DELLANERA OFFSHORE BREAKWATER STUDY: A MULTIPLE MODEL STRATEGY TO OPTIMIZE BREAKWATER LOCATION AND SHAPE

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INTRODUCTION

The U.S. Army Corps of Engineers Galveston District (SWG) in partnership with the Galveston Park Board (GPB) entered into a Planning Assistance to States (PAS) study to examine the feasibility of an offshore breakwater as a mitigation feature for an anticipated GPB Federal Emergency Management Agency (FEMA) 406 Hazard Mitigation Proposal. SWG performed data collection, numerical modeling, alternatives development, and conceptual design work. The conceptual design and cost estimation developed as part of this study can be used by the GPB in their FEMA 406 Hazard Mitigation Proposal and permitting efforts.

The Dellanera project area is the most highly eroded shoreline along Galveston Island. It is located immediately west to the end of the Galveston Seawall. Previous studies have identified that the dominant (even though it is slight) direction of littoral drift along Galveston Island is East to West. The shoreline at the Galveston Sea Wall has eroded to the base of the sea wall, because there are numerous groins that span the sea wall, as well as the Houston Ship Channel jetties further east, causing a shortage of sediment supply that enters the project area from the East. This is further exacerbated by the recessed offset of the beach in the lee of the Galveston Sea Wall, that causes transfer of material from the swash zone at the sea wall to the surf zone in the project area, meaning that any downdrift material at the sea wall tends to bypass the project area (Figure 1).

Figure 1 - Study Area Location

Previous efforts such as Frey (2016) have added to the development of a living Sand Management Plan (SMP) for Galveston Island. In 2018, an investigation of numerous system alternatives identified this project as a system priority.

As part of this study, SWG performed an assessment of alternatives using numerical modeling and identified out of several viable alternatives a recommendation for a submerged horseshoe shoal breakwater at the east end of the Dellanera project area near the end of the seawall constructed of cut block stone and marine mattresses, and a pre-filled salient. The opinion of probable cost for the construction of an offshore breakwater and salient feature is estimated to cost roughly $10.3 million, depending on final design.

METHODOLOGY

For this study, SWG utilized GenCade, XBeach, FUNWAVE-TVD, and Delft3D as the numerical model tools, of which each resolves coastal sediment transport at different spatial and temporal scales. A total of 27 alternatives were analyzed which were a combination of 9 locations and 3 breakwater shapes: linear, curved, and horseshoe. In addition, the modeling also investigated the benefits and stability of a pre-filled salient. An estimated budget of $10 million and a design life of 50 years was used to develop the conceptual breakwater alternatives.

The primary intent of the study was to the find the optimal breakwater location and type that would provide the benefits in terms of damages (defined as reduced shoreline erosion) to offset its construction and maintenance costs. Each alternative was assessed for episodic events, such as Ike (2008), Rita (2005), and Harvey (2017) and long-term conditions (5-years and 50-years) at the project site and its impacts downdrift.

RESULTS

Each model served unique objectives. GenCade is a one-line tool intended for planning purposes. For this project it was used to compare the various breakwater shapes and locations as well as the salient development (Figure 2) over 50-years. Xbeach was also utilized to assess each breakwater alternative (Figure 3), but with respect to the overall sediment change within the project area over the course of the selected storms in order to assess the damage reduction (i.e. benefit) versus storm recurrence.

Figure 2 – Salient Development using GenCade

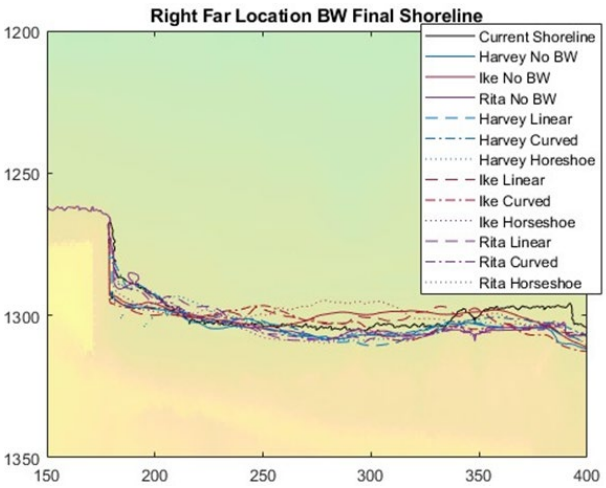

Figure 3 – Shoreline profiles using Xbeach

It was interpreted from the GenCade and Xbeach model results that the ideal location was the "Right Far" because 1) it provides greater shelter for the project area from the dominant wave direction and 2) it immediately interrupts the longshore current at the end of the sea wall preventing shedding vortices. "Right Far" is the furthest offshore a breakwater would be considered without interrupting recreational navigation as determined by the reach of the nearest fishing pier.

To compare each breakwater shape, as well as to assess the regional impacts, Delft3D was simulated for 5-years. The changes to erosion downdrift and within the project area was compared with the objective of identifying which shape best stabilized the project area as well as minimizing adverse impacts downdrift (Figure 4). In addition, FUNWAVE was simulated to assess wave attenuation, local scour, and rip-currents for public safety purposes.

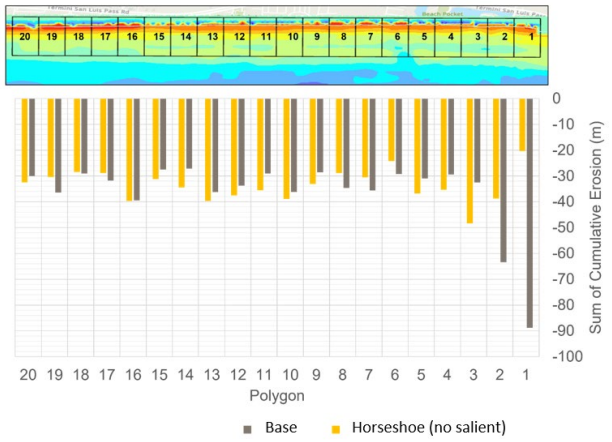

Figure 4 – Comparison of Downdrift Erosion

CONCLUSIONS

The linear breakwater created the largest salient, followed by the curved breakwater, and then the horseshoe shoal. This also meant that the linear breakwater caused the greatest downdrift impacts, and the horseshoe created least; however, if a pre-filled salient was constructed most of the shoreline impacts were lessened. A pre-filled salient is a beach nourishment along the shoreline in the shape of what a natural salient would eventually develop. Historically, it should be noted that whereas the Dellanera shoreline has the greatest local erosion, the shoreline immediately to the west has some of the lowest erosion, due in large part to sediment supply derived from Dellanera's erosion in terms of natural shoreline and "regularly placed" nourishment material. With the construction of a breakwater at Dellanera, that sediment supply will be reduced immediately downdrift causing a localized increase in erosion rate along this adjacent stretch of shoreline, but the impacts will not be felt much further downdrift, as the system acclimates. Among all the alternatives, the horseshoe showed the least overall communal impacts for the long-term simulations and the smallest and most cost-effective pre-filled salient.

In terms of damage, all three breakwater types attenuated waves and provided substantial damage reductions to the project site. Of the three types, the linear produced the least damage in the project site, but these benefits were offset by the greater impacts downdrift, partially due to the circulation cells that were created; thus again pointing to the horseshoe breakwater as the preferred solution.

In conclusion, SWG used advanced numerical coastal models to analyze numerous breakwater alternatives and identified the submerged horseshoe shape at the far east edge of the project area in combination with a pre-filled salient as the preferred option estimated at $10.3 million dollars.

REFERENCES

Frey, Morang, & King (2016): Galveston, Island, Texas, sand management strategies, ERDC/CHL TR-16-13.