MITIGATION OF BEACH EROSIONAL HOTSPOTS WITH COASTAL STRUCTURES: THE USE OF MORPHOLOGICAL MODELS TO OPTIMIZE THE BALANCE BETWEEN SAND RETENTION AND DOWNDRIFT IMPACTS

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INTRODUCTION

Although eroded beaches can be restored in many ways, beach nourishment is the preferred method of shore protection in the United States (Elko *et al.*, 2021). While evaluating the performance of constructed beach nourishment projects, additional attention is generally given to the development of erosional hot spots (EHS) within the project boundaries. EHS erodes faster than the average rate of the project erosion and can negatively affect the overall performance of a beach nourishment project. Several parameters have been historically used to identify EHS such as percentage of fill remaining in a specific beach segment vs. the entire fill area (Stauble, 1994) and comparison of erosion rates of specified beach segments with the average rate of erosion of the entire project (Benedet., *et. al.*, 2007). EHS can pose severe challenges to coastal management, damage to infrastructure, loss of habitat and hazards to beachgoers. The occurrence of an EHS within a nourishment project can also significantly shorten the design lifetime of the project.

Common methods utilized to mitigate accelerated erosion at EHS consist of adding extra sand at the hotspot area, so it lasts as long as the rest of the project while simultaneously acting as a 'feeder' beach. However, as sand resources become scarce and/or more expensive in the U.S., a second frequently utilized alternative is to combine the beach nourishment project with strategic placement of coastal structures at the hotspot area to stabilize the specific section of the beach where the EHS occurs (*i.e.,* Pierro, 2015). This paper focuses on the latter method through examples of projects where combinations of beach nourishments and coastal structures were utilized to mitigate hotspot erosion.

TYPES OF PROJECTS EVALUATED

A range of projects where numerical modeling was utilized to refine the design and placement of coastal structures and optimize the balance between sand retention and downdrift impacts are used as examples in this study. The projects are located in the state of Florida and North Carolina, in the United States. In all cases, the coastal structures were designed in combination with ongoing beach nourishment programs, and the structures were designed to address an erosional hot spot observed after construction of the initial sand-only nourishment. The types of structures described here include permeable groins, terminal groins, emergent and submerged breakwaters. The main tool used to refine the design of the structures was the process-based numerical model Delft3D.

THE USE OF MODELS IN THE DESIGN PROCESS

Initial design aspects that are commonly optimized with the assistance of the model include the coastal structure placement location, number of structures, length of the structure and spacing between successive structures. The design goal in all the projects described here was to mitigate hotspot erosion, while letting some percentage of sand bypass the structures to reduce downdrift impacts to manageable levels. The sand bypassing goal was achieved in different ways in each project.

The first project was designed to stabilize an EHS located at Longboat Key, on the West Coast of Florida. In this case, groins were designed to be permeable to allow sand bypass the structures. In addition to the permeability within the structures, the groins did not cross the entire surf zone, so bypassing in front of the structures could also occur (Figure 1). The performance of such unique groins was modeled utilizing Delft3D through multi-year morphology simulations. The permeability of the structures was replicated utilizing the 'porous plates' option of the Delft3D model. Hundreds of model tests were conducted to test the sensitivity of the model to the porous plate permeability parameter and identify the proper permeability parameter of the porous plates necessary to represent the permeable groins.

Figure 1. Longboat Key permeable adjustable groins a decade after initial construction, note the permeability of the structure allows for a subtle shoreline signature compared to traditional groins.

The second project is located at Coquina Beach in Anna Maria Island, also on the west Coast of Florida, just south of Tampa Bay. This area is an erosion hotspot in an especially vulnerable portion of the barrier island. The performance of different structural alternatives to reduce hotspot erosion in these areas was evaluated utilizing multi-year morphology simulations with Delft3D. Structure types evaluated included permeable groins, and breakwaters. The ultimately selected design with assistance of dozens of models runs consists of an offshore emergent breakwater field. The sand bypassing requirement in this project was achieved by designing breakwaters that had their distance to shore/length and spacing parameters designed in a way not to form tombolos, but only beach salients as demonstrated by both the numerical model and analytical calculations. By doing so, the structures were able to slowdown erosion rates at the EHS to manageable levels, but also allow some sand to bypass the structure field on its landward side and feed adjacent shorelines.

A third project currently under design is located near Cape San Blas, in the Florida Panhandle Coast, on the St. Joseph Peninsula. The project area has one of the highest rates of beach erosion in the State of Florida. Coastal structures were designed to stabilize a critical EHS in an area where the beach serves as the last line of defense to the only evacuation route for residents of the barrier island. Several structure alternatives were evaluated in this location utilizing multi-year morphological simulations with Delft3D. The preferred alternative, that achieves the goals of reducing erosion rates at the project area while maintaining an acceptable level of downdrift impacts and other environmentally friendly characteristics, consists in a field of submerged breakwaters combined with beach nourishment. The submerged breakwaters were represented in the Delft3D model by using non-erodible bathymetric surfaces with increased bed roughness. An example of model output showing the benefits and impacts of the preferred project alternative is provided in Figure 2.

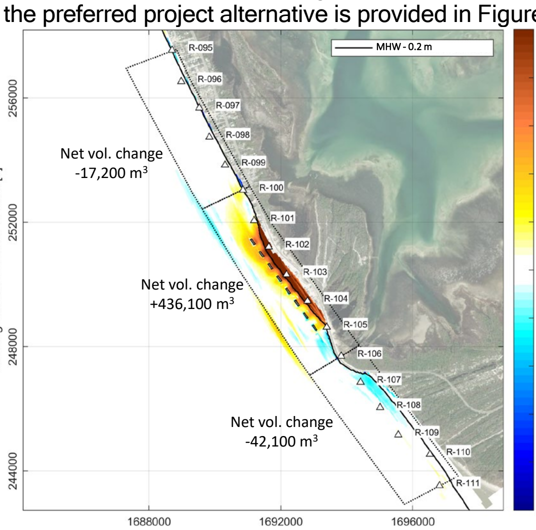

Figure 2. Simulated net benefits and impacts associated with the preferred project alternative (submerged breakwaters + beach fill) in relation to the baseline condition without project after 6 years. St. Joseph Peninsula, Gulf County, FL.

The fourth and final project to be used as an example in this presentation is the Ocean Isle Beach terminal groin, located in Ocean Isle, Brunswick County, NC. The project area was the terminal end of a barrier island where nourishment sand would be rapidly eroded after placement and where houses were falling into the ocean. Structural solutions in this area, however, could not completely block the alongshore transport of sand towards the end of the island to avoid impacts to a sand spit identified as critical bird habitat. The preferred alternative identified in this case with assistance of modeling and additional engineering analysis was a terminal groin in combination with a beach nourishment program. The groin was designed to be permeable allowing sand bypass through the structure and, by combining it with the beach nourishment it also caused bypassing to occur in front of the structure (Figure 3). Multi-year morphological modeling simulations with Delft3D were crucial to identify the preferred alternative in this project and to identify the optimal length of the terminal groin that would provide the needed protection to the community while allowing sand to bypass and nourish the critical barrier spit habitat.

Figure 3. Post-construction drone image of the preferred alternative showing a prominent bypassing bar developing immediately after construction of the project.

FINAL CONSIDERATIONS

With the increasing cost associated with placing sand on beaches to keep pace with erosion and sea level rise, controlling EHS with coastal structures is becoming an attractive and economically feasible approach on the East Coast of the US. Coastal structures, however, need to be carefully designed to be able to simultaneously slow down hotspot erosion and not cause unmanageable impacts to adjacent shorelines. To achieve this objective, some sand must be allowed to bypass the structure field and feed adjacent shorelines, which can be done by different engineering design strategies. As shown in the examples here, there are no one-size fits all solution, but each design must be tailored to the specific needs of the project area. In the search for the optimal balance between sand retainage and downdrift impacts, predictive tools of coastal behavior are essential. In the projects presented here this balance was identified utilizing multi-year morphological simulations with Delft3D. The model, when properly used, proved to be an extremely useful tool to refine the engineering design and evaluate its potential impacts to adjacent shorelines. This presentation will focus on the main lessons learned in terms of numerical model application and management of erosional hotspots with coastal structures based on these four unique case studies.

REFERENCES

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