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Salt Ponds Shore Zone Modeling for Breakwater Placement: Summary Report

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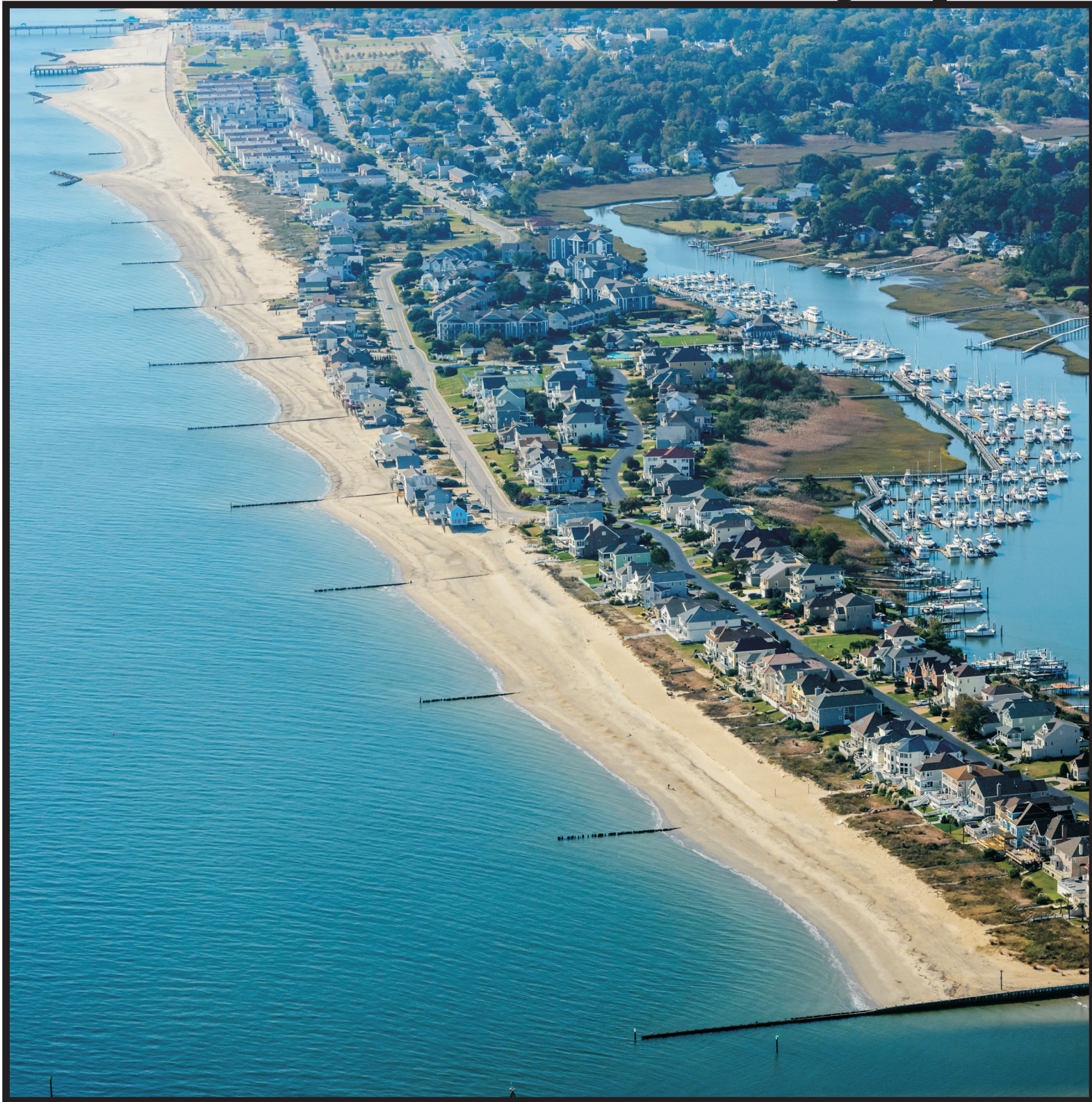*Virginia Institute of Marine Science*

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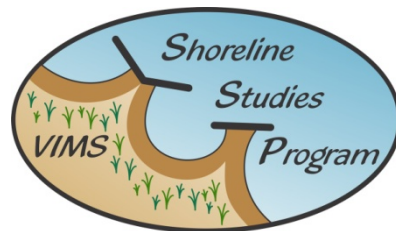# Salt Ponds Shore Zone Modeling for Breakwater Placement:

Summary Report

For
Waterway Surveys & Engineering, Ltd.
And
City of Hampton

By

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Executive Summary

The City of Hampton Beachfront and Storm Protection Management Plan (Waterway Surveys, VIMS, and URS, 2011) has been used to construct and manage three breakwaters along Buckroe Public Beach. The City of Hampton presently is planning to design and construct the recommended breakwater along the Salt Ponds (SP) Beach. Since much of the original shoreline modeling and conceptual planning was performed before structures were placed there, existing shore conditions have changed, and thus the modeling component was recently updated to better site the proposed breakwater. Using present conditions, the modeling results can be used as guidance to maximize storm protection, minimize downdrift impacts, and better manage sediment transport. The purpose of this project is to recommend a position for the Salt Ponds breakwater that will fit with the City's goals. To accomplish these goals, vertical aerial photograph were taken and orthorectified in order to provide the most recent site-conditions. In addition, the shore zone was modeled using the one-line numerical model, GenCade (Aquaveo, 2014). Based on the results of the modeling study and working with personnel from Waterway Surveys & Engineering (Waterway) and URS Corporation, recommendations were made for the placement of a breakwater at Salt Ponds Public Beach.

Shoreline change analysis reveals that present management strategies of strategic breakwater placement and backpassing at Salt Ponds Inlet are maintaining beaches along Hampton's shoreline. The structures are performing as designed. Placing a breakwater along Salt Ponds Public Beach will create a wide, protective beach and may reduce the frequency of maintenance dredging at the Inlet.

Each scenario modeled includes a 250 ft long breakwater structure in various positions along the Salt Ponds Public Beach. For each scenario, the model was run with and without sand backpassing (pumping dredged sand on to the beach) from Salt Ponds Inlet. It was assumed that dredged material from the Inlet would be placed on the Salt Ponds shoreline every two years. In scenarios 1, 2, and 3, the proposed breakwater structure will create a T-head with one of the three existing groins. Scenario 4 attaches the breakwater to the end of the south jetty at Salt Ponds Inlet. This scenario would allow the breakwater to act as a spur to the Inlet's existing south jetty rather than as a typical attached breakwater. For scenarios 5 and 6, the proposed breakwater attached to the south jetty was moved closer to the shoreline. In scenario 5, the proposed breakwater was placed closest to the shoreline, while for scenario 6 the structure was placed about mid-way between the shoreline and the end of the south jetty. The proposed structure could not be attached to the south jetty as intended due to model limitations. Scenarios 4, 5 and 6 also were modeled with a reduced rate of sand backpassing at the Inlet (every three years).

The recommendation for the proposed breakwater location was based on several factors including overall effectiveness in terms of sand retention and positive impacts to the public beach shoreline as well as reduction in Salt Ponds Inlet maintenance dredging. In addition, containing the project's impacts to the public beach was a priority.

When the model results were reviewed, Scenarios 1, 2, and 4 were excluded from consideration. Scenarios 1 and 2 would likely have a short-term negative impact on the

downdrift shorelines. Scenario 4 had little effect on shore change. Scenarios 5 and 6 could be viable options since their results indicate that inlet maintenance could be reduced while still maintaining a wide, protective beach. These were not chosen as the recommended structures because their construction could potentially impact future plans for improvements to the Salt Ponds Inlet.

Scenario 3, a T-head structure at the end of the northernmost groin, is the recommended placement of a breakwater at Salt Ponds Public Beach. It will provide storm protection to much of the public beach shoreline by increasing shore width. In addition, the project impacts should be contained to the publicly-owned coast. The recommended structure at SP groin 3 provides flexibility for continued evolution of Hampton's shore zone management program at the Inlet. Future recommendations include rebuilding and raising the south jetty in order to reduce sand transport into Salt Ponds Inlet. In addition, a spur at the end of the groin would work in conjunction with the recommended breakwater to set an embayment or pocket beach. Any future structures conceived for the southern reach of Salt Ponds Public Beach could be designed to work within the system.

It is important to note that shore zone modeling simulates existing conditions along a coast and can provide a method to evaluate structural options along a shoreline. Over time, as shore conditions change and storms impact the shoreline, the model results become less dependable. The results should be used as guidance and should not replace the experience of coastal specialists.

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1 Introduction

The City of Hampton Beachfront and Storm Protection Management Plan (Waterway Surveys, VIMS, and URS, 2011) provides a conceptual plan for the placement of structures along Hampton's shoreline (Figure 1). The Shoreline Studies Program (SSP) at the Virginia Institute of Marine Science (VIMS) provided the original shoreline modeling used for this plan in 1999. The modeling was used to provide guidance on structure placement for management of the entire beach fronting shoreline. The City has built three of the structures in the Plan along the public beach at Buckroe and presently is planning to design and construct the recommended breakwater in the Salt Ponds Reach. Since much of the original modeling and conceptual planning was performed before structures were placed along the shoreline and existing shore conditions have changed, updating the modeling component is necessary in order to better site the breakwater. Using present conditions, the modeling results can be used as guidance to maximize storm protection, minimize downdrift impacts, and better manage sediment transport. The purpose of this project is to recommend a structure position that will fit with the City's goals.

To accomplish this project, vertical aerial photograph were taken and orthorectified in order to provide the most recent site-conditions. This shoreline was compared to existing shorelines in the SSP's Shoreline Evolution Database in order to look at
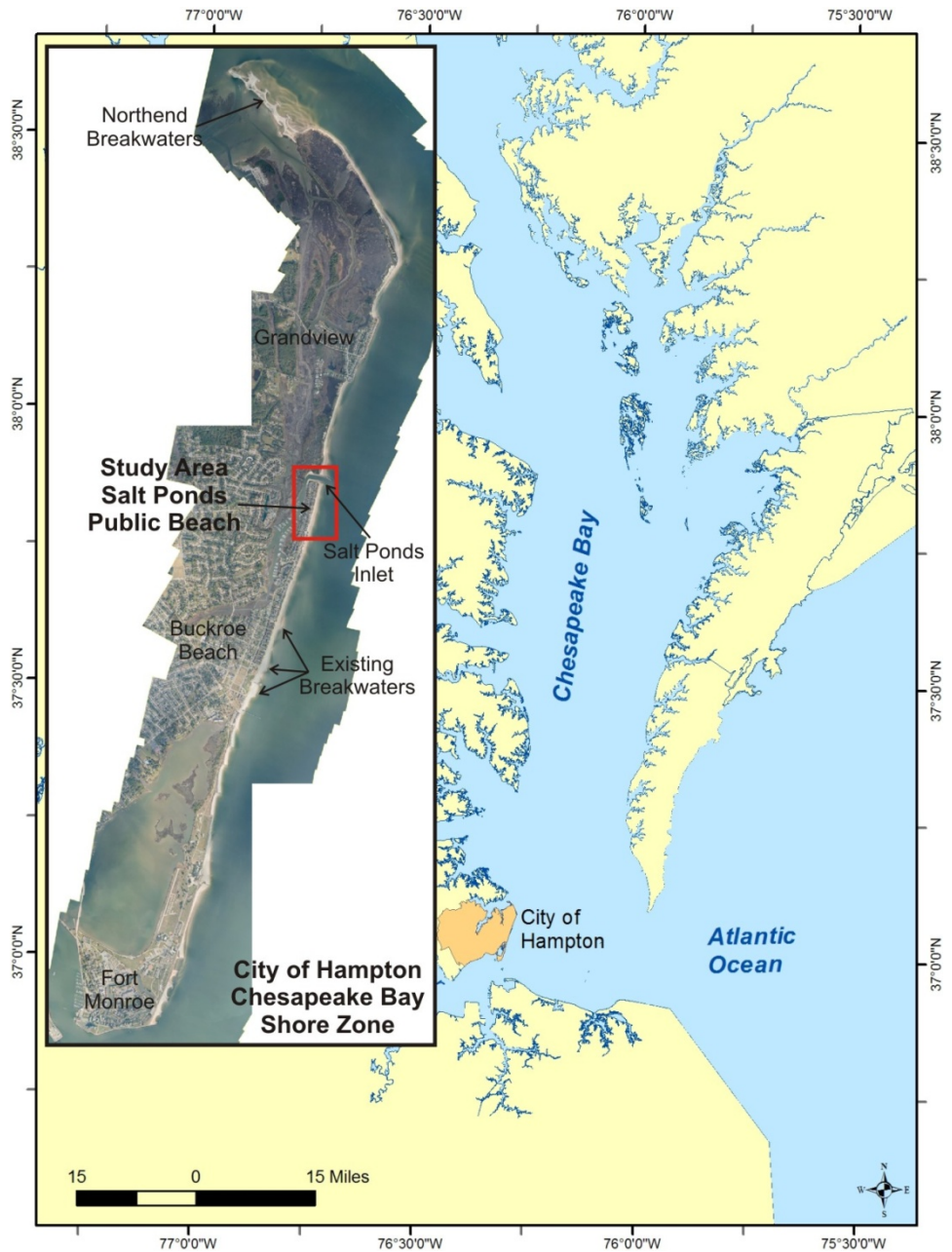

Figure 1. Location of City of Hampton and Salt Ponds Public Beach within the Chesapeake Bay estuarine system.

the impact of the structures through time. In addition, the shore zone was modeled using the one-line numerical model, GenCade (Aquaveo, 2014). Based on the results of the modeling study and working with personnel from Waterway Surveys & Engineering (Waterway) and URS Corporation, recommendations were made for the placement of a breakwater at Salt Ponds Public Beach.

2 Methods

Aerial Photography

In order to model effectively, up-to-date shoreline information is necessary for positioning of the structure. Ortho-rectified aerial photography, taken on October 27, 2013, was used to determine the relationships between existing shoreline structures, infrastructure, and present location of the shoreline. A digitized shoreline is a necessary component of modeling.

Vertical aerial digital photographs were taken of the entire Hampton shoreline. The images were orthorectified in Leica Photogrammetry Suite using ground control points taken by Shoreline Studies Program personnel. The ground control points were taken with a real-time kinematic global positioning system. The position of the approximate mean high water shoreline was determined from the aerial photos and from shore surveys provided by Waterway. The position was digitized in Esri ArcGIS. The shoreline was used to compare to the predicted shoreline in the model calibration process.

This recent image and shoreline along with historical aerial photos, Virginia Base Mapping Program images, and digitized shorelines that presently exist in the SSP's Shoreline Evolution Database were used to analyze shoreline change. The analysis centered on changes at Salt Ponds Public Beach and the effectiveness of the breakwaters constructed at Buckroe Beach through the determination of the width of the visible backshore and subaerial beach.

Shore Zone Modeling

GenCade is a newly developed numerical model which combines the engineering power of GENESIS and the regional processes capability of the Cascade model. GenCade calculates shoreline change, wave-induced long-shore sand transport on a local to regional scale and can be applied as a planning or engineering tool. GenCade simulates shoreline change relative to regional morphologic constraints upon which these processes take place. The evolution of multiple interacting coastal projects and morphologic features and pathways may also be simulated. The model supports responses to imposed wave conditions, coastal structures, and other engineering activity (e.g., beach nourishment). The main utility of the modeling system lies in simulating the response of the shoreline to structures sited in the nearshore.

Calibration of the GenCade model occurred along Hampton's Chesapeake Bay shoreline in order to determine necessary setting, parameters and coefficients to most accurately predict shorelines. The initial shoreline used was the approximate high water shoreline digitized from the 2009 Virginia Base Mapping Program (VBMP) orthorectified photos. By varying settings,

parameters, and coefficients, iterative model runs attempted to calculate a predicted shoreline that closely corresponded to the final (existing) shoreline. The final (existing) shoreline was the MHW shoreline digitized from the October 2013 orthorectified images and survey data provided by Waterway. The data and methods that apply to the area south of Salt Ponds Inlet at Salt Ponds Public Beach (Figure 2) are the focus of this report.
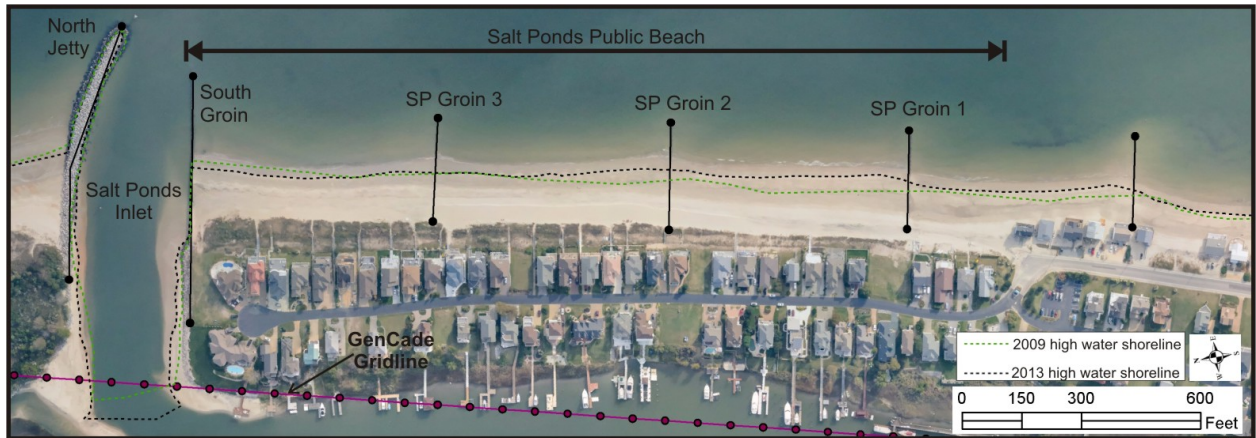

Figure 2. Location of structures and the GenCade gridline at Salt Ponds Public Beach. Also shown is the digitized 2009 and 2013 approximate high water shoreline.

The October 2013 ortho-rectified aerial photos were imported to GenCade and used a base to digitize the location of shore structures. Breakwater and groins were digitized directly from the photos. GenCade allows for wave transmission through breakwaters, and the groin settings ranged from nearly transparent to impermeable to sediment transport. Due to model complications, Salt Ponds was modeled as two groins rather than inlet jetties. During model runs, the Inlet fills in with sand which is indicative of the amount of sediment transport along this reach. The resulting modeled shoreline crosses the Inlet. The sand backpassing that occurs at Salt Ponds Inlet was modeled as beach fill. To accommodate the volume of material, a berm 26 ft wide was simulated in the 22 cells south of the Inlet. This encompasses most of Salt Ponds Inlet Beach. The backpassing events modeled occurred in July 2009, January 2011, and May 2013.

After defining the shorelines and structures, a 1D grid was created in GenCade. The gridline originated at 3697482.0, 1084648.0 (VA South State Plane NAD83, meters) in Grandview and extended south-southwest at a heading of 194° for 14,600 ft to the southern end of Buckroe Beach. It consisted of 178 alongshore cells, each cell being 82 ft wide. Wave data collected by VIMS researchers at Thimble Shoal Light (Boon *et al.* 1990, 1992, and 1993) were loaded into GenCade. In addition to these older wave data, several idealized wave conditions derived from Hurricane Isabel (one of the largest storms to impact Chesapeake Bay shorelines) were added to simulate the higher energy waves that have impacted the shore during storms.

The GenCade model simulated change along the Hampton shoreline between January 1, 2009 and December 31, 2013 at 6 hr time steps. A breakwater was input for each scenario listed below and run both with and without backpassing. The final model shorelines were exported as

locally-gridded ASCII data points and converted to ASCII XYZ points for input to GIS. The modeled shorelines were plotted on the October 2013 orthorectified photo.

Breakwater Scenarios and Recommendations

Breakwaters were input to the model to determine shore changes relative to the structures. In general, breakwaters were placed as T-heads to the existing groins along the Salt Ponds Public Beach shoreline. Model limitations require the breakwater to have a straight line configuration. However, when designed, the breakwater will likely be shaped like the breakwaters at Buckroe Beach. This shape, a chevron, provides a more Bayward advance to the breakwater ends which extend the diffraction points to intercept the incoming wave train. Diffraction involves the change in direction of waves as they pass through an opening or around a barrier due to the spreading of wave energy which affects sediment deposition. The point around which the diffraction occurs is known as the diffraction point. The chevron shape allows the diffraction points to occur farther offshore while keeping the bulk of the breakwater in shallower water. Since breakwater costs are dependent on the amount of rock needed, building the breakwater in shallower water saves on construction costs.

Scenarios 1, 2, and 3 include 250 ft long structures attached to the end of existing groins along the Salt Pond Reach (Table 1). The structure will create a T-head with the existing structure. For these scenarios, the groin to which the structure would be attached would be covered by a sand tombolo during construction. Scenario 4 attaches the breakwater to the end of the south groin at Salt Ponds Inlet (Table 1). This scenario would allow the breakwater to act as a spur to the existing structure rather than as a typical attached breakwater. The difference is that a typical breakwater has two diffraction points on each end whereas a spur is a continuation of a shore-attached structure with only one diffraction point on the outboard end.

For scenarios 5 and 6, the structure could not be attached to the south groin as intended due to model limitations (Table 1). GenCade only allows for breakwaters or spurs to connect at the end of groin or jetty. As such, the breakwater was moved one cell southward. The short distance between the end of the breakwater and the south groin led to some model instability between these two structures leading to modeled shoreline configurations that likely will not occur. These scenarios were included to see the effect of the structures on the rest of the public beach as well as on the rate of sand backpassing necessary to retain the present beach. Scenarios 4, 5 and 6 were modeled with a reduced rate of sand backpassing at the Inlet. For these model runs, only two sand backpassing events were modeled.

The recommendation for the proposed structure location was based on several factors including overall effectiveness of the structure in terms of sand retention and positive impacts to the public beach shoreline as well as reduction in Salt Ponds Inlet maintenance dredging. In addition, containing the project's impacts to the public beach was a priority.

Table 1. The six structure scenarios modeled in GenCade at Salt Ponds Public Beach. The scenarios were modeled with and without various levels of backpassing.

Scenario 1	250 ft T-head structure at the end of Salt Ponds groin 1
Scenario 2	250 ft T-head structure at the end of Salt Ponds groin 2
Scenario 3	250 ft T-head structure at the end of Salt Ponds groin 3
Scenario 4	250 ft spur structure at the end of Salt Ponds Inlet south groin
Scenario 5	250 ft breakwater structure closer to shore at the approximate location of the end of groins
Scenario 6	250 ft breakwater structure close to the shoreline south of south groin

3   Results and Discussion

Shoreline Change

Shoreline change analysis shows the cumulative impact of reach based shoreline management along Hampton's shoreline. In 1937, Hampton's Chesapeake Bay shoreline was a continuous sandy beach and some development existed at Buckroe Beach (Figure 3A). Sediment transport in this region is generally to the south as indicated by the sand accumulated on the northern/updrift side of the groins. In the 1990s several large beach nourishment projects placed sand along Buckroe's shoreline. As such, the 1994 shoreline had advanced Bayward relative to the 1937 shoreline. In 2001, the first breakwater was built at Buckroe (Bw1) (Figure 3B). The Federal Hurricane and Storm Damage Reduction project was constructed along Buckroe in 2005 and consisted of the placement of 320,000 cy of sand along the public beach. By 2009, the sand updrift of the breakwater had maintained its beach width. Additional sand was placed on the beach in 2009 after the Veteran's Day storm in November 2009; however the VBMP photos were taken in the spring of 2009.

Another breakwater (Bw2) with limited fill was constructed along Buckroe in May 2010 (Figure 3C) widening the beach along the southern section of Buckroe Beach. In October 2011, a breakwater (Bw3) was constructed along the northern reach of Buckroe Beach at Pilot Avenue (Figure 3D). Additional material was placed on the shoreline in the fall of 20123 along the center of the public beach. The VBMP image shown was taken in the early spring of 2013 and shows that the breakwater has a subaqueous attachment. However, at the time the photo was taken, sand was being dredged from Salt Ponds and placed on the beach. By October 2013, some of that sand appeared to have moved south to fill in behind the breakwaters and in the embayments.

Between 1937 and 2003 (Figure 4A), the shoreline at Salt Ponds was eroding at about -8 ft/yr (Waterway, VIMS, and URS, 2011). In the 1970s, Salt Ponds Inlet was dredged and stabilized which, in turn, began to stabilize the shorelines in its vicinity due to placement of dredged sand south of the Inlet and the construction of the north jetty which allows the southerly moving sediment to accumulate (Waterway and VIMS, 2011). Construction of groins as well as the placement of beach fill has maintained relative stability along this reach of shoreline (Figure 4B). Since the 1990s, the Inlet has been dredged every two to three years.   The material is placed south of the Inlet in deference to the net southerly sediment transport along the reach. However, due to the amount of sand returning to the Inlet, it is likely that there is reversal of

sediment transport in the region of Salt Ponds. The dredging and placement of sand along the beach is shown occurring in Figure 4C in the early spring of 2013. The October 2013 shoreline shows the advancement of the shoreline due to the placement of sand.
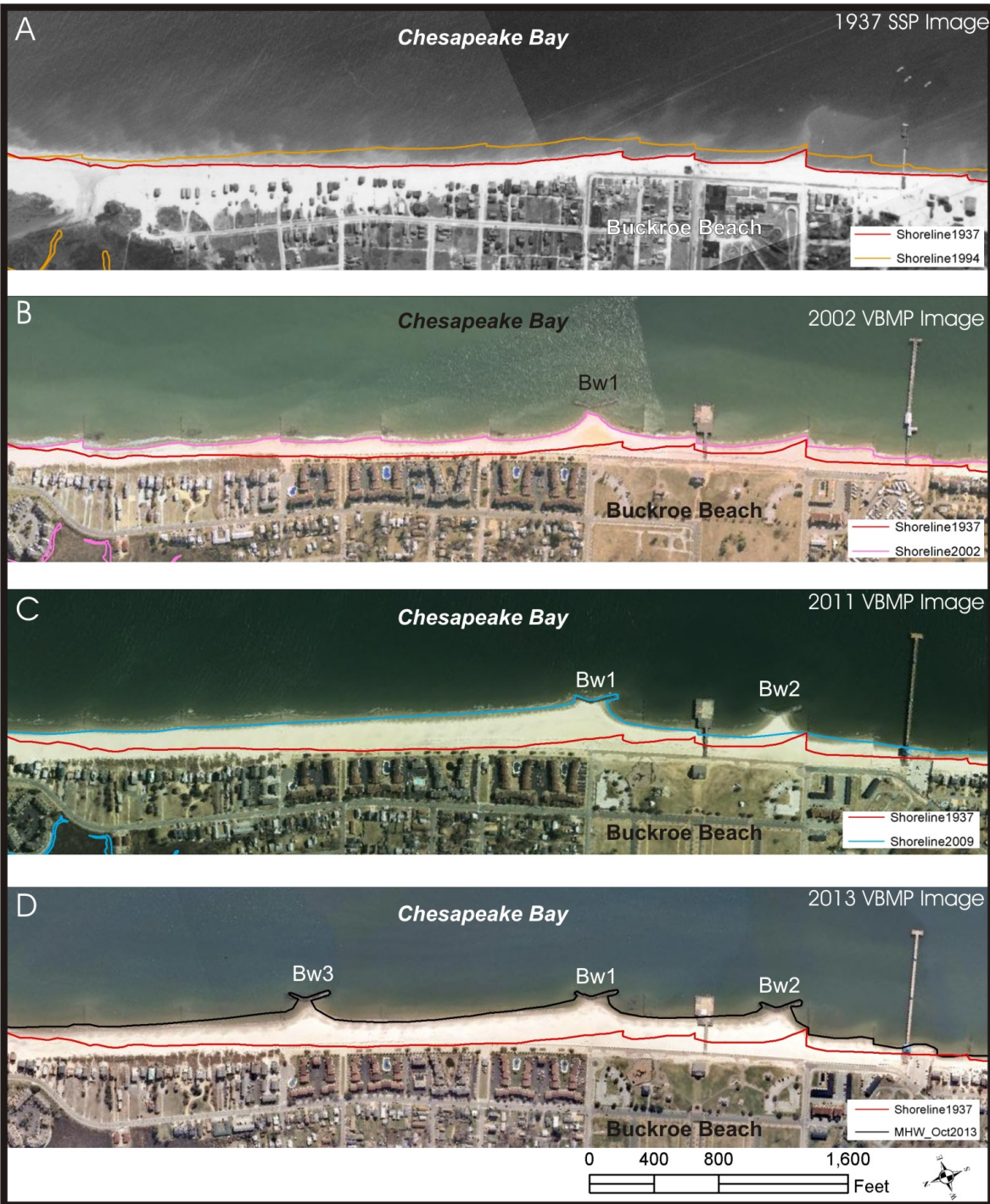

Figure 3. Images from VBMP and the SSP Shoreline Evolution Database. Shorelines digitized by SSP for the Shoreline Evolution Database. Note: the 2013 VBMP was taken in the early spring of 2013 whereas the 2013 shoreline was digitized from aerial photos taken in October 2013.
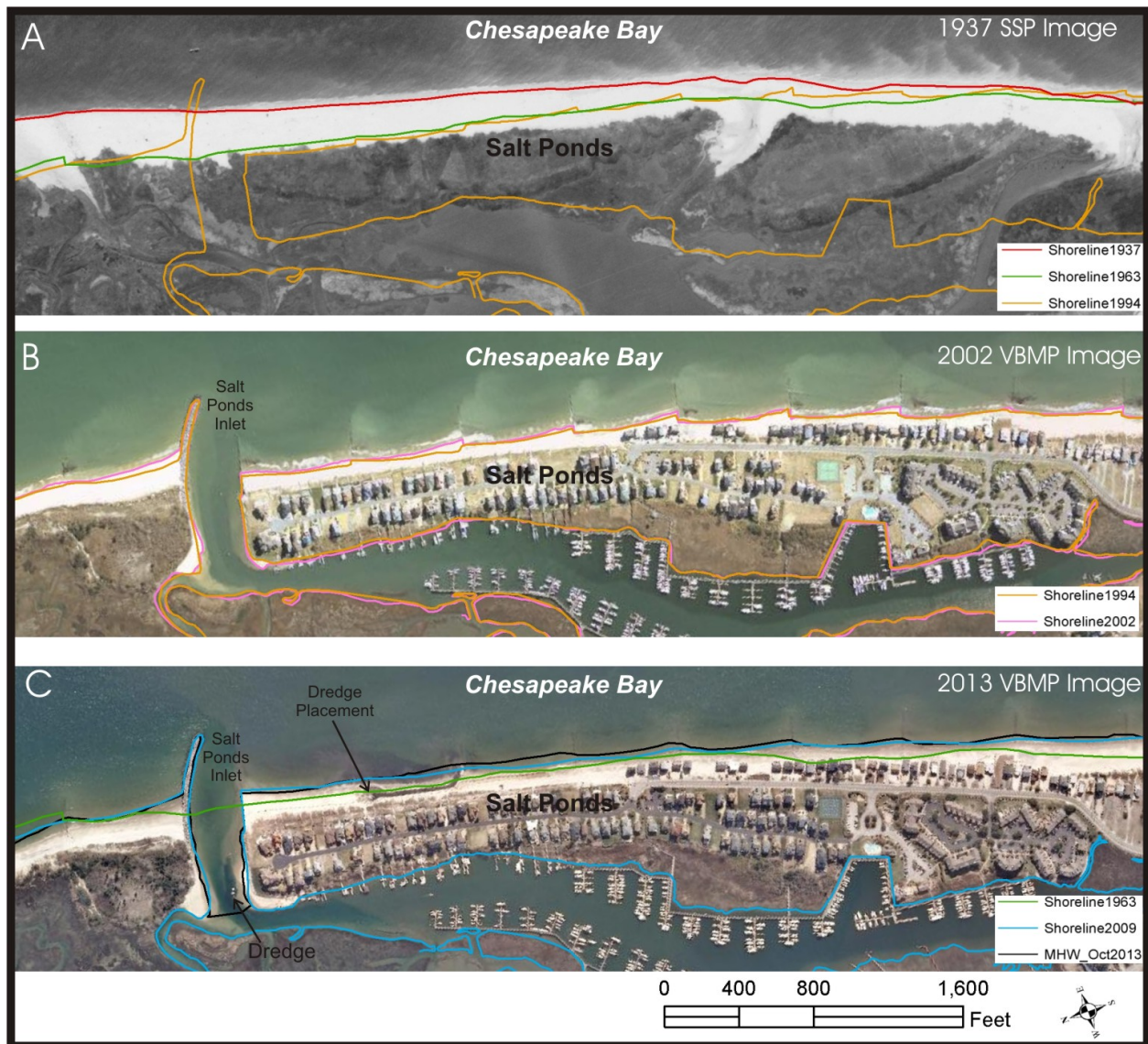
Figure 4. Images from VBMP and the SSP Shoreline Evolution Database. Shorelines digitized by SSP for the Shoreline Evolution Database. Note: the 2013 VBMP was taken in the early spring of 2013 whereas the 2013 shoreline was digitized from aerial photos taken in October 2013.

Shore Zone Modeling

The shoreline reach south of Salt Ponds Inlet is shown in Figures 5 to 10. Each Figure shows the actual October 2013 shoreline and the model results for each breakwater configuration. The model shorelines include a model run without sand backpassing from the Inlet and a model run with sand backpassing from the Inlet.

Scenario 1 places a breakwater at the end of SP groin 1 (Figure 5). Without sand backpassing, a sand tombolo behind the structure barely attaches and the shoreline overall is about 50 ft landward of the 2013 shoreline. With backpassing, sand placed on the beach

generally stays within the Salt Ponds Public Beach reach. The modeling indicates that the structure may limit, in the short-term, the amount of sand transported south to the other sections of the Hampton shoreline particularly the privately-owned beach adjacent to Salt Ponds Public Beach. This is indicated by the large difference between the modeled shorelines and the existing (2013) shoreline.
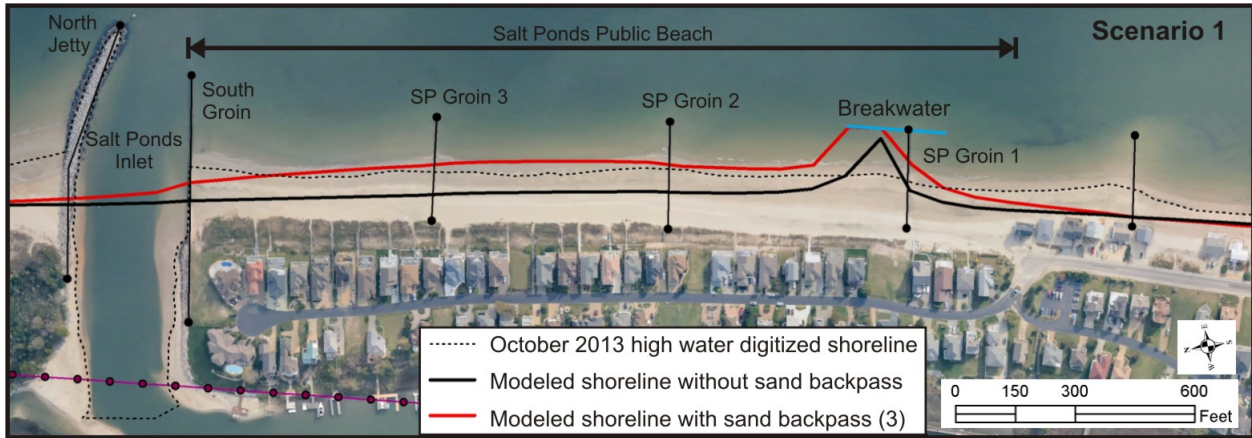

Figure 5. GenCade model results for Scenario 1 at Salt Ponds Public Beach.

Scenario 2 places a breakwater at the end of SP groin 2 (Figure 6). Without backpassing, sand is limited along the shoreline such that, the structure may not have a subaerial attachment. If backpassing continues at its present level, the breakwater will likely completely attach and impacts to downdrift (more southerly) shores will be less than Scenario 1. However, the modeling does show impacts to the privately-owned shoreline adjacent to Salt Ponds Public Beach as indicated by the difference between the modeled shorelines and the existing (2013) shoreline.
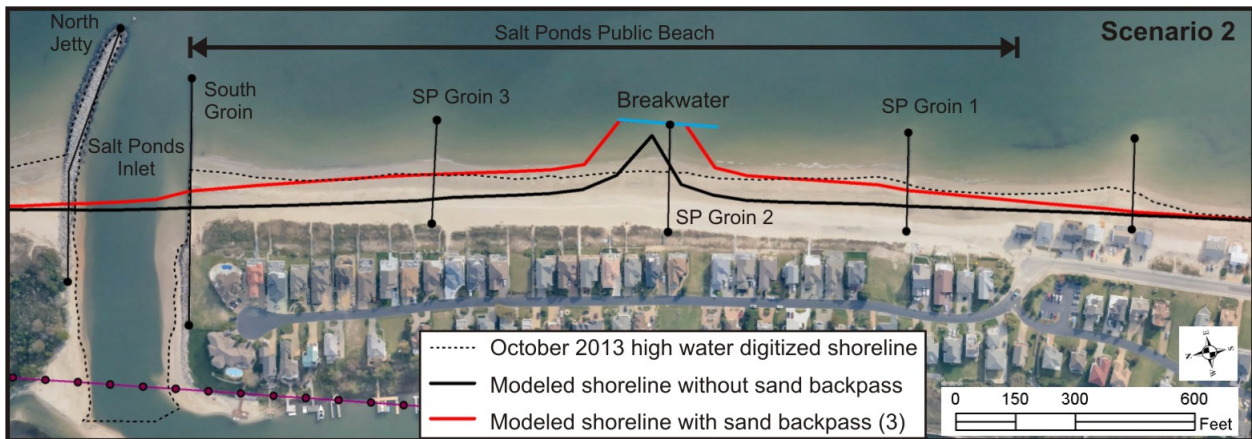

Figure 6. GenCade model results for Scenario 2 at Salt Ponds Public Beach.

Scenario 3 places a breakwater at the end of SP groin 3 (Figure 7). This scenario was modeled with backpassing at its present rate as well as with a reduced backpassing schedule. With three backpassing events, the breakwater has a well-developed tombolo behind it and downdrift impacts are minimized. The shoreline between the breakwater and the south groin

respond similarly to two and three backpassing events. With a reduced effort at backpassing, the breakwater maintains its attachment and downdrift impacts are minimized.
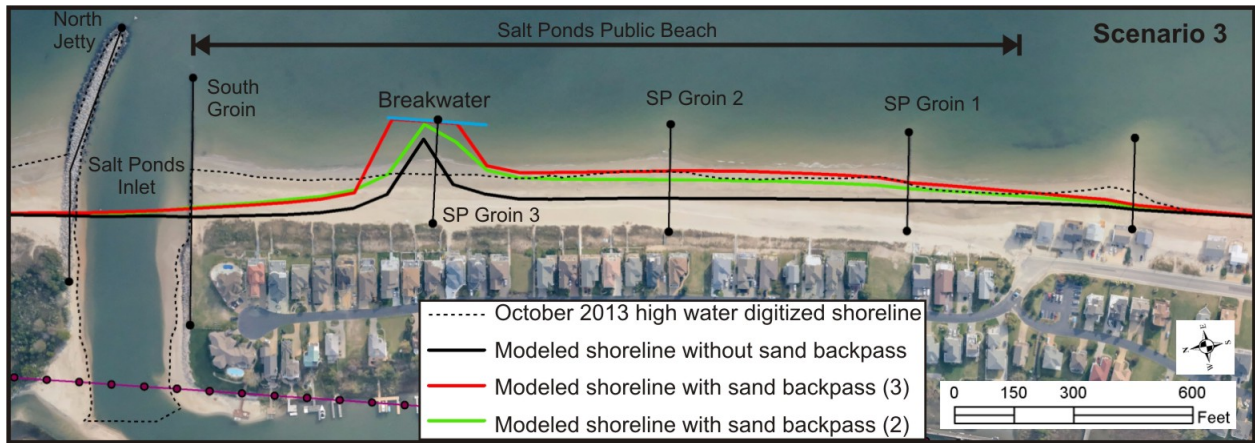

Figure 7. GenCade model results for Scenario 3 at Salt Ponds Public Beach.

Scenario 4 places a breakwater as a spur to the south groin (Figure 8). This structure would be a detached breakwater which would influence the shoreline somewhat behind it. However, it would have little impact to most of the public beach shoreline configuration over time. With sand backpassing, the modeled shoreline is comparable to the existing 2013 shoreline meaning that the structure is not significantly impacting sand transport in the system.
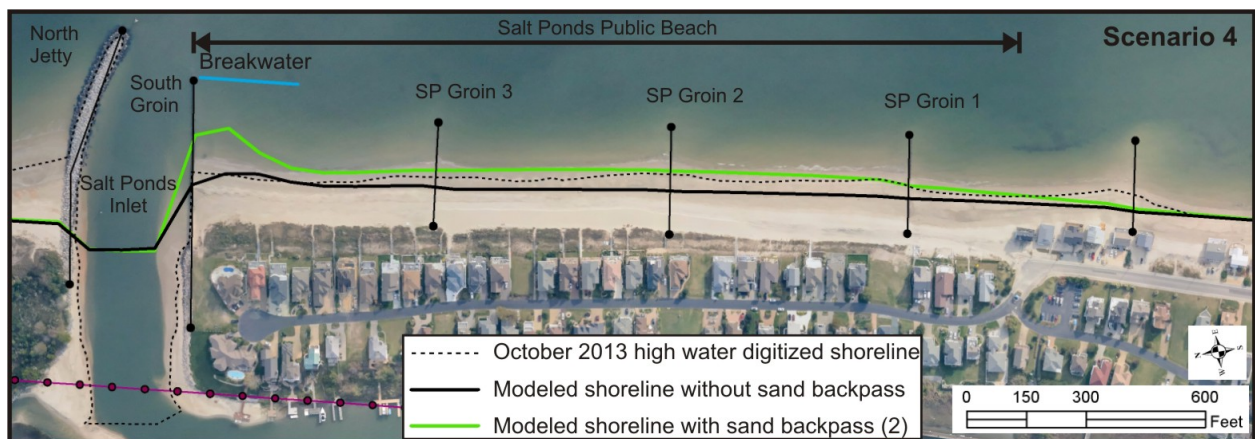

Figure 8. GenCade model results for Scenario 4 at Salt Ponds Public Beach.

Scenarios 5 and 6 move the structure landward (Figure 9 and Figure 10). Due to model limitations, the structure could not be attached to the south groin as intended. For scenario 5, the breakwater is moved in close to the beach, and for Figure 10, the structure is at approximately the same location offshore as previous scenarios that were configured as t-heads. These model runs were made with reduced sand backpassing as an input component. Only two backpassing/beach fill events were modeled instead of three. Even with the reduced rate of sand backpassing, both of these configurations provide a subaerially-attached tombolo and the shoreline is maintained at its present location along the length of Salt Ponds Public Beach.
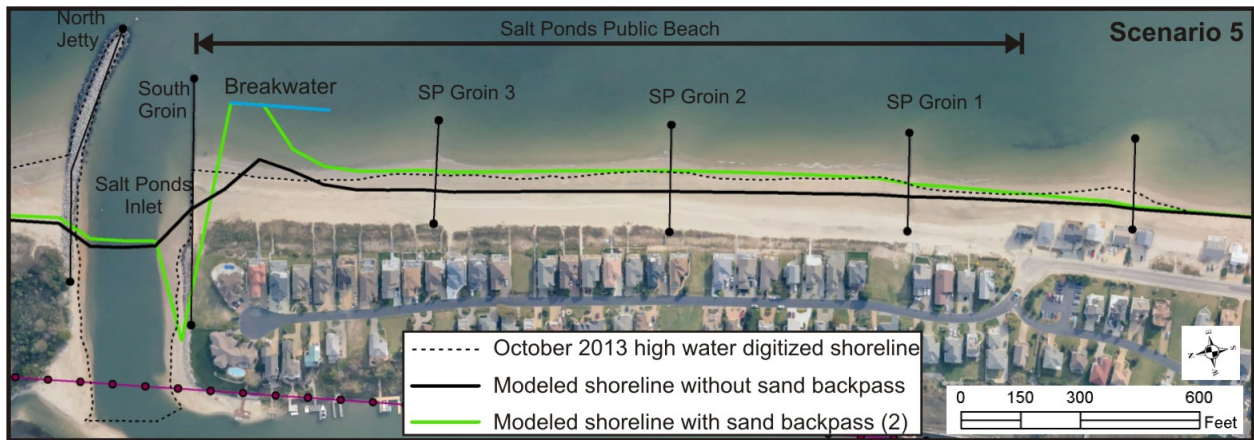
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Figure 9. GenCade model results for Scenario 5 at Salt Ponds Public Beach.
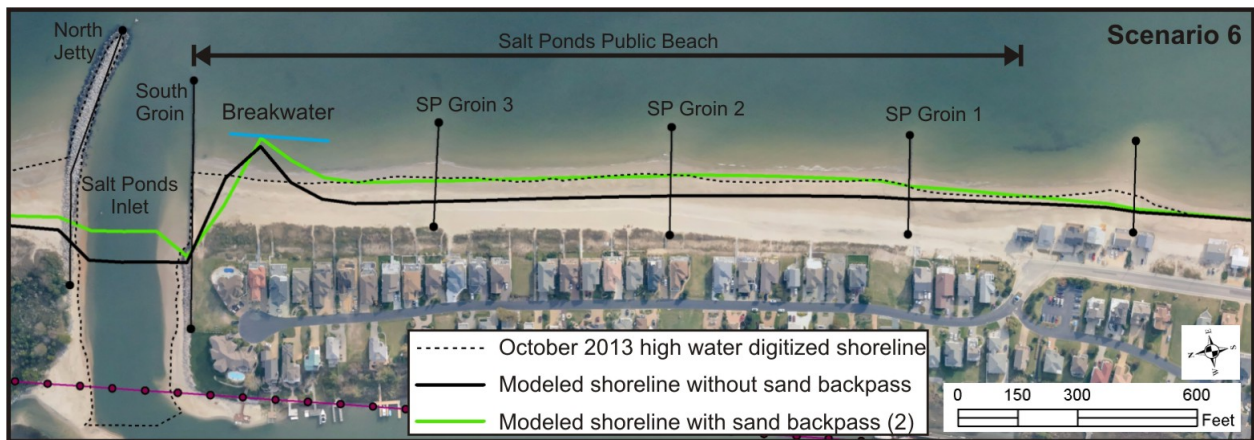

Figure 10. GenCade model results for Scenario 6 at Salt Ponds Public Beach.

4   Summary and Recommendations

Shoreline change analysis reveals that present management strategies of strategic breakwater placement and backpassing at Salt Ponds Inlet are maintaining beaches along Hampton's shoreline. The structures are performing as designed. Placing a breakwater along Salt Ponds Public Beach will create a wide, protective beach and also may reduce the frequency of maintenance dredging at the Inlet.

Shore zone modeling simulates existing conditions along a coast and can provide a method to evaluate structural options along a shoreline. As shore conditions change and storms impact the shoreline, the model results become less dependable. They should be used as guidance but do not completely replace the experience of coastal specialists.

When the model results were reviewed, Scenarios 1, 2, and 4 were excluded from consideration. Scenario 1 would most likely have a short-term negative impact on the downdrift

shorelines and thus private property. Scenario 2 did not show significant downdrift impacts; however, negative impacts were considered a possibility to private property. Scenario 4 had little impact on the shoreline. For this project, scenario 3 is the recommended placement of a breakwater at Salt Ponds Public Beach. It will provide storm protection to much of the public beach shoreline by increasing shore width. In addition, the project impacts should be contained to the publicly-owned coast. Scenarios 5 and 6 could be viable options since their results indicate that inlet maintenance could be reduced while still maintaining a wide, protective beach. These were not chosen as the recommended structures because their construction could potentially impact future management plans.

The recommended structure at SP groin 3 provides flexibility for continued evolution of Hampton's shore zone management program. In order to reduce sand transport into Salt Ponds Inlet, the south groin should be rebuilt and raised. A spur at the end of the groin would work in conjunction with the recommended breakwater to set an embayment. In addition, if structures are planned south of Salt Ponds Public Beach, they could be designed to work within the system.

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