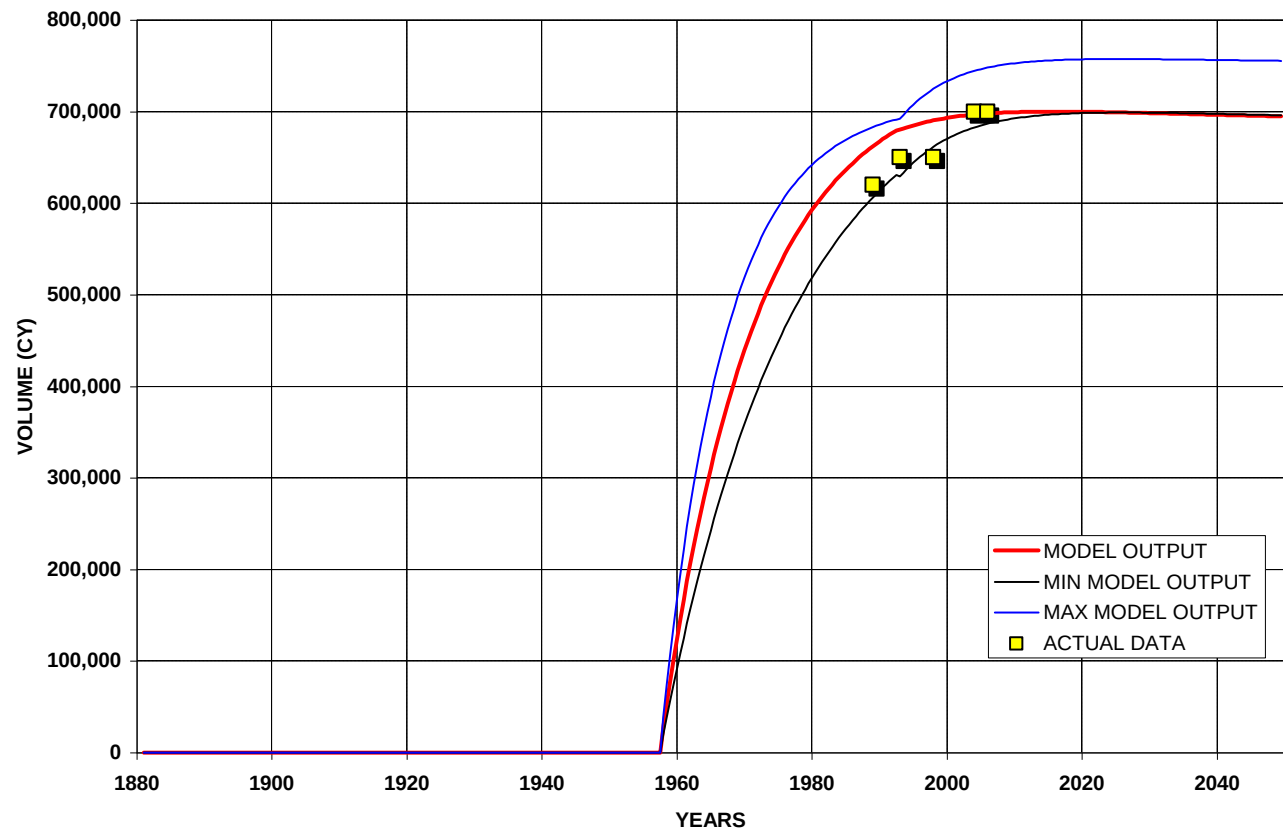
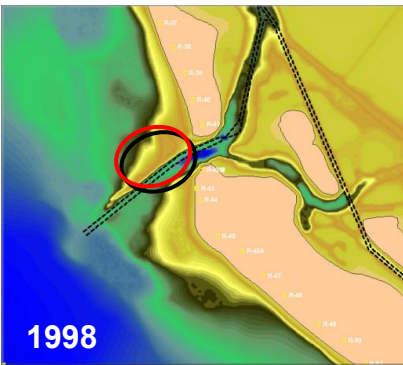
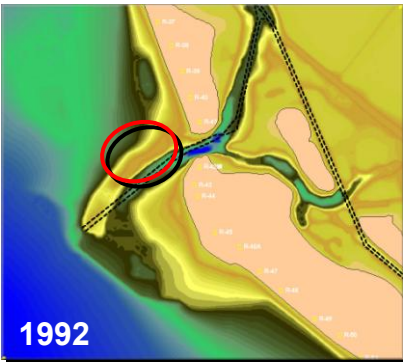
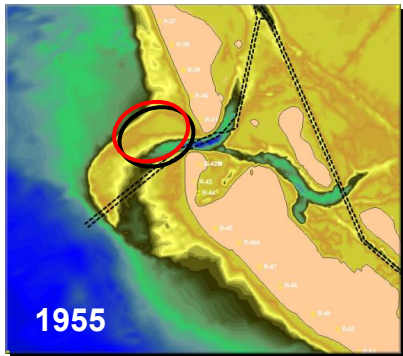


Figure B-1 Reservoir Model Results – Anna Maria Beach Volume



### JETTY IMPOUNDMENT RESERVOIR MODEL OUTPUT





### ANNA MARIA BAR RESERVOIR MODEL OUTPUT

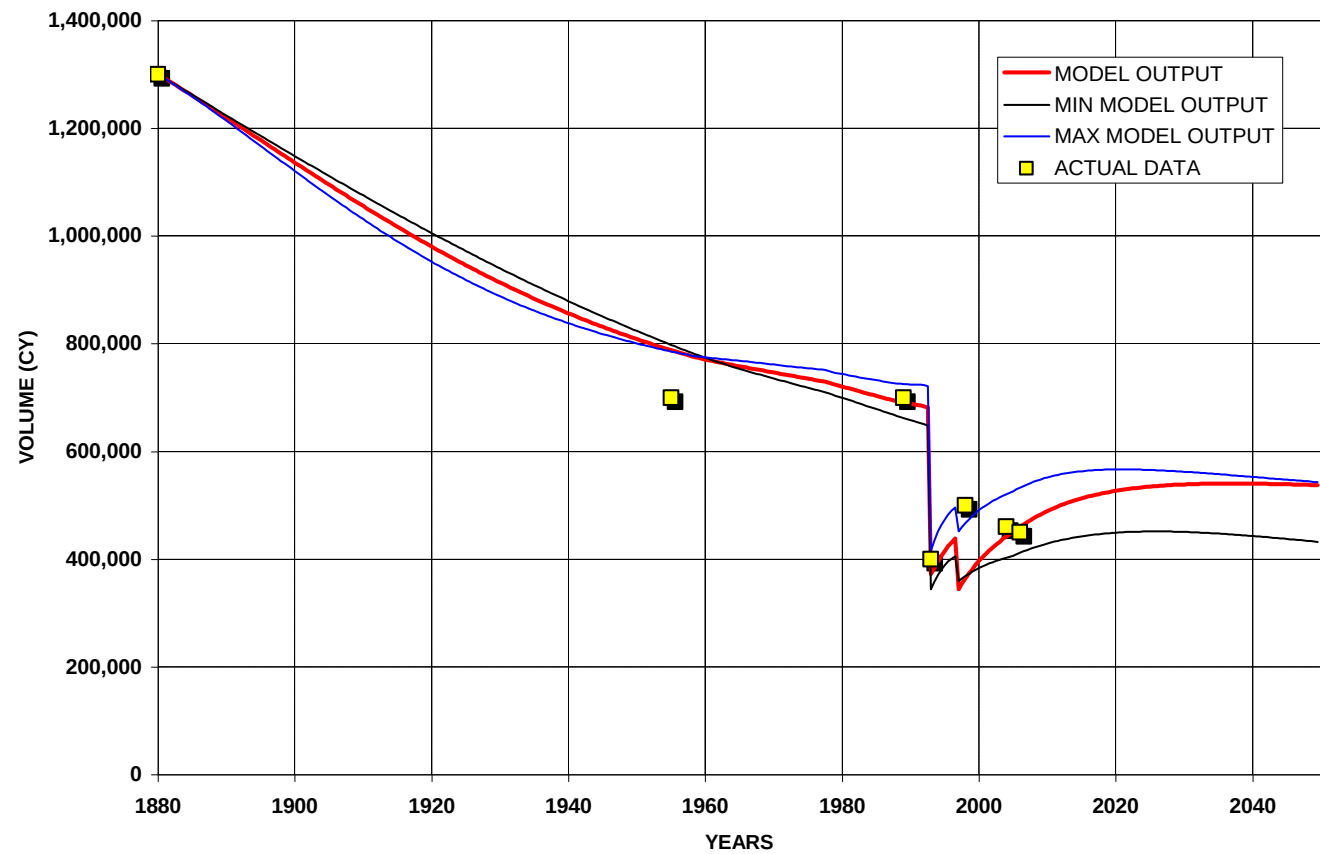
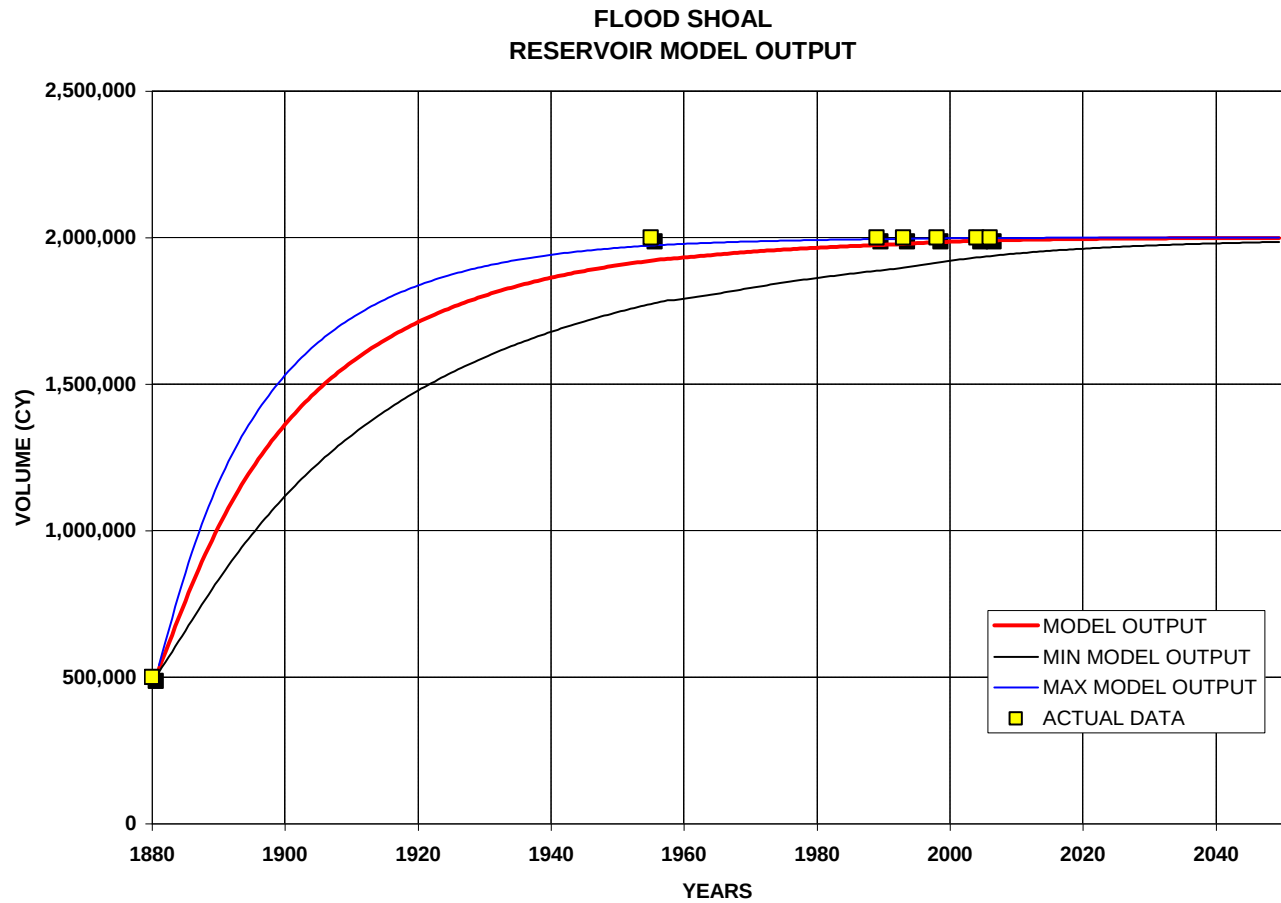
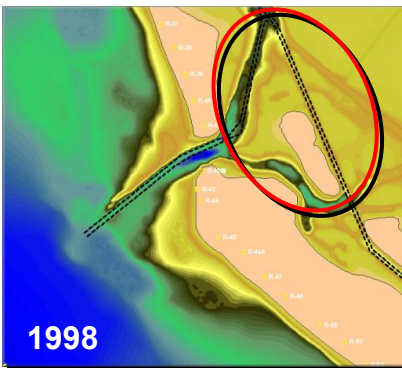
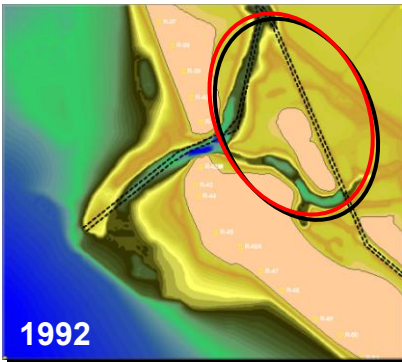
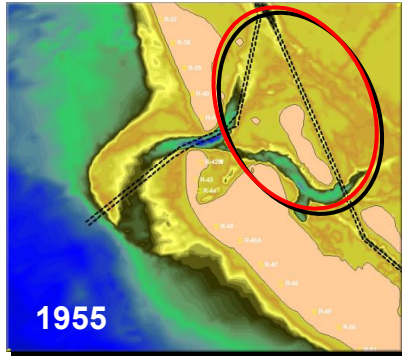
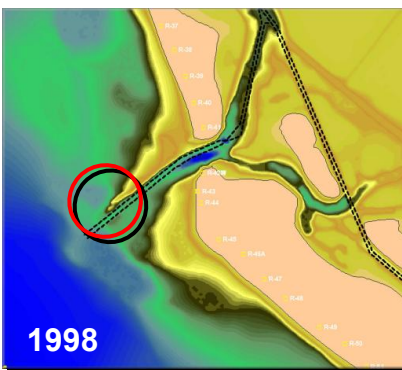
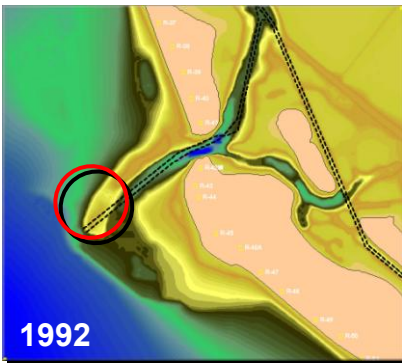
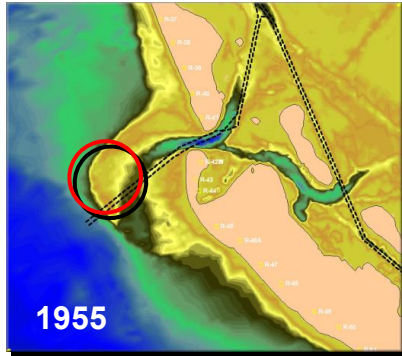


Figure B-3 Reservoir Model Results – Anna Maria Bar Volume





**Figure B-4 Reservoir Model Results – Flood Shoal Volume**



### EBB SHOAL NORTH RESERVOIR MODEL OUTPUT

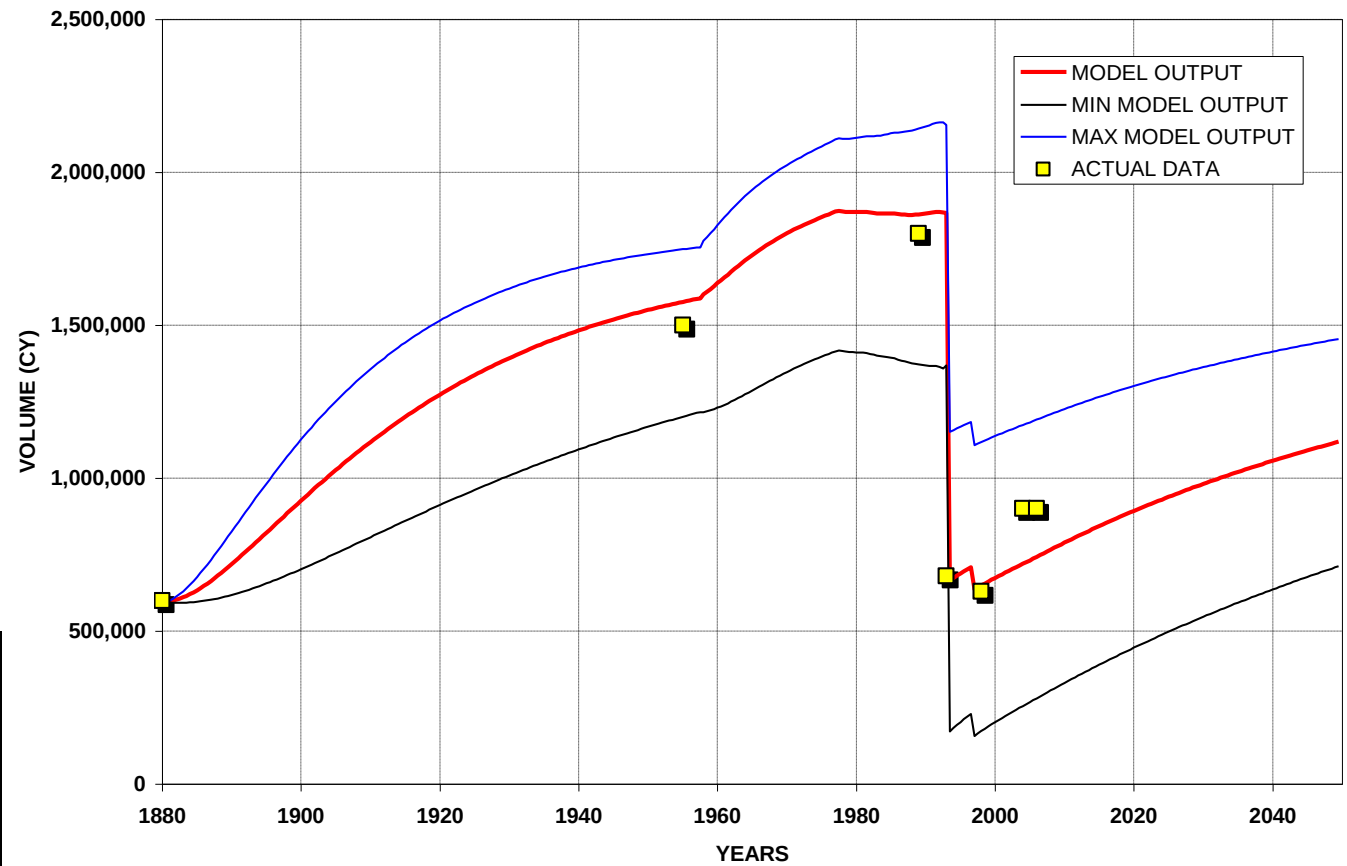
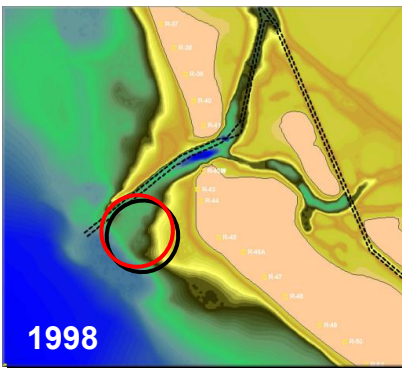
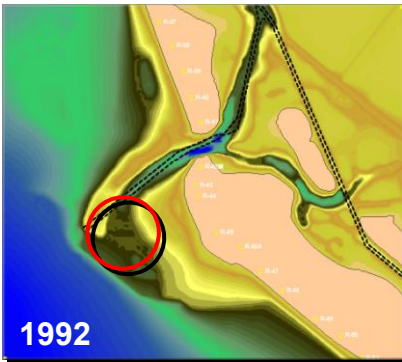
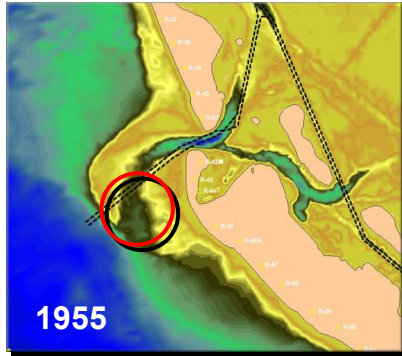


Figure B-5 Reservoir Model Results – Ebb Shoal North Volume



### EBB SHOAL SOUTH RESERVOIR MODEL OUTPUT

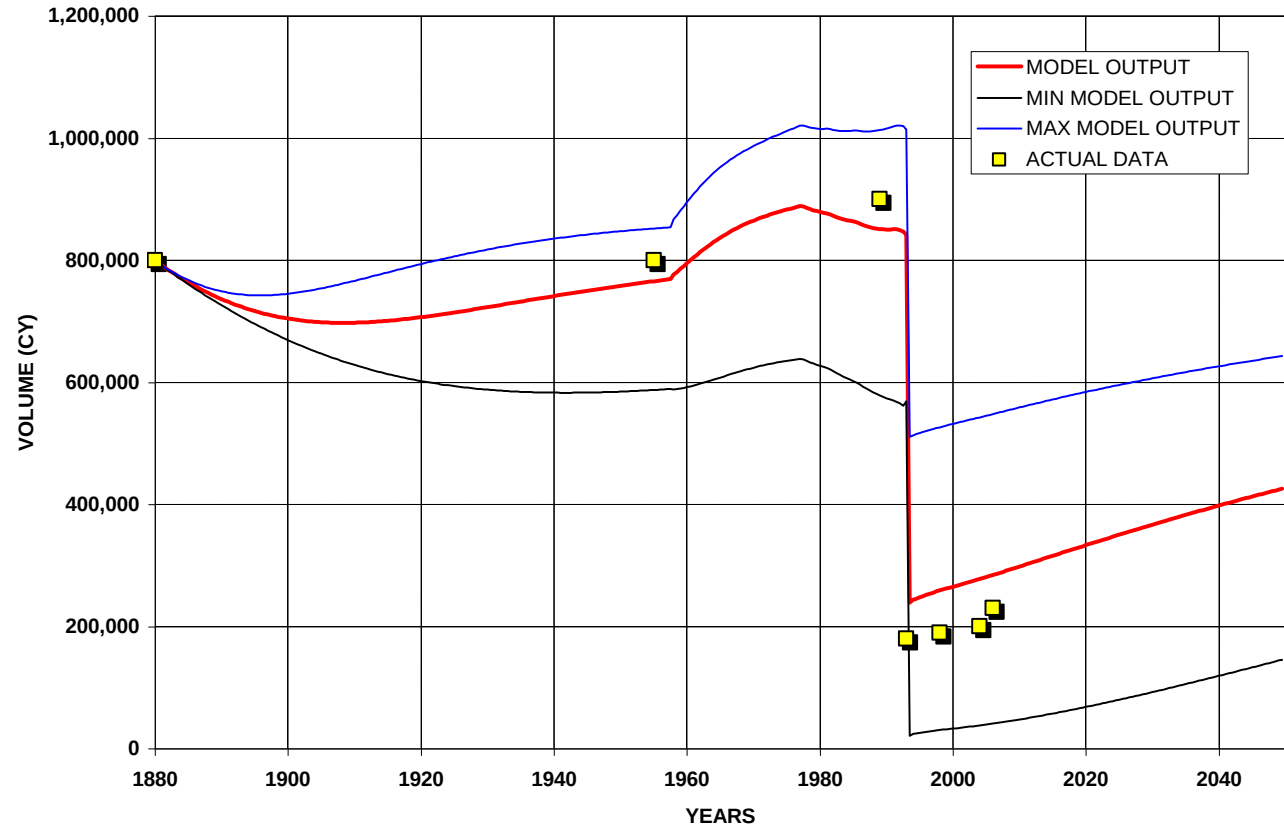
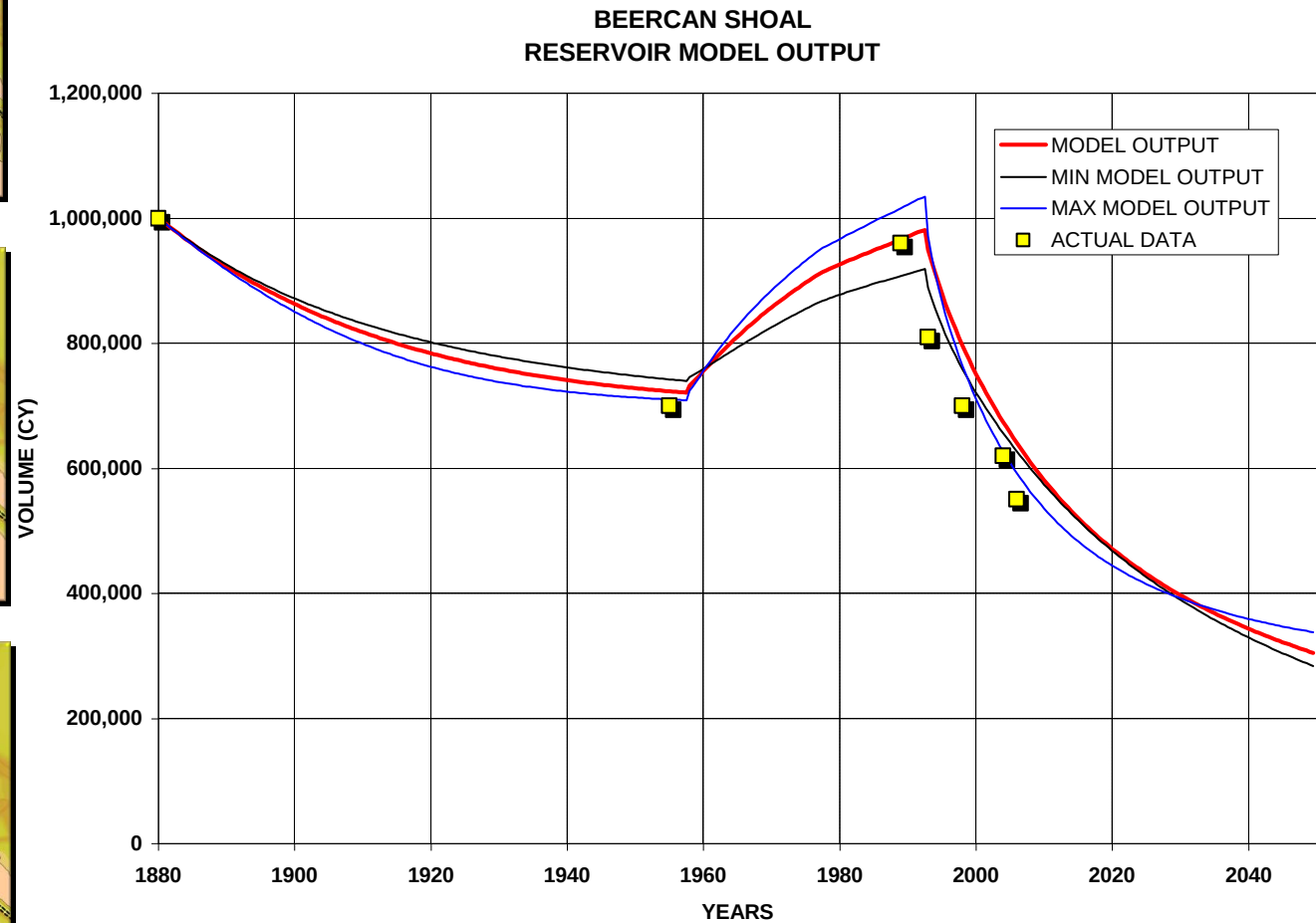
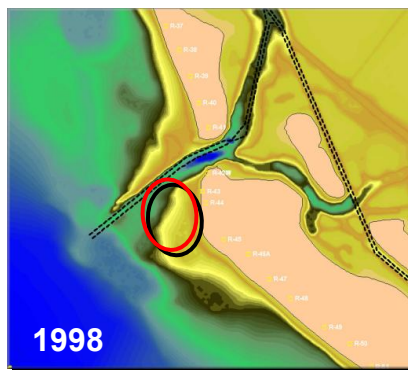
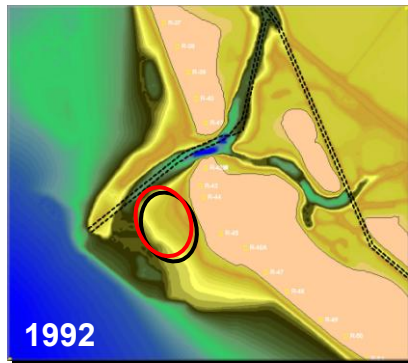
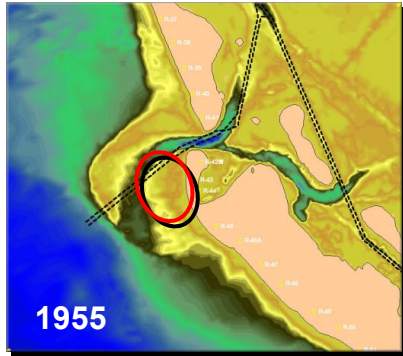
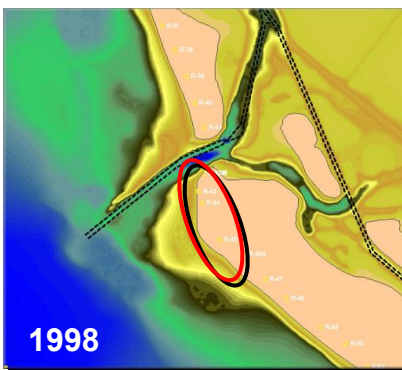
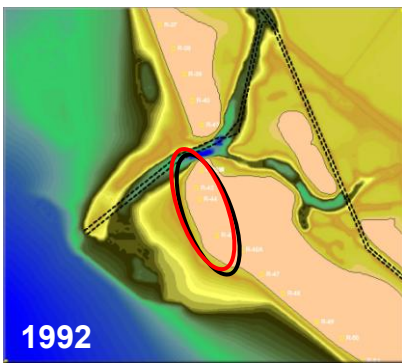
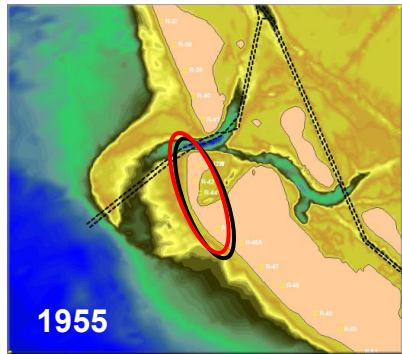


Figure B-6 Reservoir Model Results – Ebb Shoal South Volume



**Figure B-7 Reservoir Model Results – Beercan Shoal Volume**





### BEERCAN ISLAND RESERVOIR MODEL OUTPUT

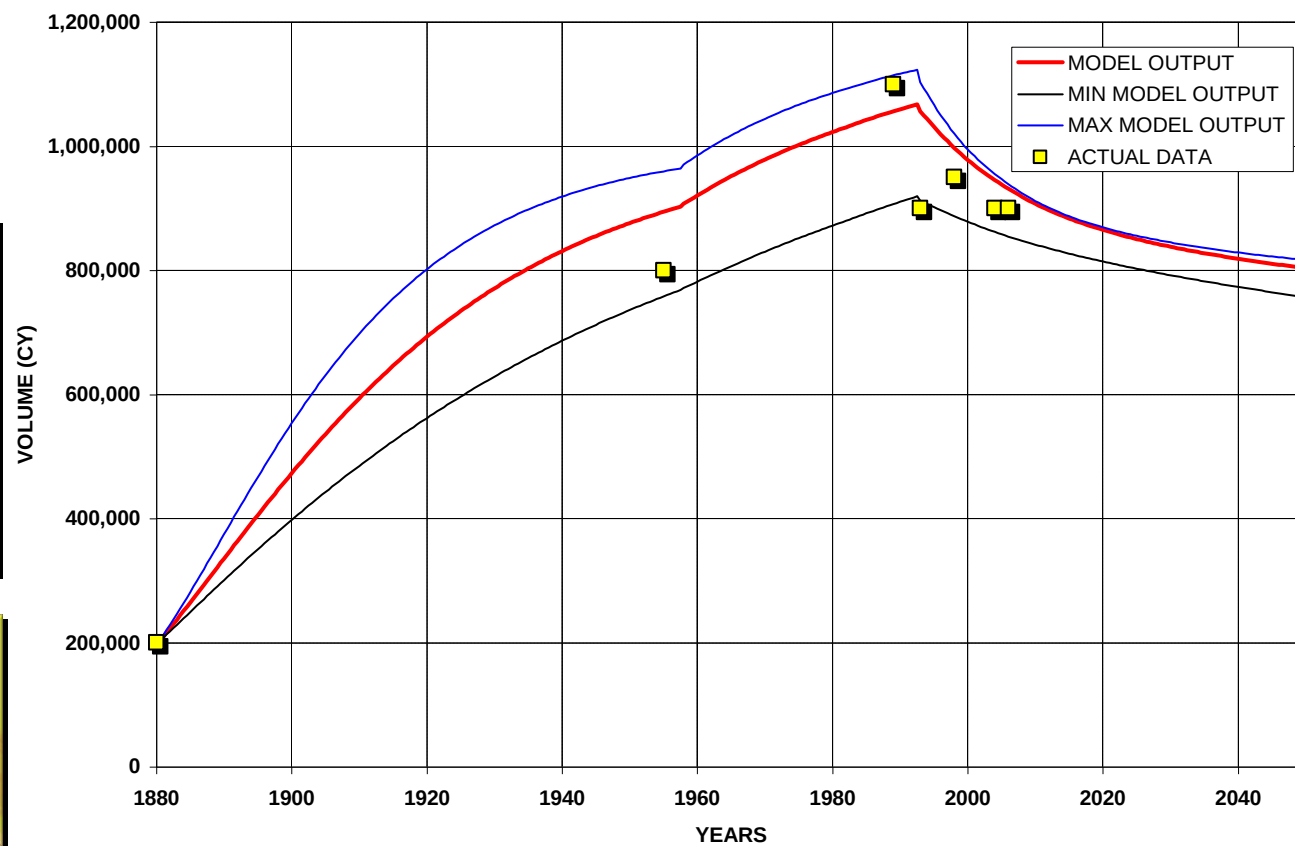
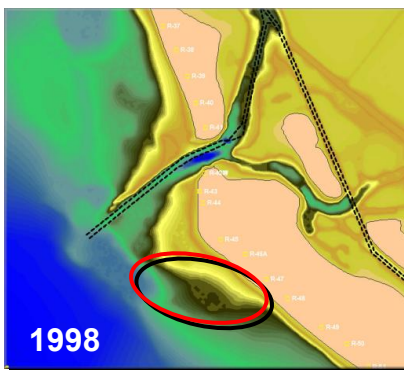
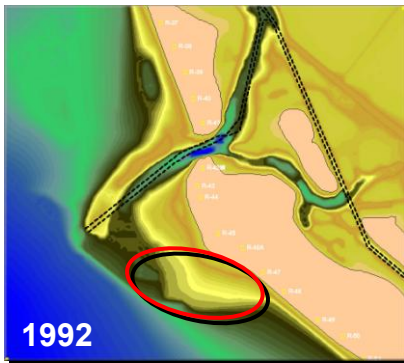
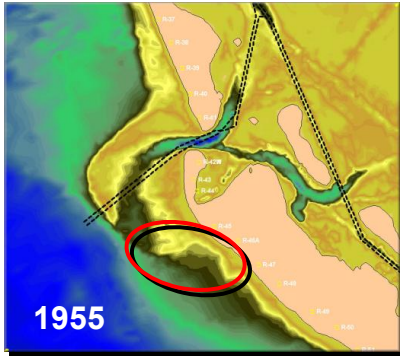


Figure B-8 Reservoir Model Results – Beercan Island Volume



### LONGBOAT BAR RESERVOIR MODEL OUTPUT

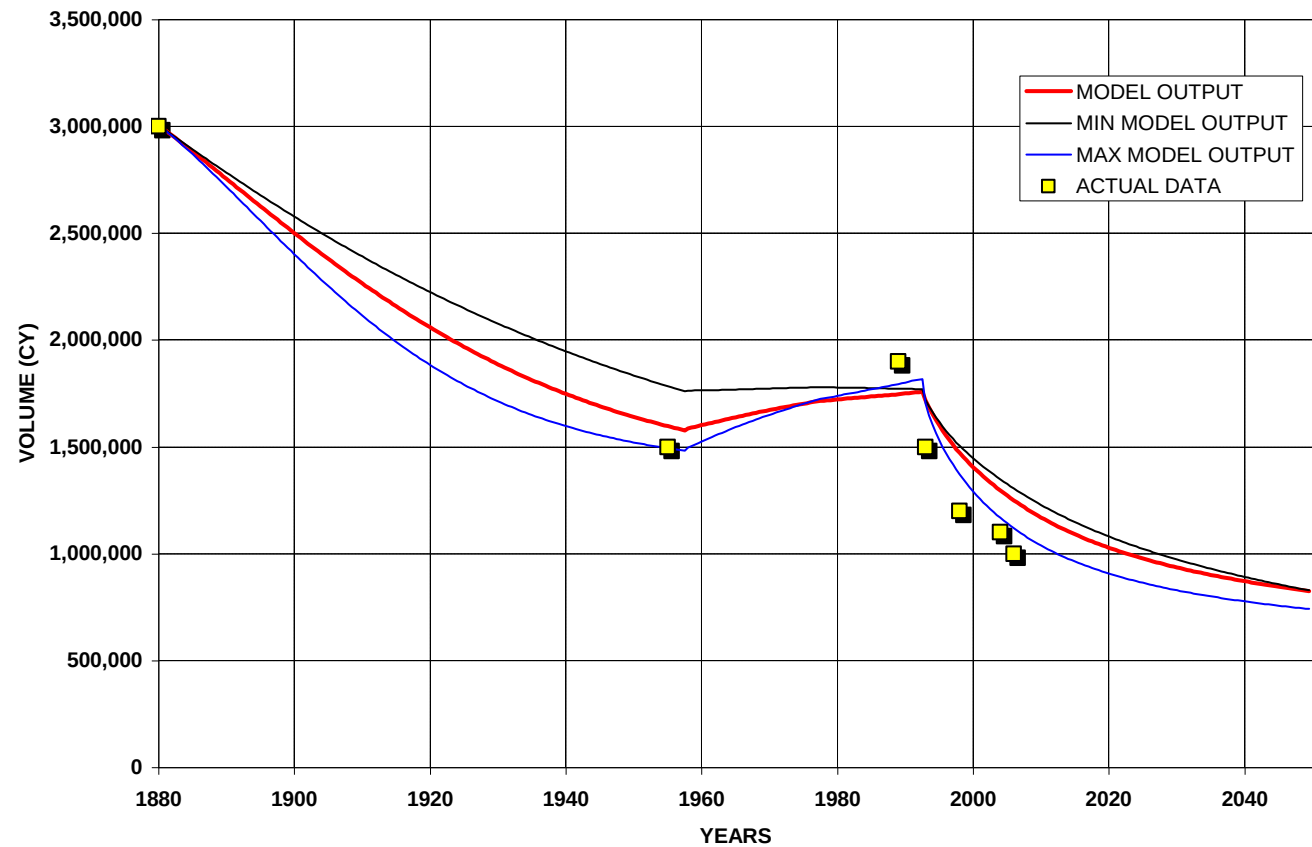
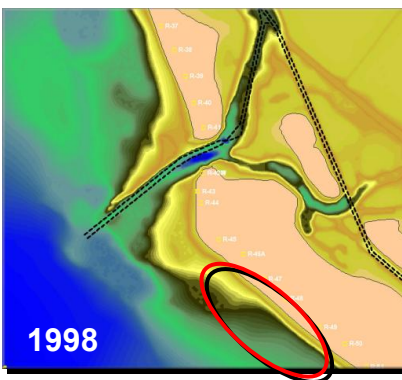
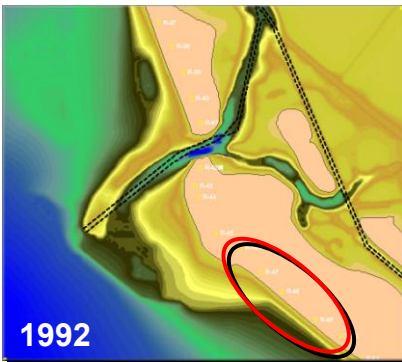
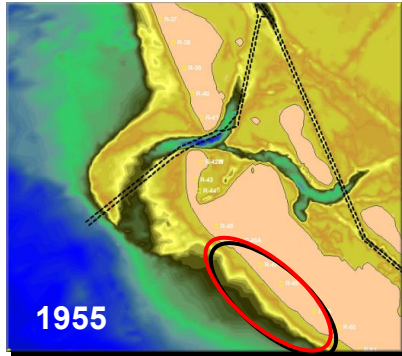


Figure B-9 Reservoir Model Results – Longboat Bar Volume



### LONGBOAT BEACH RESERVOIR MODEL OUTPUT

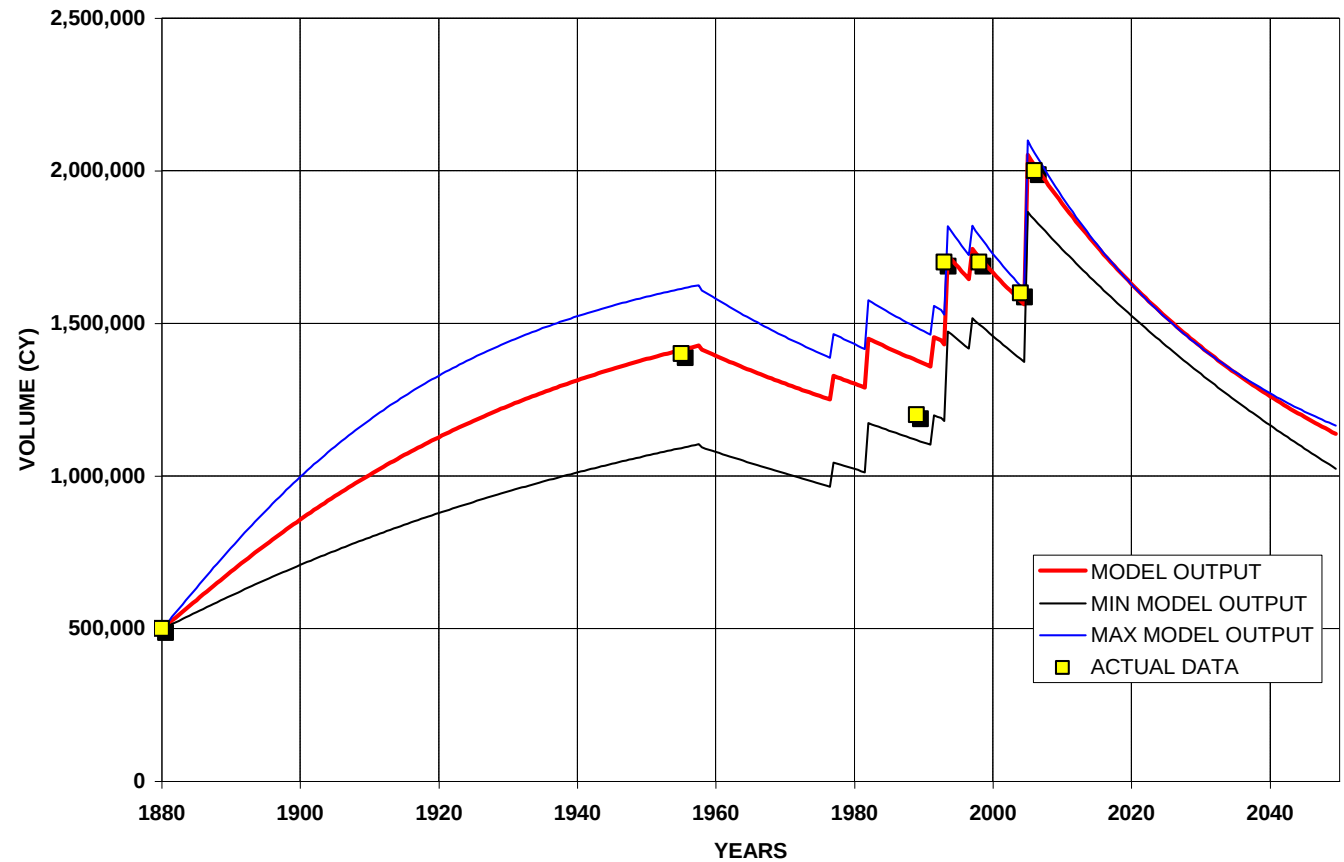
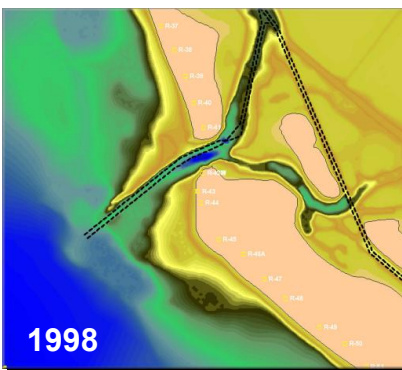
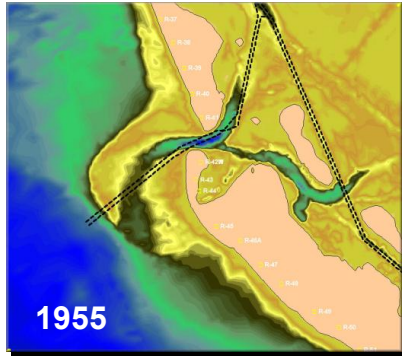
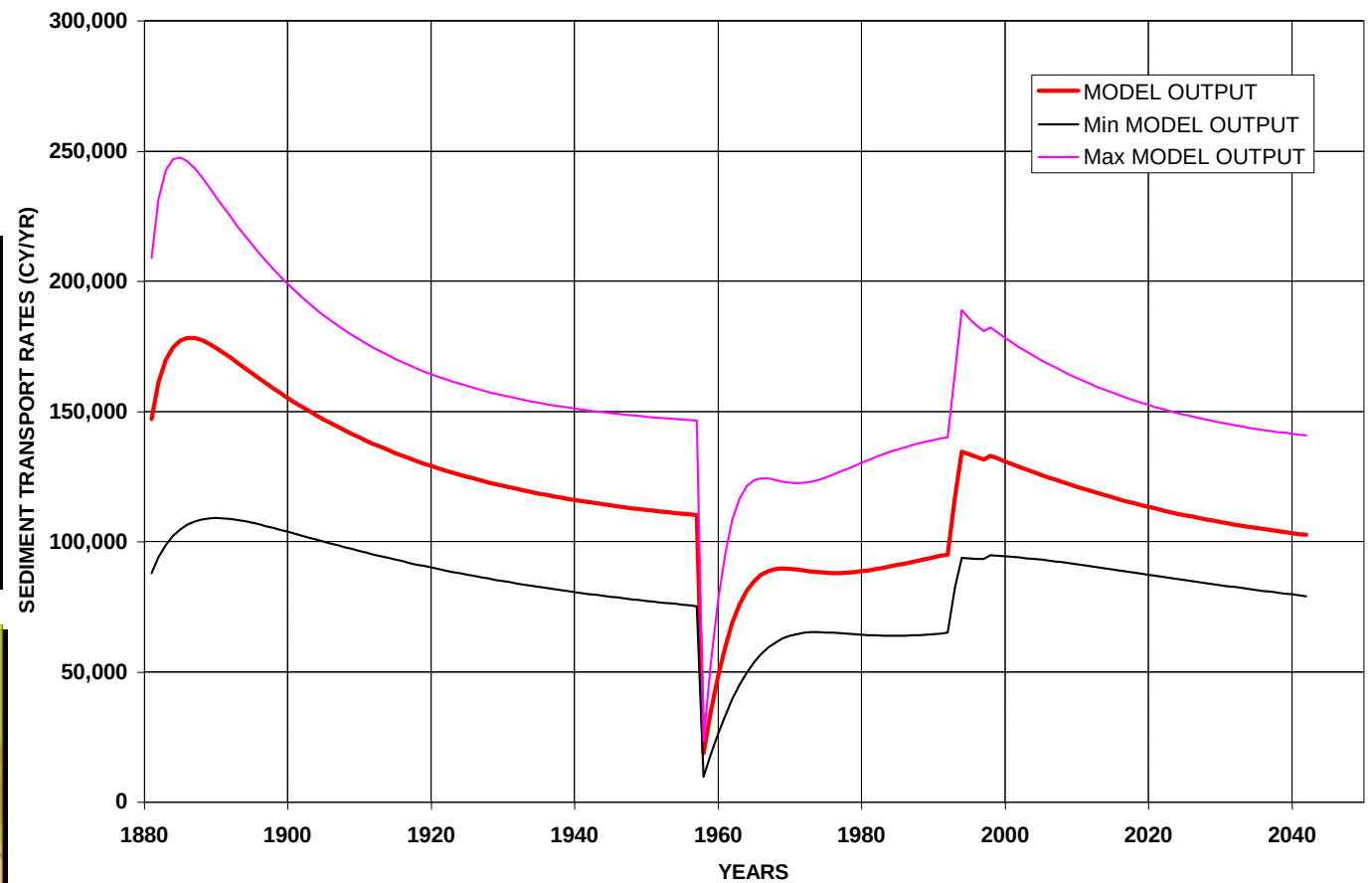


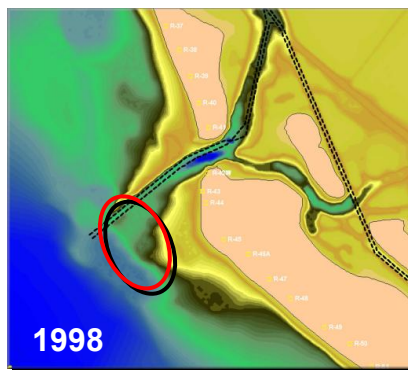
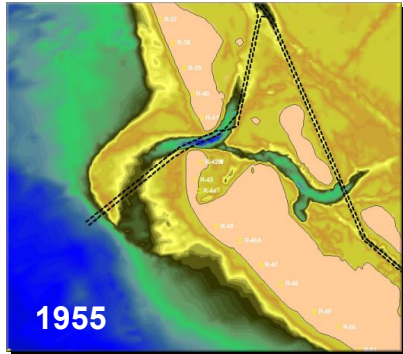
Figure B-10 Reservoir Model Results – Longboat Beach Volume



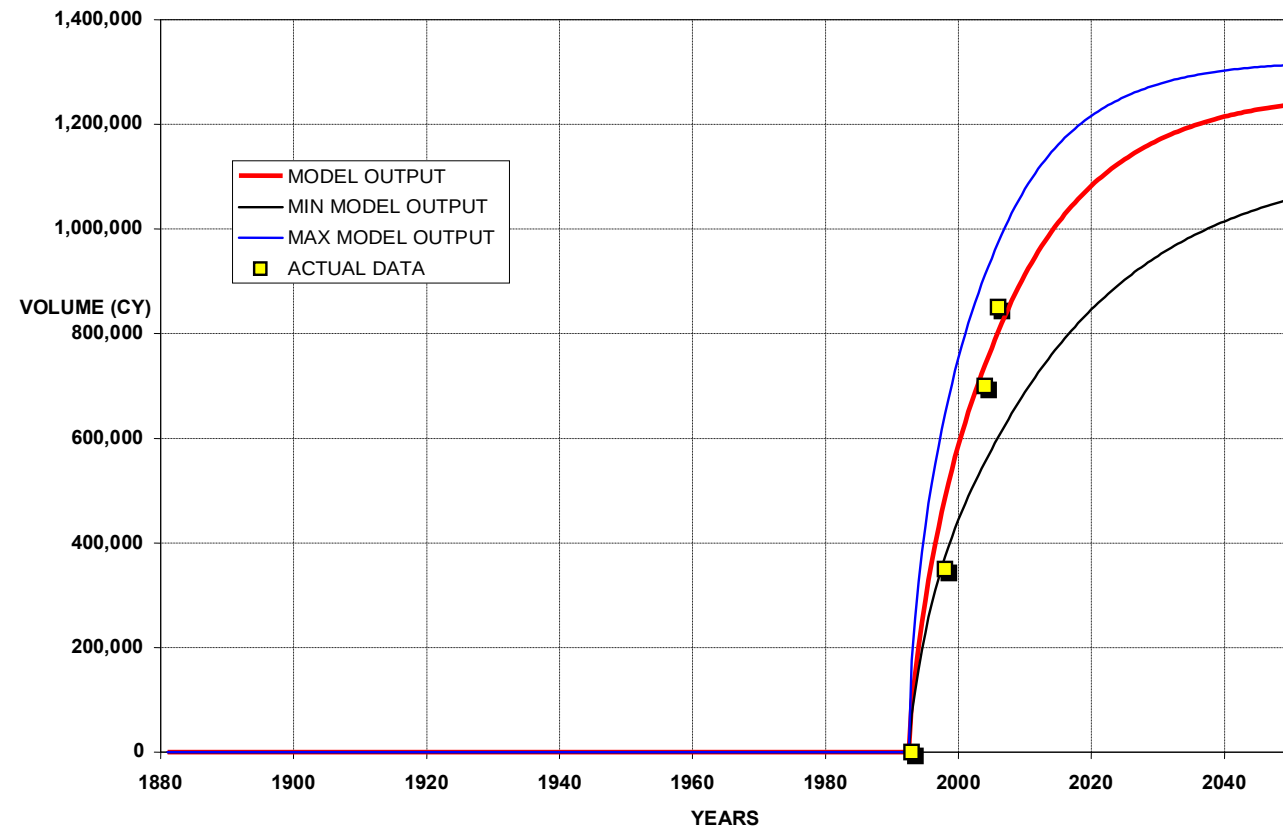
### FLOOD CHANNEL SEDIMENT TRANSPORT AVERAGE RATES RESERVOIR MODEL OUTPUT

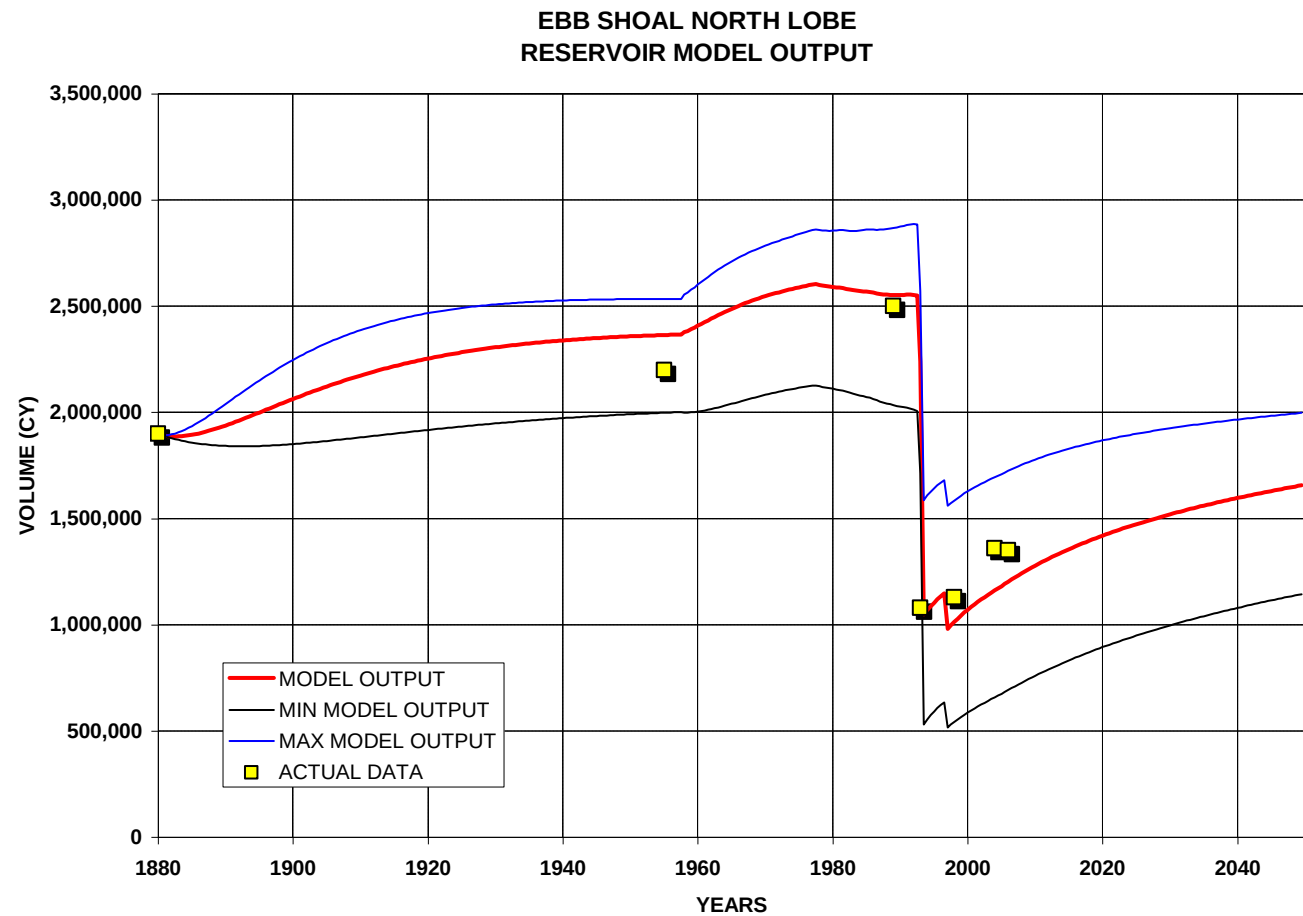
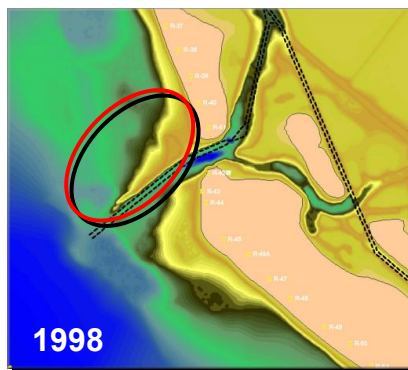
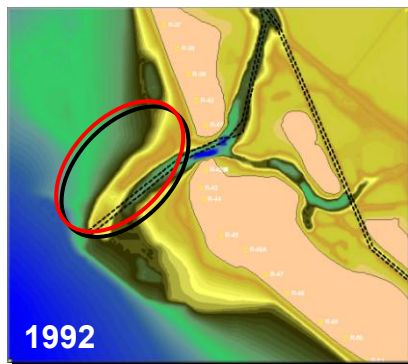
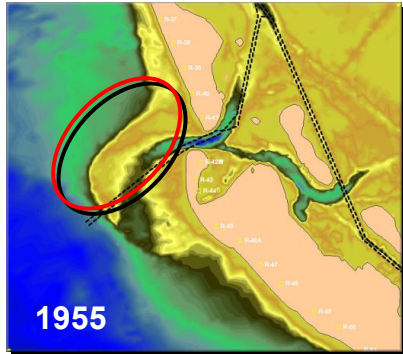




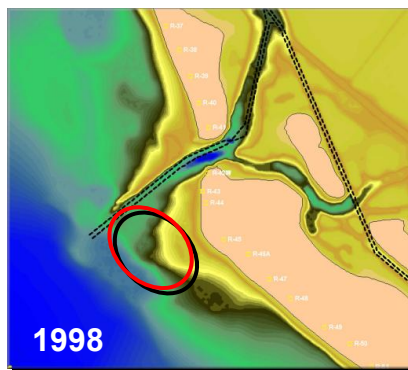


### EBB SHOAL 2 RESERVOIR MODEL OUTPUT

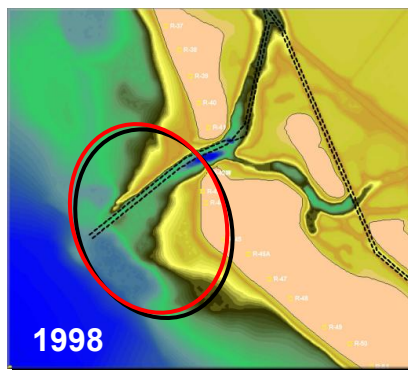
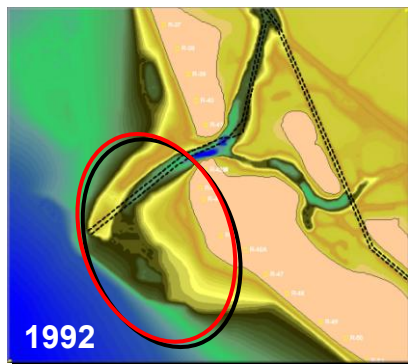
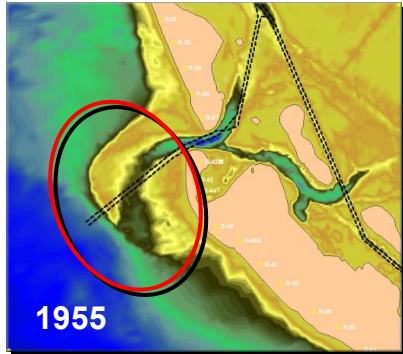




**Figure B-13 Reservoir Model Results – Ebb Shoal North Lobe Volume**



**Figure B-14 Reservoir Model Results – Ebb Shoal South Lobe Volume**



### EBB SHOAL TOTAL RESERVOIR MODEL OUTPUT

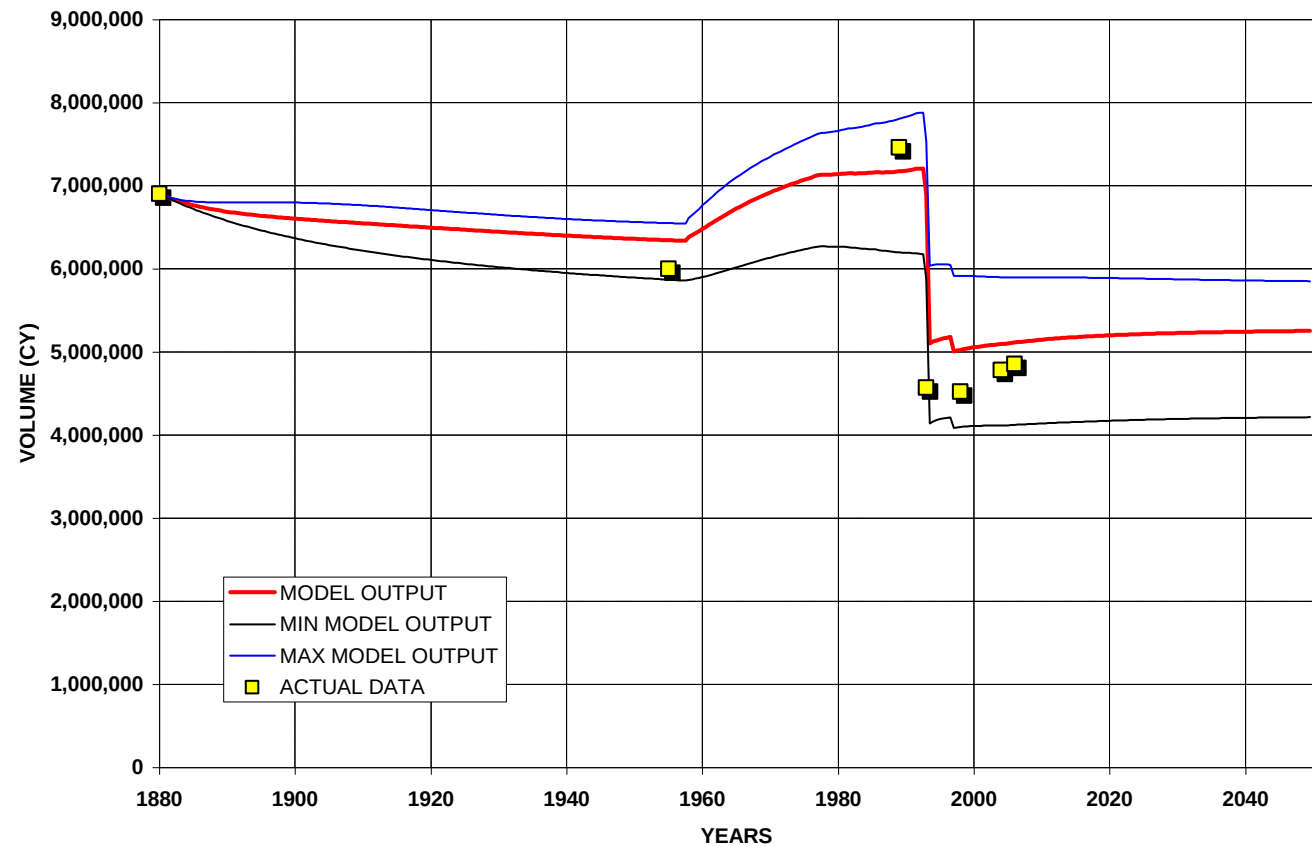
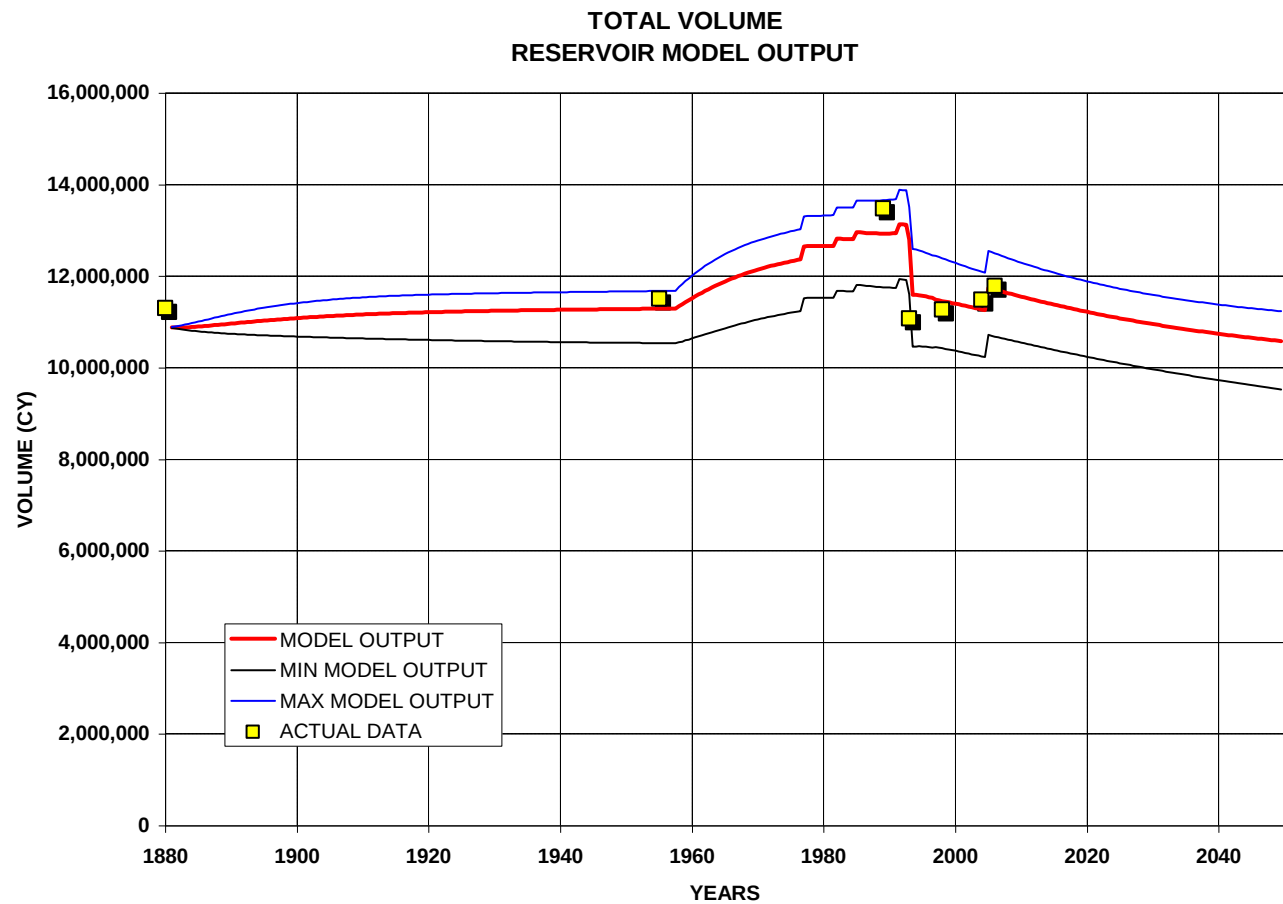
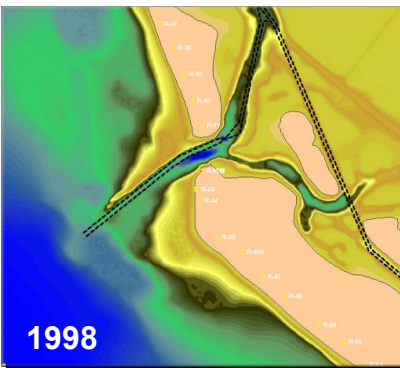
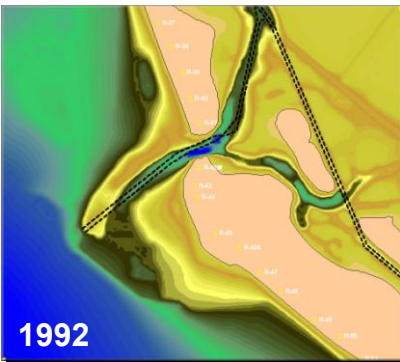
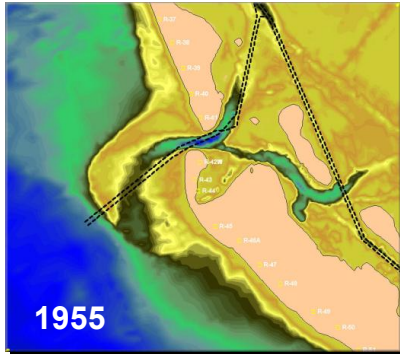


Figure B-15 Reservoir Model Results – Ebb Shoal All Volume

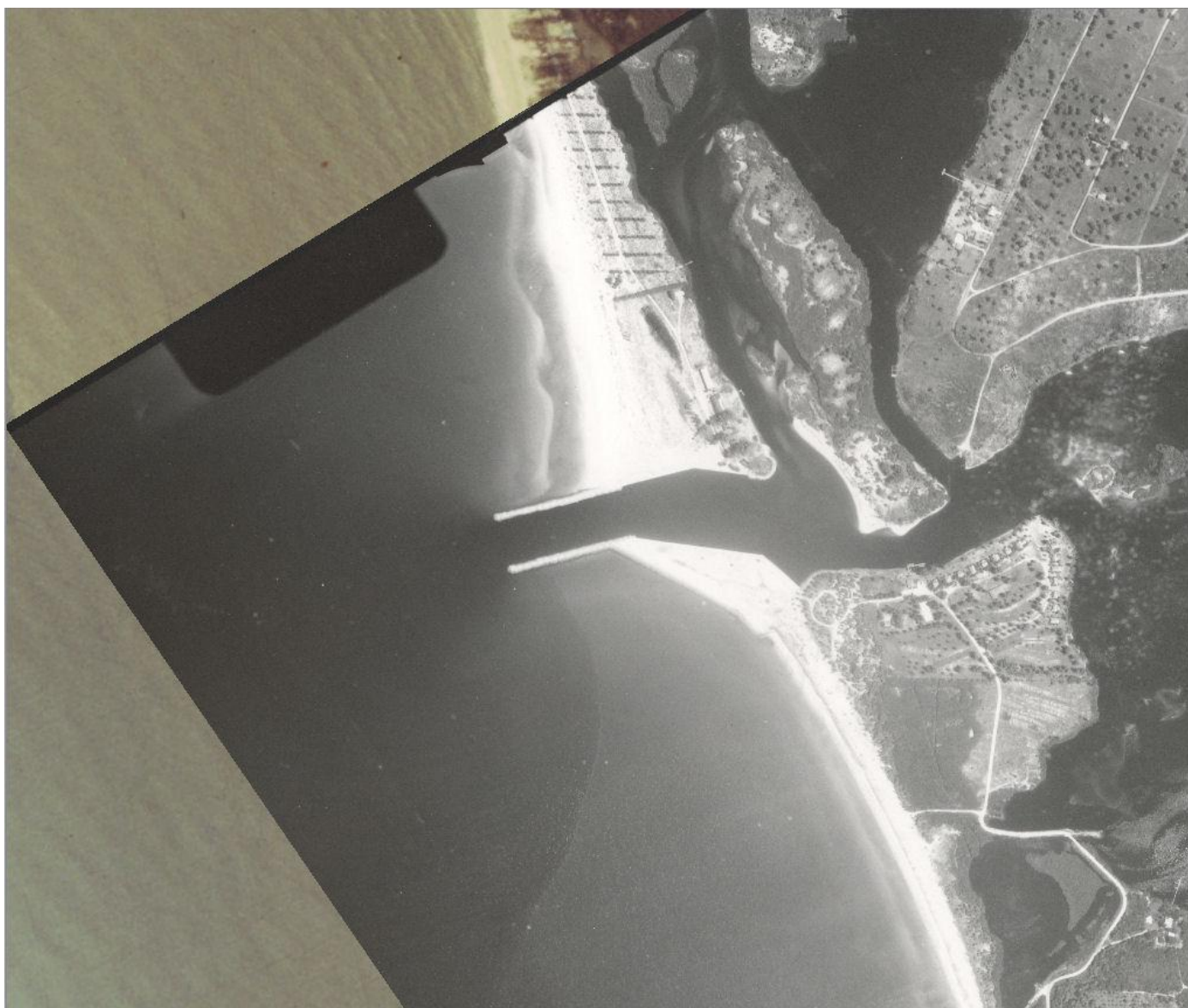




**Figure B-16 Reservoir Model Results – Total Volume**

## **Appendix 4A**

### **Venice Inlet Aerial Photos**



**Figure 4A-1. Venice Inlet 1943 Aerial**



**Figure 4A-2. Venice Inlet 1961 Aerial**





**Figure 4A-3. Venice Inlet 1962 Aerial**



**Figure 4A-4. Venice Inlet 1969 Aerial**



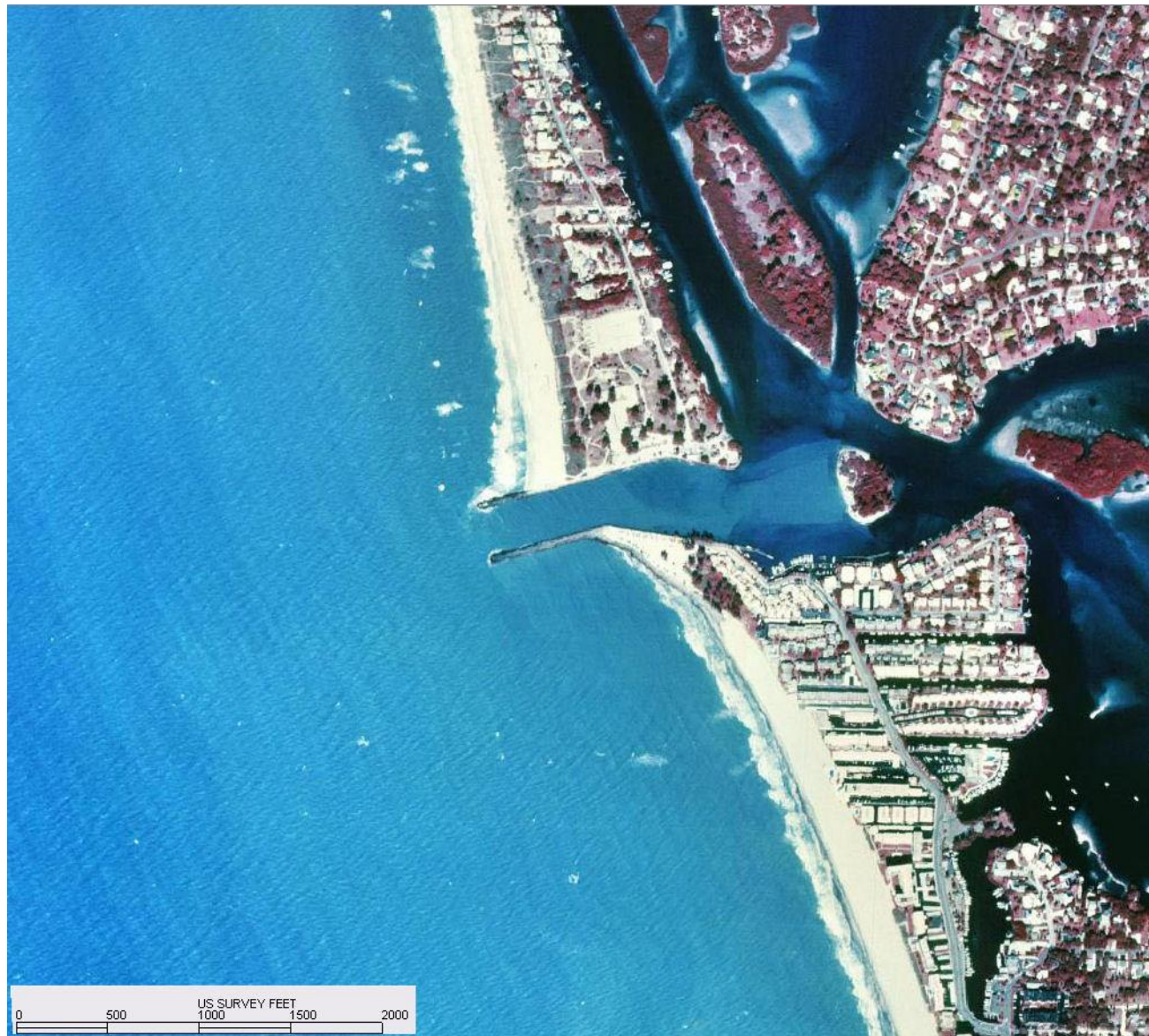


**Figure 4A-5. Venice Inlet 1981 Aerial**



**Figure 4A-6. Venice Inlet 1990 Aerial**



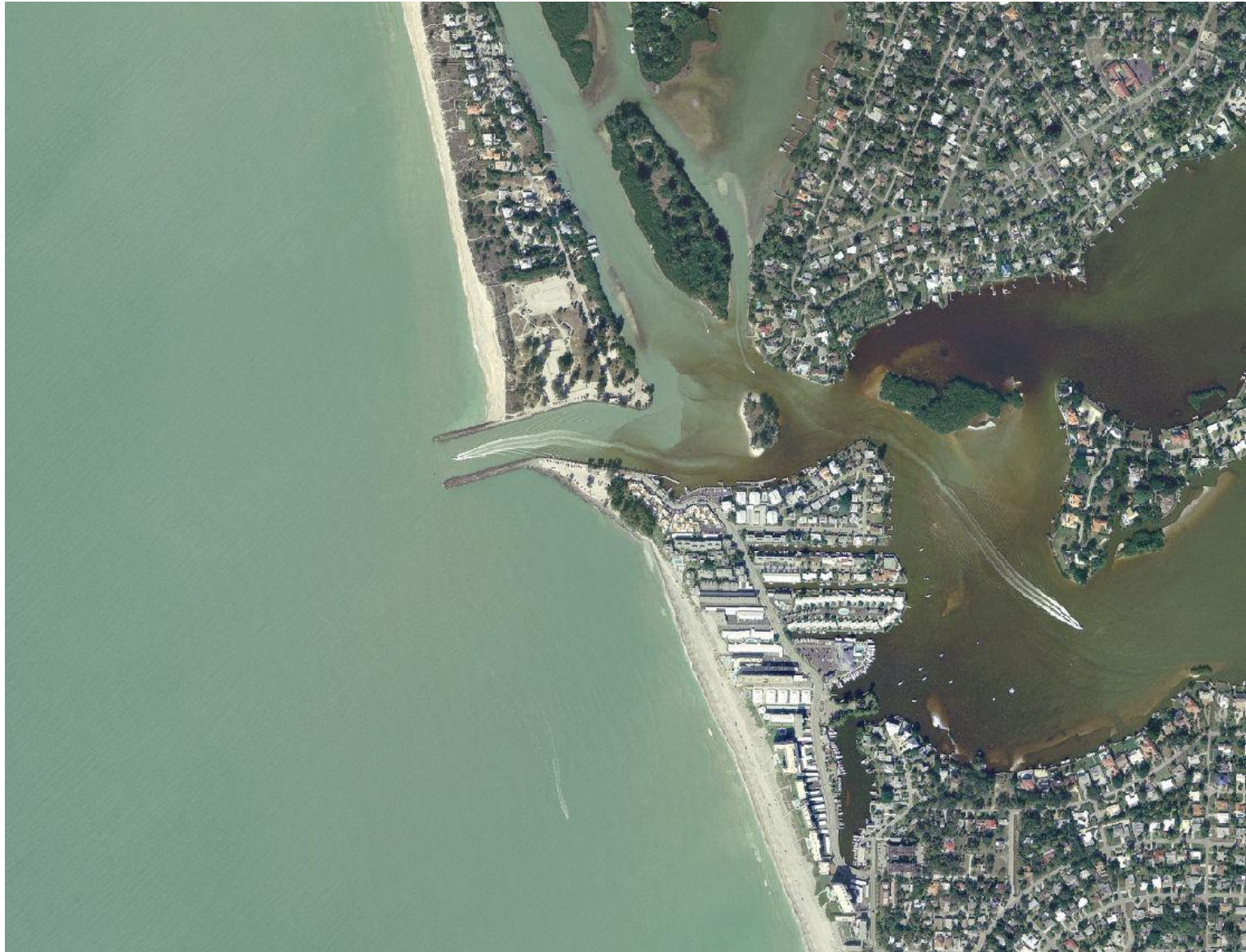


**Figure 4A-7. Venice Inlet 1995 Aerial**



**Figure 4A-8. Venice Inlet 1998 Aerial**



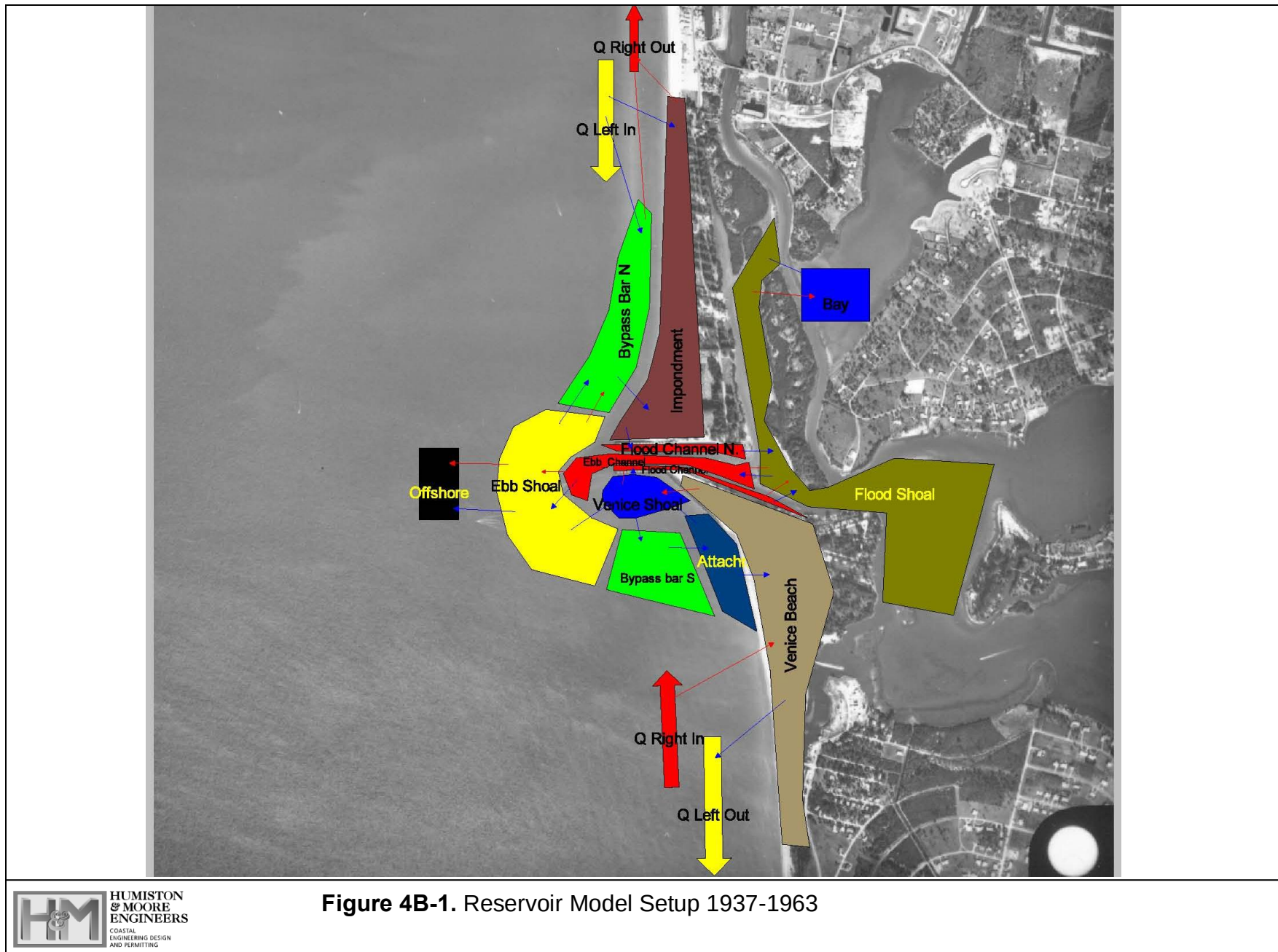


**Figure 4A-9. Venice Inlet 2004 Aerial**

## **Appendix 4B**

### **Reservoir Model Results for Venice Inlet**

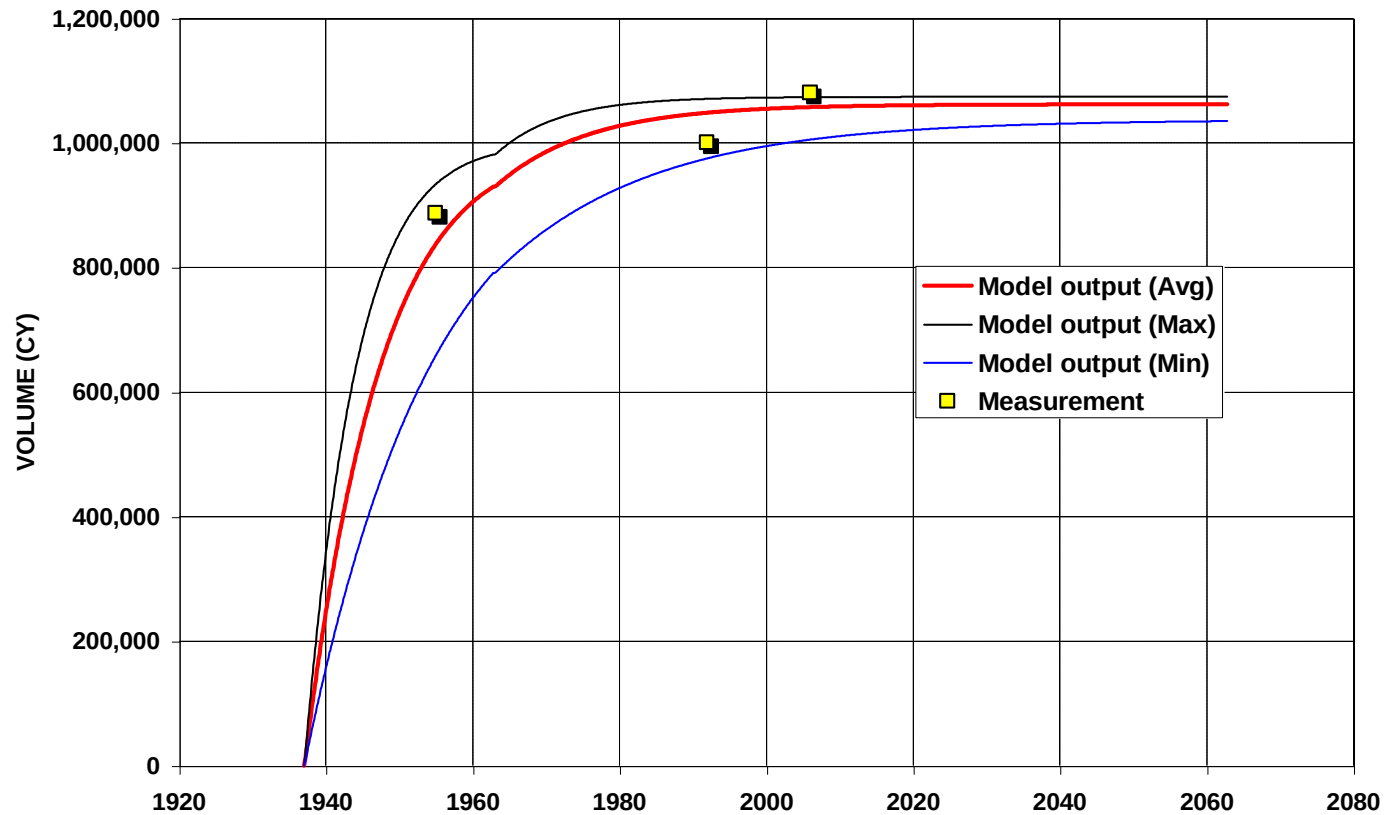
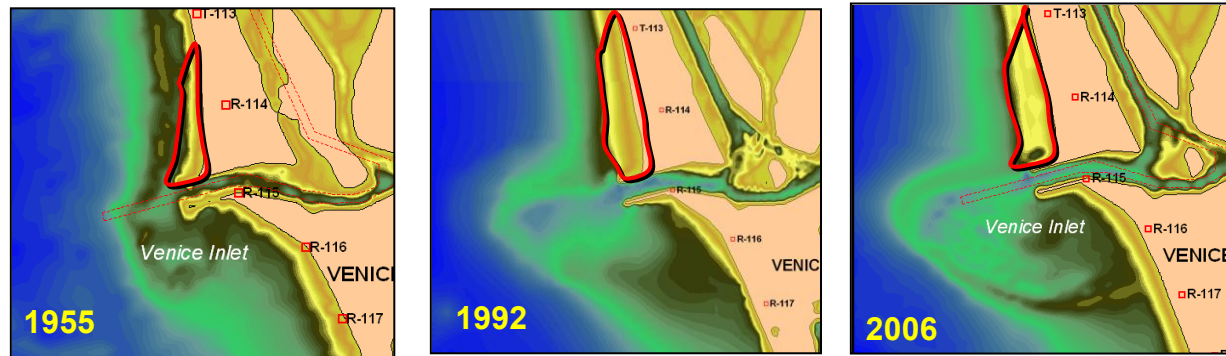




**Figure 4B-1. Reservoir Model Setup 1937-1963**

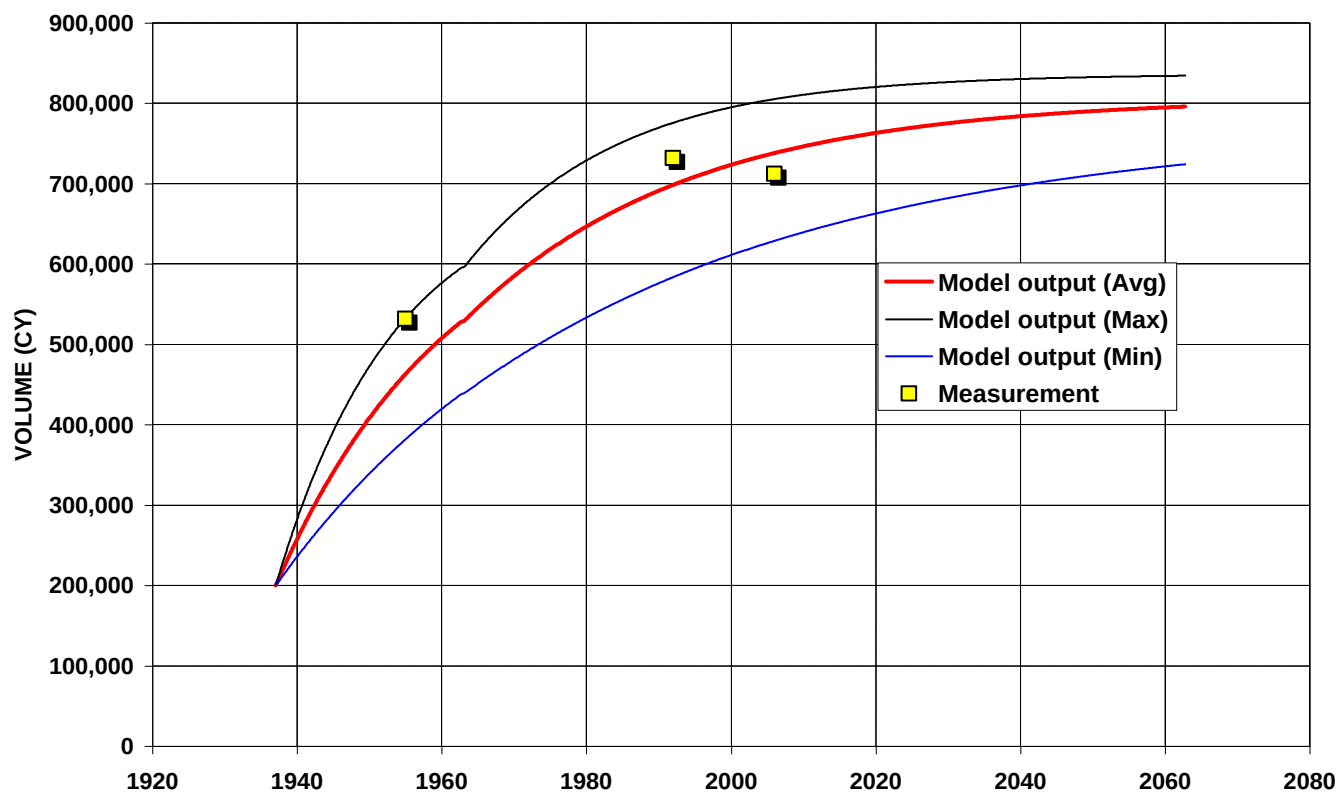
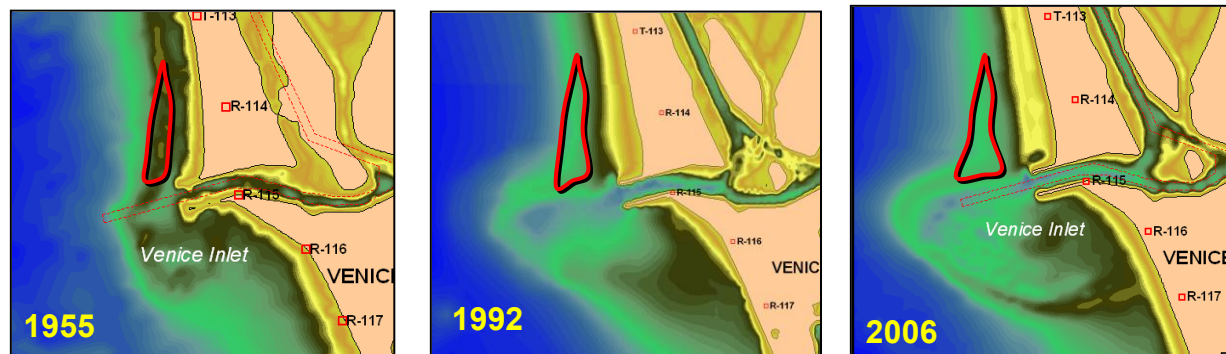


171



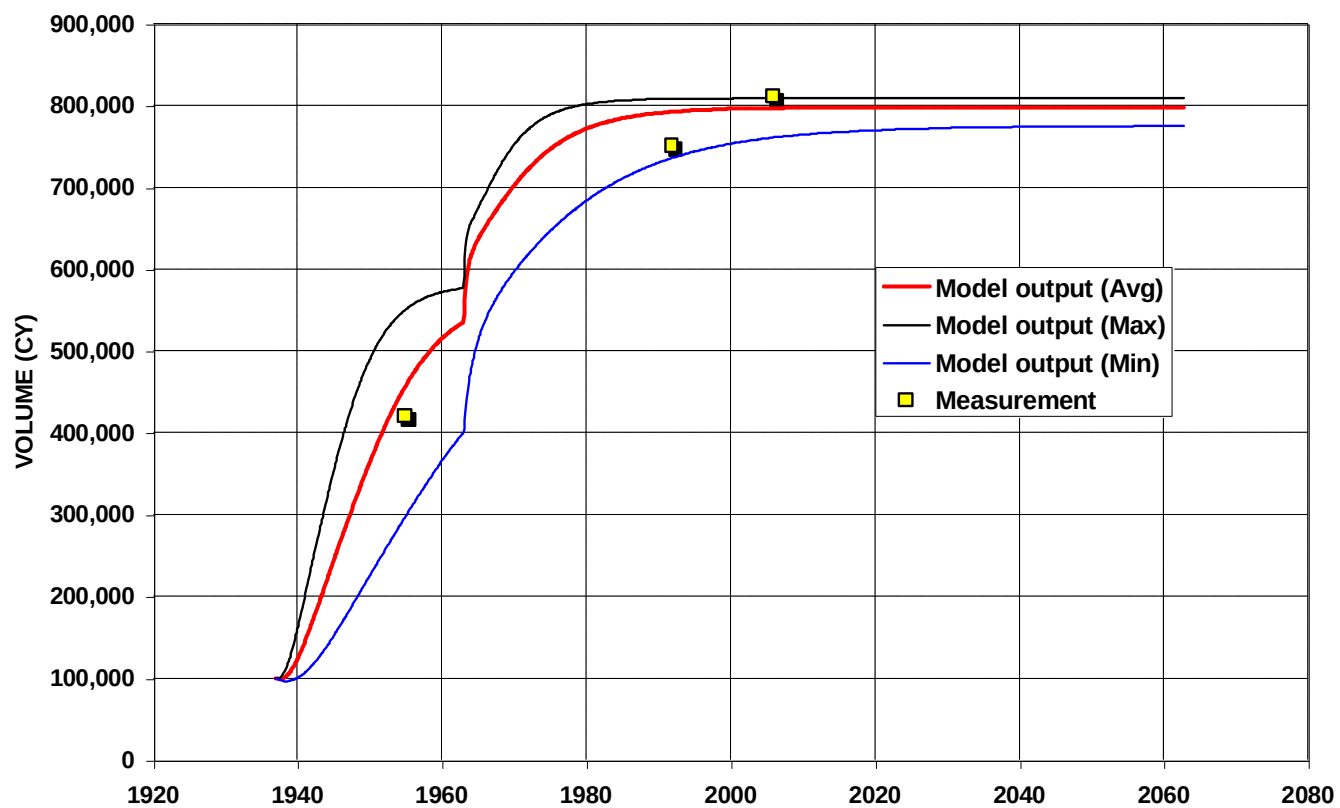
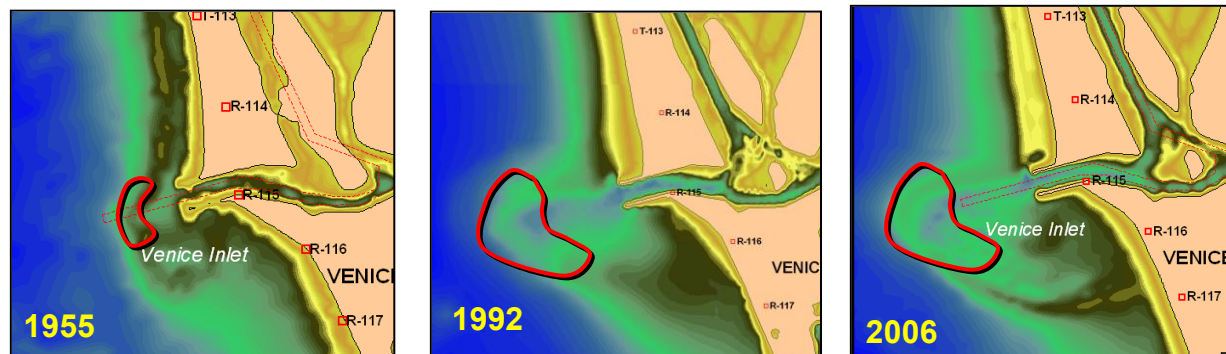
**Figure 4B-3. Reservoir Model Results for the Impoundment feature**



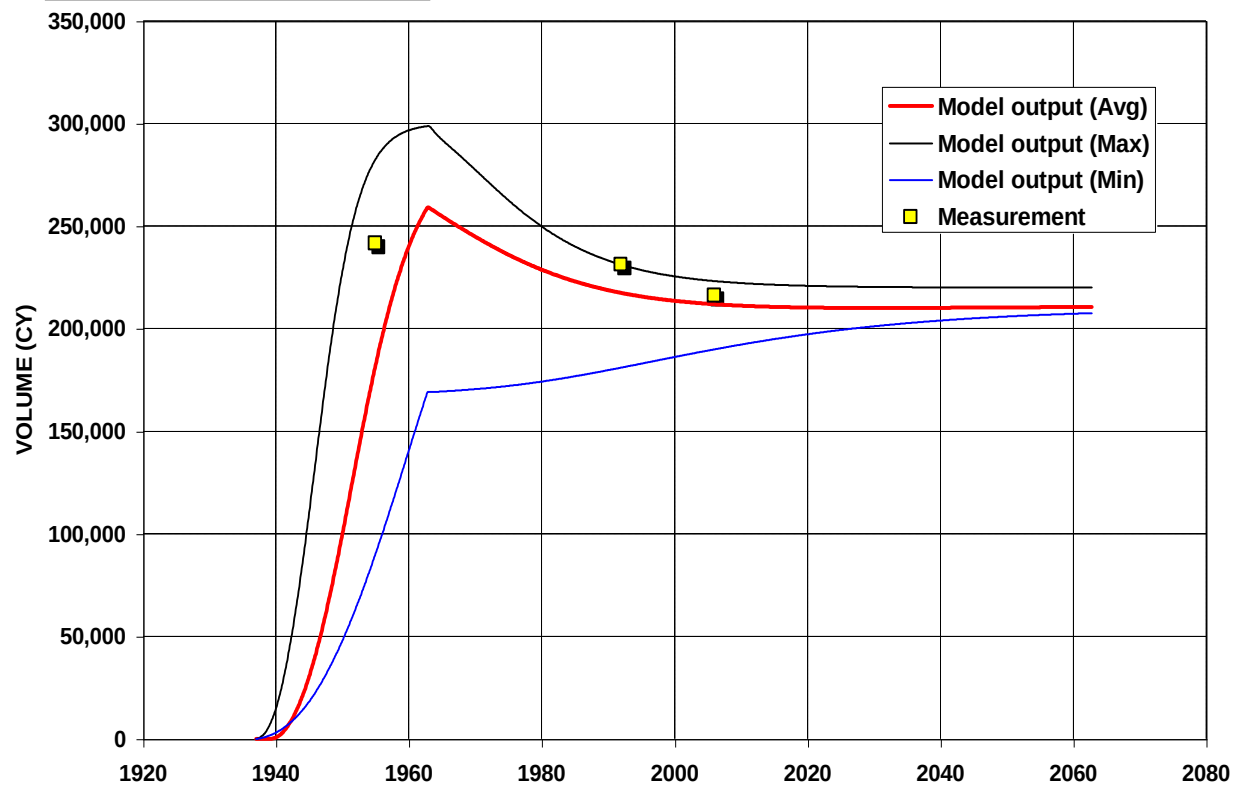
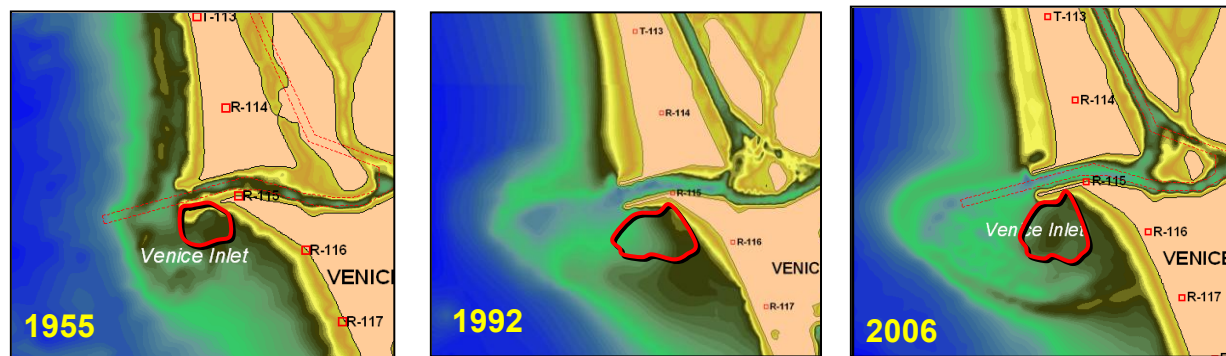


**Figure 4B-4. Venice Inlet North Bypass Bar Volume**

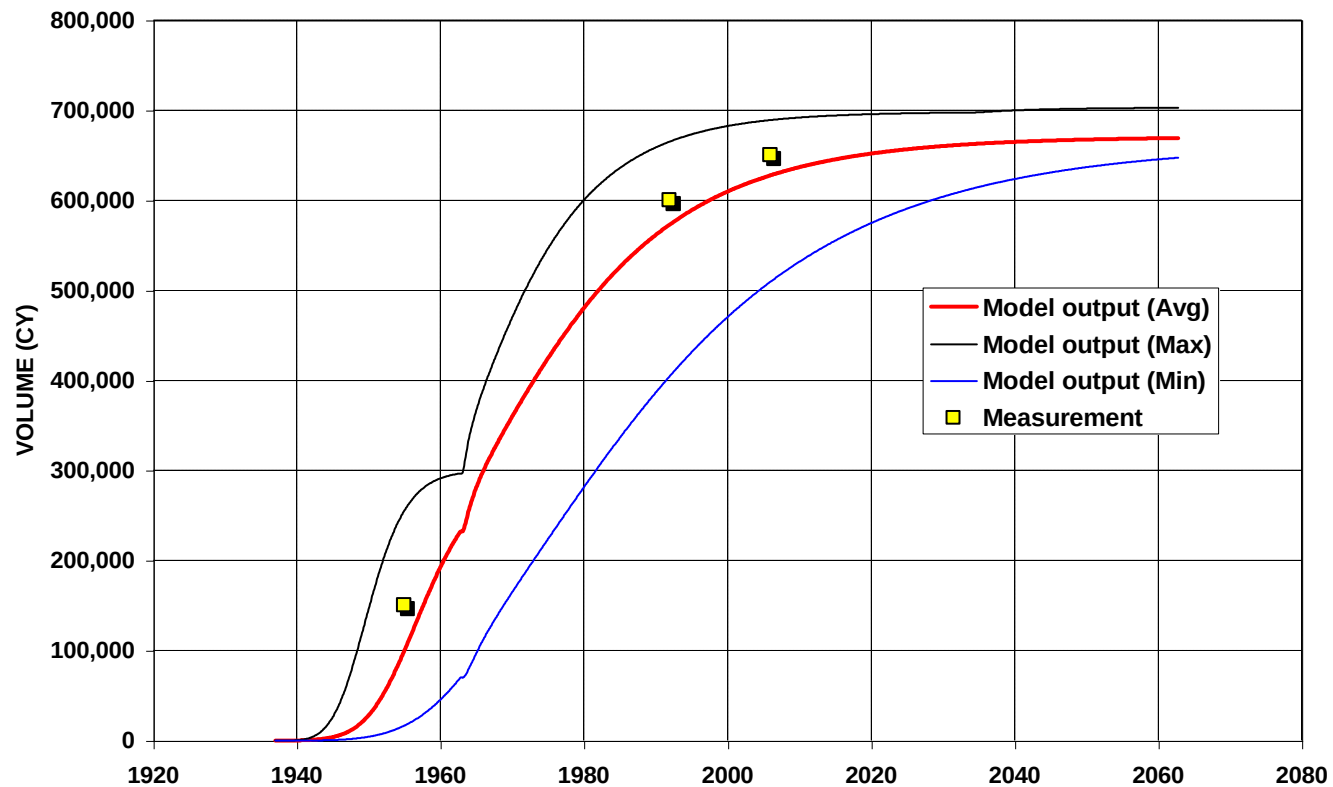
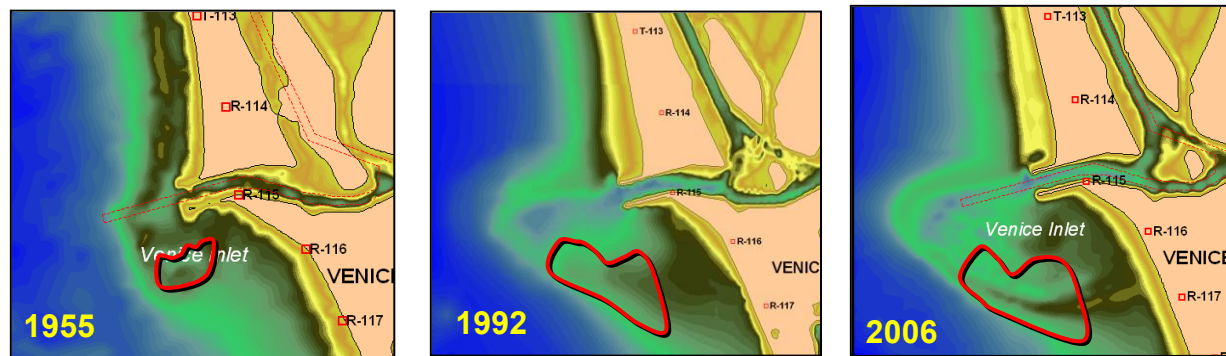




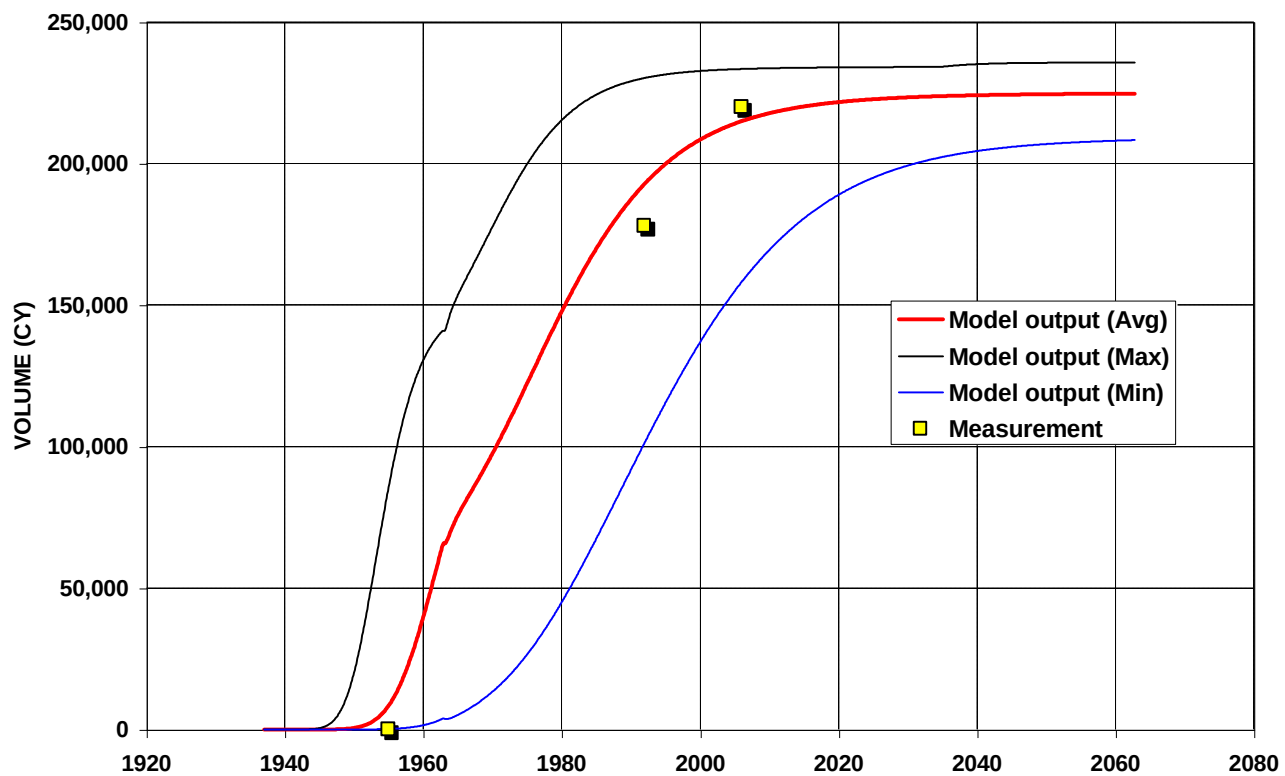
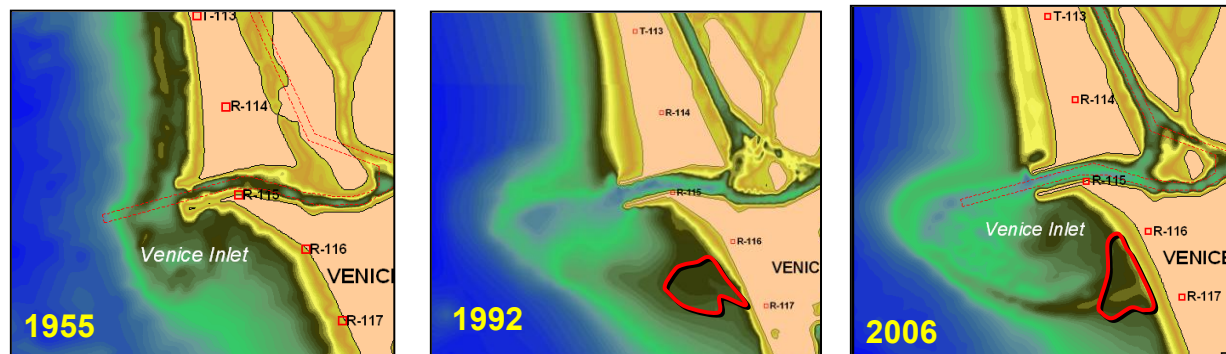
**Figure 4B-5. Venice Inlet Ebb Shoal Volume**



**Figure 4B-6. Venice Inlet South Shoal Volume**

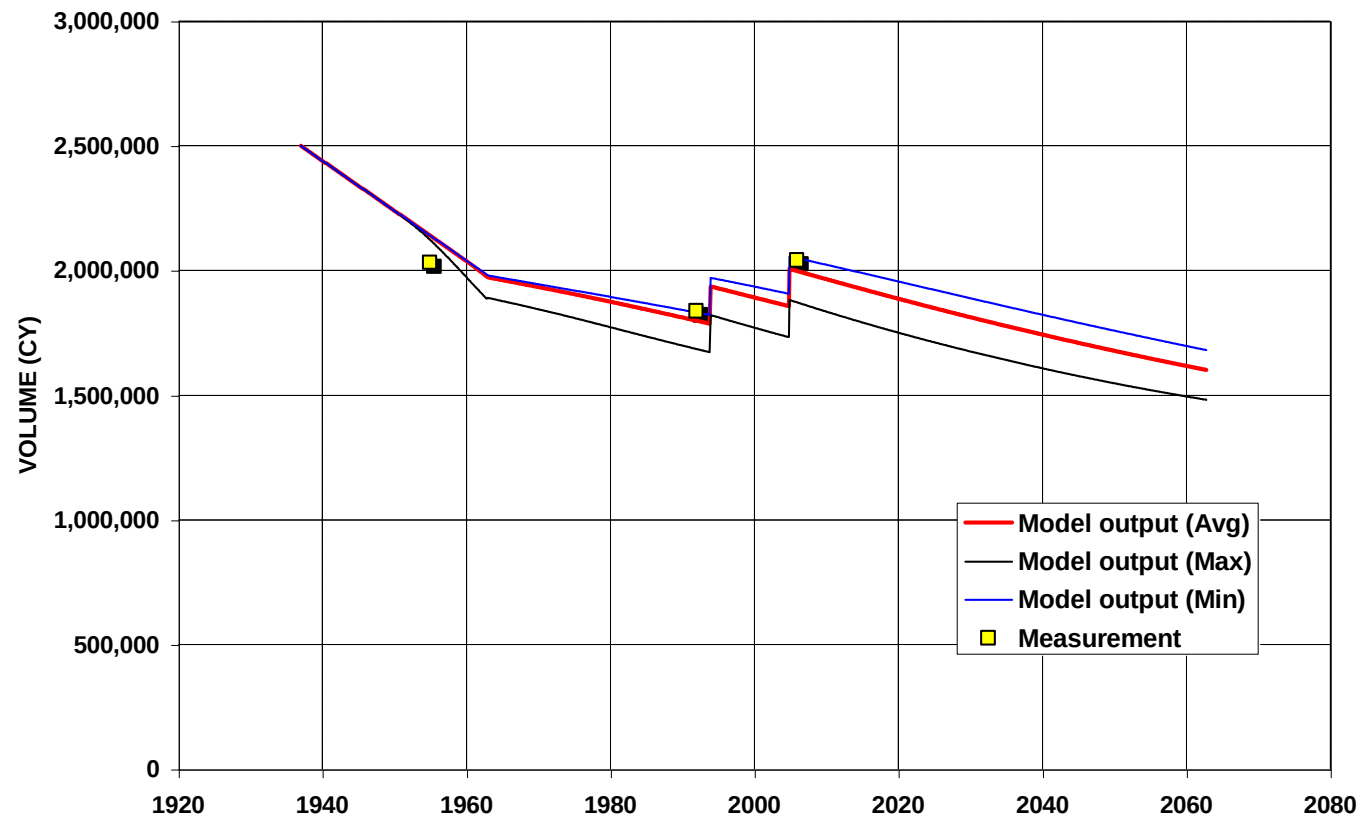
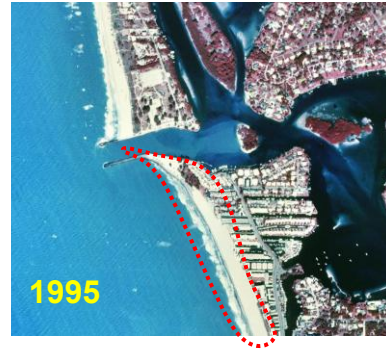
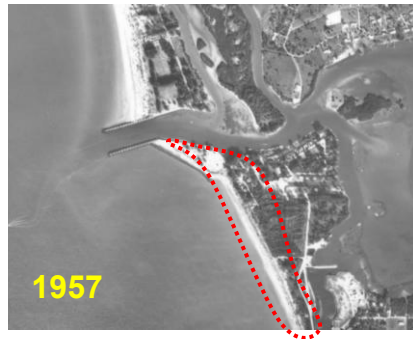


**Figure 4B-7. Venice Inlet South Bypass Bar Volume**

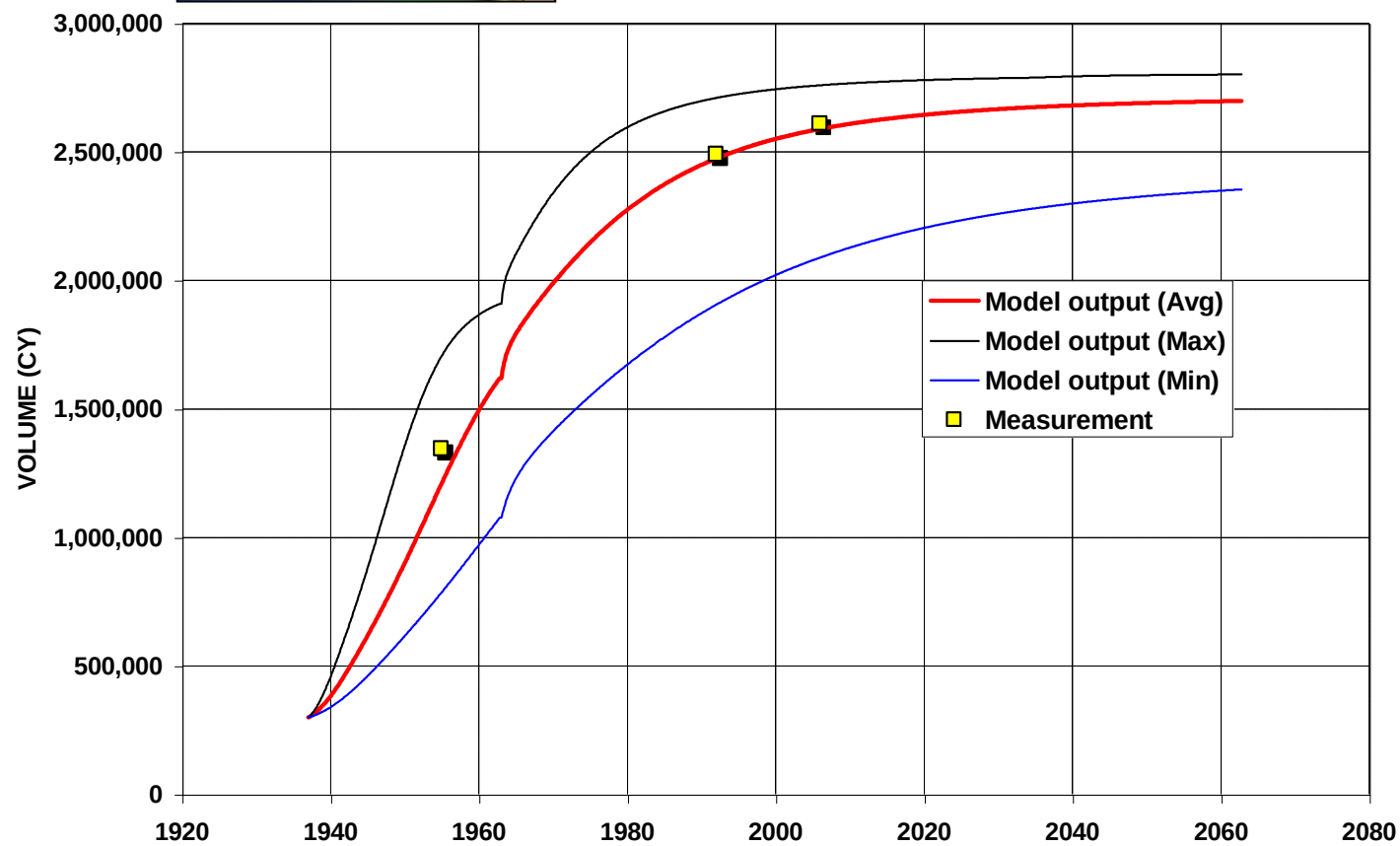
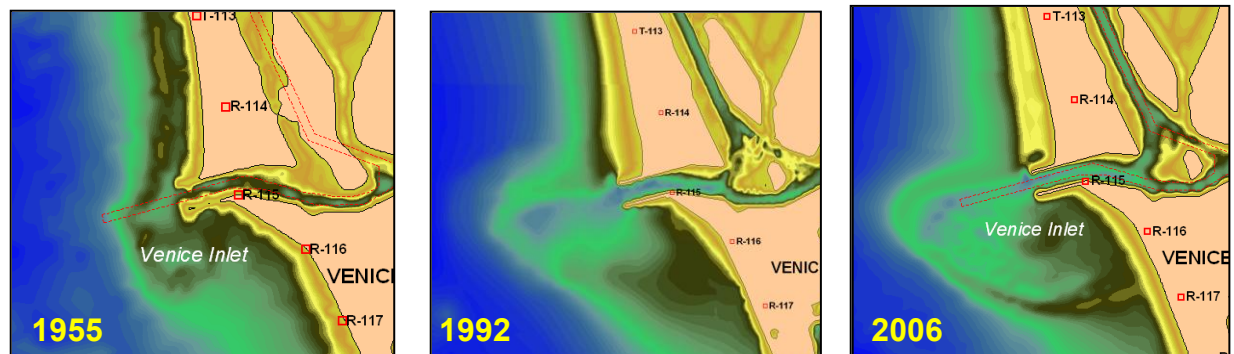


**Figure 4B-8. Venice Inlet Attachment Bar Volume**

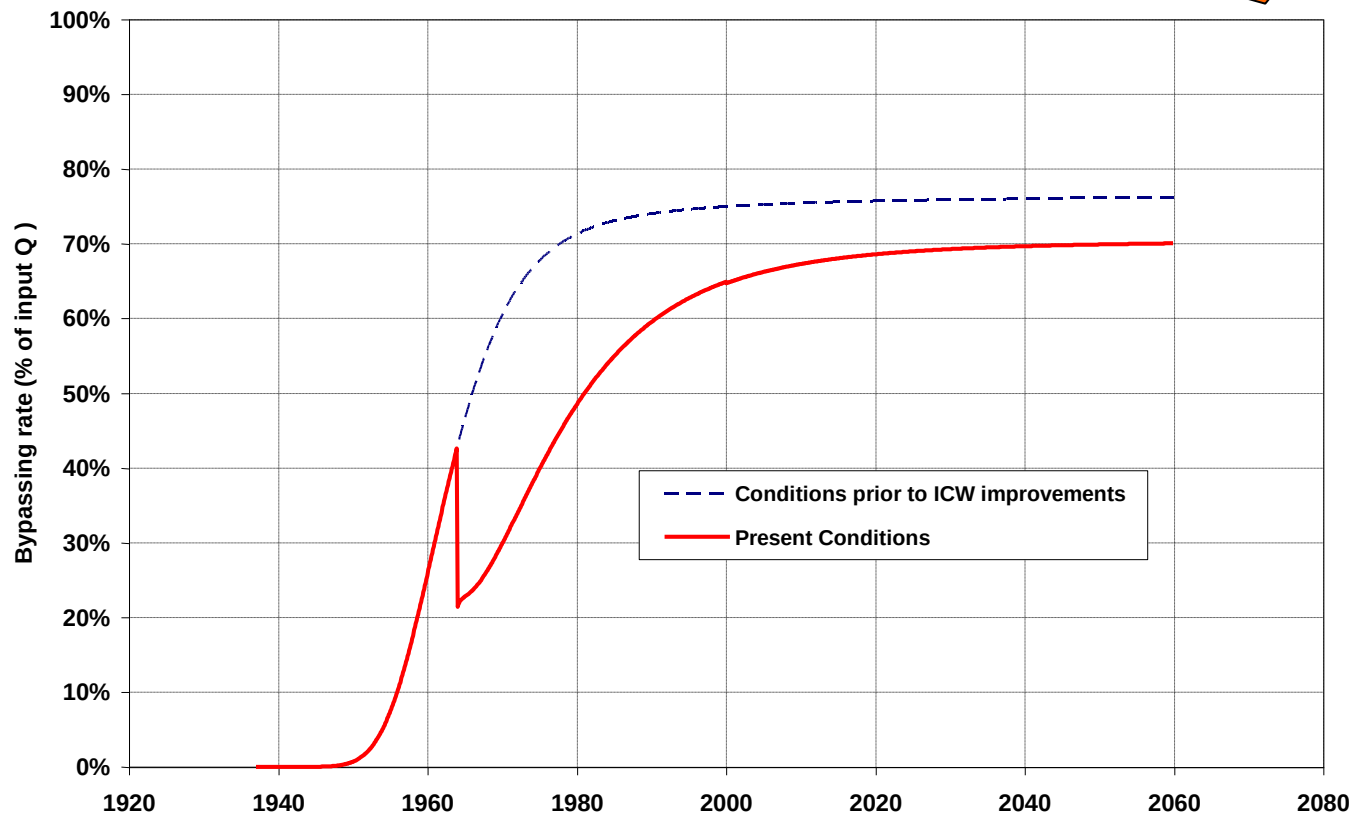
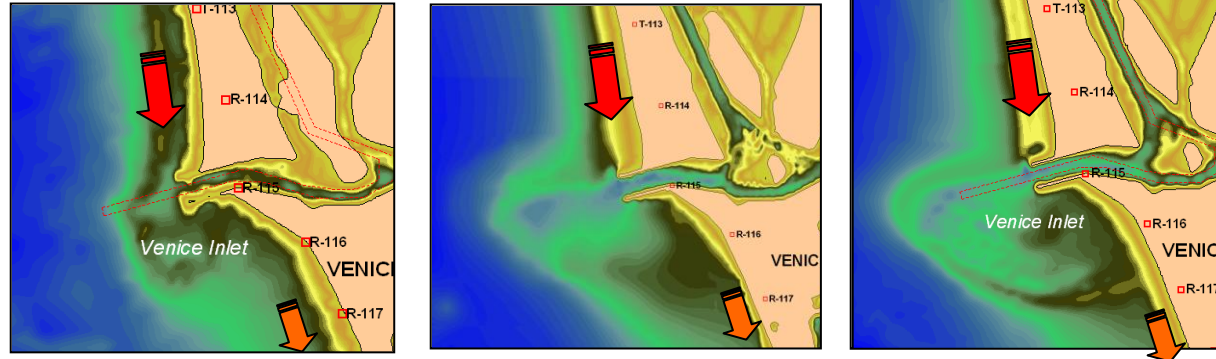




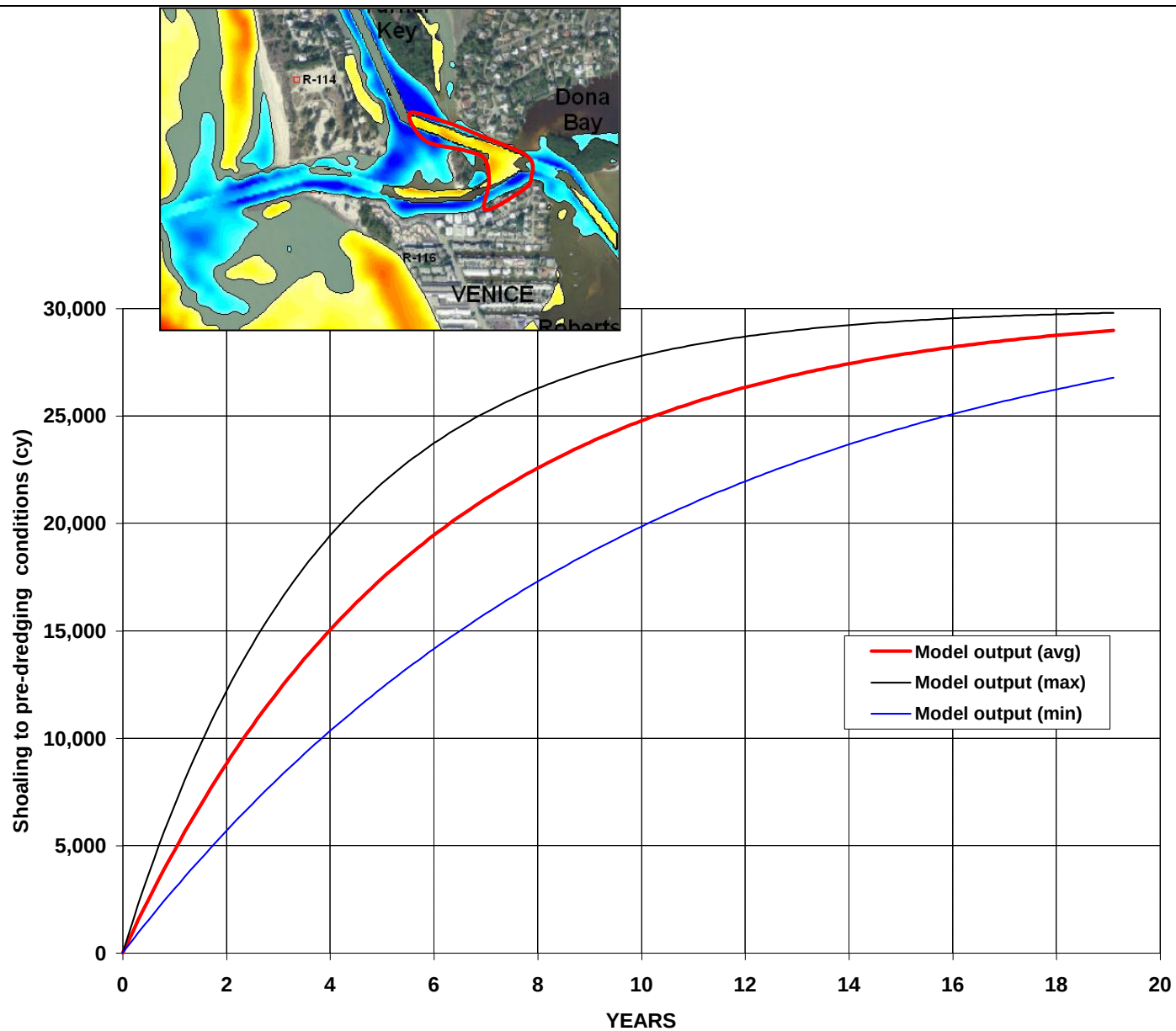
**Figure 4B-9. Venice Beach Volume**



**Figure 4B-10. Venice Inlet Ebb Shoal Total Volume**



**Figure 4B-11. Bypassing rates south of Venice Inlet**



**Figure 4B-12. Venice Inlet Reservoir Model Predictions**

Shoaling rates post dredging 30,000 CY from shoaling areas of the ICW