COST-EFFECTIVE SHOALING REDUCTION ALTERNATIVES FOR A NAVIGATION CHANNEL NEAR AN INLET

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INTRODUCTION

The Intracoastal Waterway (IWW) near Bakers Haulover Inlet in Miami, Florida passes 0.64 km west of the inlet. Wave- and tide-generated currents entrain and transport some of the littoral sediments through the inlet and the rest to downdrift nearshore areas. These currents can move sediments inshore until flow velocities decrease below a critical value, at which point sediments fall out of suspension and can form shoals in the IWW and surrounding areas (Figure 1). A Florida Department of Environmental Protection study (FDEP, 2021) estimates a total net transport into the inlet of approximately 46,410 m^3/yr for 2007 - 2016.

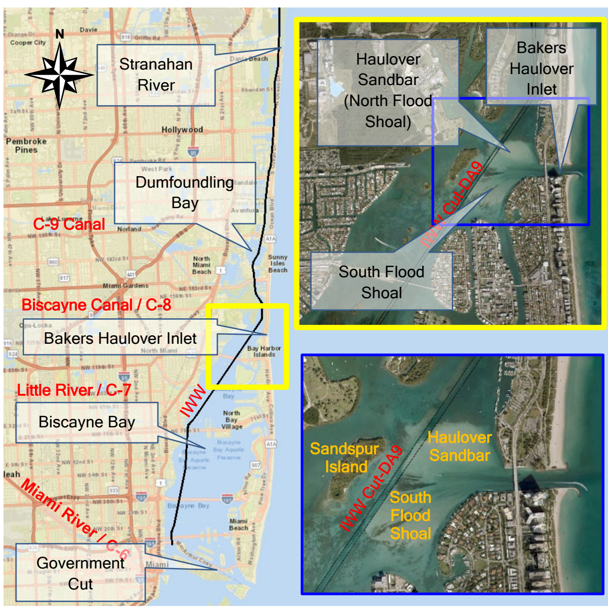

Figure 1 - Bakers Haulover Inlet and Location of the Area of Interest (Map Data: World Street Map, World Imagery)

A review of U.S. Army Corps of Engineers (USACE) data of IWW maintenance dredging events near Bakers Haulover Inlet from 1969 to 2017 shows shoaling volumes total 314,754 m^3. Of this total volume, at least 71% was dredged between 1969 and 1998 from within the 1.77-km portion of Cut-DA9 adjacent to Haulover Sandbar (North Flood Shoal in Figure 1) and South Flood Shoal. Thus, this portion of the IWW Cut-DA9 is vulnerable to large shoaling and historically required dredging on average once every 4 - 5 years to maintain the authorized IWW navigation depth of 3.05 m below mean lower low water.

SHOALING REDUCTION ALTERNATIVES

At the IWW near Bakers Haulover Inlet, construction of deposition basins and/or removal of nearby shoal sediment sources (e.g., Haulover Sandbar) could, with periodic dredging, reduce shoaling in the IWW. Alternatively, rerouting of the IWW Cut-DA9 to west of Sandspur Island could also reduce maintenance dredging requirements and improve navigation safety as rerouting would move the navigation channel farther away from the inlet and Haulover Sandbar to an area with low flow velocity and sediment transport. The prospect of these cost-saving outcomes encouraged the Florida Inland Navigation District (FIND) to request Taylor Engineering to perform a sediment deposition basin and IWW Cut-DA9 rerouting study at Bakers Haulover Inlet and adjacent waterways.

NUMERICAL MODELING AND METHODOLOGY

To analyze the effect of sediment impoundment basins and IWW channel rerouting, this study developed and applied MIKE21 Flexible Mesh (FM) hydrodynamic (HD), wave (SW), sediment transport and morphology (ST), and particle tracking (PT) models. Figure 2 shows the existing condition model domain bed elevations referenced to NAVD88 and indicates the area of interest in the red inset. The PT model provided the sediment transport pathways to help locate the sediment deposition basin.

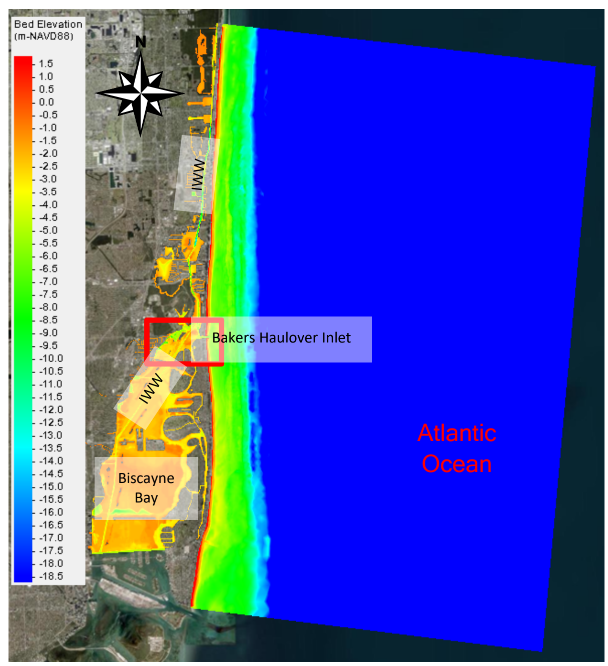

Figure 2 - Model Domain, Bed Elevations, and Model Mesh (Inset, shown in Figure 3) at the Area of Interest (Map Data: World Imagery)

HD model calibration and verification provided good agreement with measured August - September 2020 inshore and May - June 2018 nearshore data. Figure 4 shows the comparisons at inshore Stations TB3 and VB3 near IWW Cut-DA9. Compared with measurements, modeled water level has a mean error of 0.004 m, root mean square error of 0.018 m, and correlation coefficient of 0.998 at Station TB3. Figure 5 shows low measured flow speeds (thus low sediment transport) and good model comparisons at inshore Station VB5 near the channel reroute location. HD and SW model calibrations/ verifications also provided good agreement with measured nearshore data in May – June 2018. The ST model sedimentation is generally consistent with the observed sedimentation pattern at the area of interest.

Figure 3 – Model Bed Elevations, Mesh at the Area of Interest, Calibration Stations, and Analyzed Alternatives (Map Data: World Imagery)

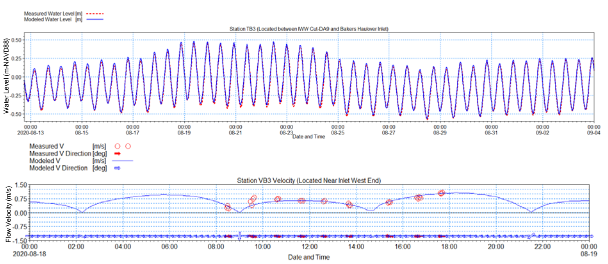
Figure 4 – Comparison of Modeled and Measured Water Level and Velocity at Stations TB3 and VB3

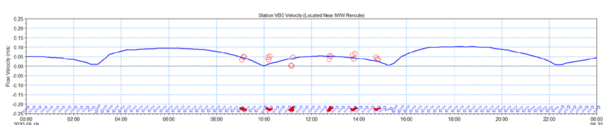
Figure 5 – Comparison of Modeled and Measured Velocity at Station VB5 (Near Channel Reroute)

Littoral transport magnitude and direction can vary by season, day, or hour because waves can vary with the same time scale. Thus, the estimation of morphological change including the shoaling rate in a sediment impoundment basin and channel reroute requires simulation of sediment transport over a long-term period (e.g., a full year). However, such long-term simulations require lengthy computational time that goes beyond the schedule of this study. Alternatively, this study simulated a month-long representative period from a representative year to estimate short-term shoaling rates and then prorated the computed shoaling rates for an average year (i.e., a year with average gross littoral transport). Notably, the model calculated shoaling rates associated with the representative month will likely not reflect the long-term basin and in-channel shoaling rates–an acceptable approximation given that future hydraulic conditions (water levels and waves) are unknown. Further, the sediment impoundment efficiency diminishes as sediment deposits in the basin and channel. However, the prorated shoaling rate offers a good approximation of the shoaling rates of alternatives to reduce in-channel shoaling relative to the shoaling rate for baseline conditions (i.e., no basins and no IWW Cut-DA9 rerouting). Moreover, the prorated shoaling rate provides an effective way of determining which alternative performs best to reduce in-channel shoaling. Comparison of the shoaling rates for baseline and shoaling reduction alternatives provides the means to estimate shoaling rates at IWW Cut-DA9.

RESULTS OF ANALYSIS AND CONCLUSIONS

Model results show the best performing deposition basin alternative (Alternative D in Figure 3) would likely change the frequency of dredging to approximately once every nine years. Each dredging operation would remove approximately 57,840 m^3 at an equivalent uniform annual cost of $507,000. Compared to the baseline equivalent uniform annual cost (i.e., the existing maintenance dredging volume and frequency at the time of this study), the estimated annual savings of $177,000 is substantial and the second largest among the analyzed alternatives.

Model results show the best performing IWW Cut-DA9 reroute alternative (Alternative G in Figure 3) requires an additional initial dredging of 66,200 m^3 for the new channel and each succeeding maintenance dredging operation would remove approximately 29,460 m^3 once every eight years or more at an equivalent uniform annual cost of $435,000. Compared to the baseline equivalent uniform annual cost, the estimated annual savings of $249,000 is the largest among the analyzed alternatives.

To determine the hydraulic effects of the deposition basin and channel reroute, this study evaluated the differences in flow velocity from baseline conditions. Peak flood and peak ebb flow velocity differences from baseline hydraulic conditions of Alternatives D and G are too small to negatively affect navigation safety. As flow velocity differences at peak flood and peak ebb (when flow velocities are maximum) are small, the flow differences between alternatives and baseline conditions for the other phases of the tidal cycle will likely be less than those shown for peak flood and ebb.

RECOMMENDATIONS

Perform a geotechnical/environmental analysis and a boat navigation analysis of the channel routes for the channel reroute alternative. Engineering design for the final channel/basin modifications should evaluate the long-term shoaling rate for better estimation of the variation of the sediment impoundment performance and to better account for more potential long-term variations of waves and water levels. Future bathymetric surveys should include the proposed basin areas and/or channel reroute locations to establish baseline shoaling rates at these locations.

REFERENCES

Florida Department of Environmental Protection (2021): Bakers Haulover Inlet Management Plan_08-2021 (floridadep.gov), 35 pages.