APPENDIX B

TIDAL HYDRODYNAMIC MODEL

TIDAL HYDRODYNAMIC MODELING
of
PEANUT ISLAND IMPROVEMENTS

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Board of County Commissioners

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I. Introduction

A. Background

Peanut Island is a spoil island created from the materials dredged from the Port of Palm Beach entrance channel and turning basin. (See Figures 1 and 2). Portions of the island continue to be used for spoil deposition. The Palm Beach County Board of County Commissioners has proposed to develop the island for recreational uses and environmental enhancement. Part of the proposed improvements include a tidal pond which, by its construction will provide improved tidal circulation to an existing mangrove area upland of the island's western shoreline. Another proposed improvement is the construction of a shallow habitat area on the southeast corner of the island. The proper function of both of these improvements depends on the good tidal flushing.

The tidal pond, proposed to be located on the west side of the island (See Figure 3), is to be dredged to -6 NGVD from the upland with one 30' wide entrance channel. The basin is proposed to be connected to adjacent mangrove areas via shallow perimeter channels. The perimeter channels will lie adjacent to the existing mangrove wetlands.

The shallow habitat area is proposed for the southeast corner of the island (See Figure 3). The shallow habitat will be dredged to -10' NGVD, partly from existing uplands. The area will be at least partially enclosed by rock revetments. The shallow habitat will have at least one 50' wide channel connection dredged to -10' NGVD and extending from the shallow habitat to the -10' NGVD bottom contour of the Lake Worth Inlet or adjacent waters. A design criteria for the shallow habitat is the maintenance of high visibility for as much of the duration of the tidal cycle as possible.

B. Purpose

The purpose of this report is to present the results of field work and modeling analyses related to the tidal dynamics in and around Peanut Island and the proposed tidal pond and shallow habitat area. The modeling was verified with flow data and to some extent turbidity data for existing conditions. The verified model was applied to simulate the behavior of the proposed tidal pond and habitat area under typical tidal conditions. The impact of the tidal dynamics on the design alternatives is presented and implications to the final design are discussed.

II. Methods

A. Field Observations

A hydrographic survey was performed by Sea Systems, Inc. for the areas around Peanut Island north to the Blue Heron Bridge/Causeway, and south to a profile across Lake Worth aligned approximately 300' south of the southern limits of the Turning Basin. Other bathymetric data available included a Sea Systems, Inc. survey of the ICWW in the same vicinity, US Army Corps of Engineers[2] surveys of the entrance channel and turning basin, ERM profiles of the nearshore area south of Phil Foster Park, other spot soundings from ERM[3], north of Blue Heron Boulevard Causeway/Bridge, and the NOS navigation charts.

Tide and flow measurements were performed on October 3-4, 1996 for application in the model calibration/verification. The tidal water levels were observed using a Stevens Type F water level recorder installed on the Coast Guard Station dock at the Southeast corner of Peanut Island (See Figure 3). The flow measurements were performed using a Model 110 ENDECO flow meter. The measurements were made at various stations in the Peanut Island vicinity over the flow depth (See Figure 4).

Concurrent to the flood tide flow measurements on October 3, 1996, measurements of horizontal visibility were performed by Palm Beach County ERM staff at points circumscribing the Peanut Island shoreline, (See Figure 5). These observations were made by one diver holding a secchi disk perpendicular to the water surface with the flat white and black target surface facing another diver. The divers would move away from each other until the secchi disk was no longer visible at which time the distance was recorded.

B. Model Analyses

The Environmental Fluid Dynamics Code (EFDC) model was applied for to perform all the simulations used in this analysis. EFDC is a three dimensional hydrodynamic/transport model that can simulate the effects of tidal flows and other forcings on the distribution of dissolved and suspended materials in the water. The Peanut Island vicinity was represented in the EFDC model by an orthogonal grid network, setup using the associated grid generation program called GEFDC.[1]

EFDC had previously been applied to simulate the tides and salinity distributions on the entire Lake Worth Lagoon in a study completed in 1996[1] (See Figure 6). The Lake Worth Model (LWM) was employed in this study to define boundary conditions (See Figure 7) to drive the finer grid Peanut Island Model (PIM) (See Figure 8). The National Ocean Service (NOS) tidal prediction program was used to generate predicted tides from Lake Worth Pier harmonic constituents. The predicted tide time series for the simulation period was then input to the LWM at the "open coast boundaries" using the same calibrated tidal amplitude and phase corrections derived in the Lake Worth Study[1]. The LWM was then run for the simulation period (Oct 1-6, 1996) and the tidal histories were saved at the grids corresponding to north and south ends of the PIM grid (see Figure 8).

The offshore boundary of the PIM (i.e. Lake Worth Inlet) was simulated using the same NOS predicted tides for Lake Worth Pier and calibrated amplitude and phase corrections. The LWM computed time series water levels were applied at the north and south boundaries of the PIM.

Various design scenarios of the proposed shallow habitat area were simulated as an integral part of the PIM. This was necessitated by the interrelationship between the tidal hydrodynamics in the vicinity of the island and the flushing characteristics of the proposed shallow habitat design scenarios.

The proposed tidal pond was simulated with the EFDC model separate from the PIM. The boundary condition applied on the outside end of the entrance channel was defined by the water level time series results of the PIM at the location of the proposed channel connection.

C. Graphic Output

The PV-Wave graphics software was used to display the model results. Dye concentrations are color coded to demonstrate the spatial and temporal variations during the tidal cycles.

Velocities are displayed by vectors assigned to each grid. Since the grid density is defined to allow higher resolution in areas of specific interest, the vectors would be more dense in these areas. It is important to remember that the vectors represent velocity and not flow rate. Thus higher density of vectors does not equate to higher flow rates.

III. Field Measurement Results

A. Bathymetry

The bathymetric data collected as part of this project's field work are reported on the Sea Systems Corporation survey drawing entitled, "Peanut Island Hydrographic Survey", dated August 26, 1996. This survey drawing also includes data that was collected by Sea Systems Corporation for a separate survey of the ICWW.

B. Flows

Tidal flows at the measurement locations shown on Figure 4 are displayed on Tables 1a and 1b. Comparisons of modeled and observed tidal flows are also presented on this table and are discussed in the Calibration Section of this report.

C. Visibility

The variation of visibility with tidal conditions was observed at the locations shown on Figure 5. The measurements were made during part of one tidal cycle on October 3, 1996. Horizontal visibility data collected by ERM are summarized on Table 2. An attempt was made by ERM staff to correlate the horizontal visibility measurements to concurrently sampled turbidity (NTU), See Appendix A.

D. Tides

The tides were measured during the performance of the visibility and flow measurements. Comparisons of the modeled and observed tides are presented in Figure 9 and discussed in the Calibration Section.

IV. Hydrodynamic Model

A. Calibration/Verification

The EFDC was applied to the Lake Worth Model (LWM) and to the Peanut Island Model (PIM) to simulate a period that included the October 3-4, 1996 field observations. The model calibration consisted of making adjustments to the boundary conditions until the measured and modeled velocities matched. The necessity for adjustments demonstrated the need for further tidal elevation and flow data collection to better calibrate the Lake Worth model. The final model comparisons of measured and modeled flows at various locations in the PIM are presented in Tables 1a and 1b. Figure 9 displays the comparison of the observed and modeled tide at the Peanut Island Coast Guard Station. The separation of the observed and modeled tides was probably due to wind setup as winds were observed to pick up to over 20 knots after the turbidity and flow measurements. No attempt was made to include winds in modeling efforts.

The simulation of an introduction of dye to the Lake Worth Lagoon is discussed in the following section. The simulation of dye distributions provides insight into the impact of tides on flushing under existing conditions and for proposed facility designs.

In Figures 10a-10l, the model simulated flushing of the introduced dye is qualitatively compared to the turbidity measurements accomplished by Palm Beach County ERM staff members on October 3, 1996. The ERM measurements at each station spanned about 5 hours starting a little less than half way into flood tide and ending in the early stages of ebb tide. The highest visibilities were evident on the east side of the island with lower visibilities on the south side and still lower visibilities on the west side. The variations in measured visibilities appear to generally coincide with the variations in modeled dye concentrations.

B. Simulations of Flushing

1. Peanut Island Vicinity

The EFDC model was applied to the Peanut Island Model (PIM) data set to simulate the tidal hydrodynamics in the Peanut Island vicinity and the exchange of resident Lake Worth Lagoon waters with incoming ocean waters. The simulations provided insight into the conditions that may impact the flushing characteristics of the proposed tidal pond and shallow habitat area.

An analysis of the impacts of inflowing seawater on the resident Lake Worth Lagoon waters was accomplished by initially assigning the waters a uniform "dye" concentration of 100.0. The inflowing sea waters were assigned a dye concentration value of 0.0. The assignment of initial lagoon dye values was accomplished at the start of an outgoing tide, so that the concentrations within the Lake Worth Lagoon all remained 100.0 until the ebb tide ended and ocean water began to flow in. The LWM was run first, and the dye concentration time series at the grids representing the north and south boundaries of the PIM (See Figures 7 and 8) were saved along with the tide levels. Simulations of the PIM used the LWM generated boundary conditions and the open ocean boundary conditions with the initially assigned lagoon dye concentrations of 100.0. As in the LWM simulation, the PIM was also started several tidal cycles prior to the introduction of dye so that the dye distributions would not be impacted by a cold start of the hydrodynamics.

The dye was introduced to the model at 1:00 AM EDT on October 3, 1996. This date was chosen to coincide with the field visibility measurements. The time of day the dye was introduced needed only to occur during the ebb tide prior to the sampling. The initial lagoon dye concentrations would not change until the flood flow of seawater began.

A 1"=800' window in the vicinity of Peanut Island (see Figure 11) was used to display the model simulated tidal flow velocities and dye concentrations. The plots are presented on 1.5 hour increments after the introduction of dye (See Figures 12-24a,b). Figures 12a and 12b show the conditions at 6 hours after dye introduction (7:00 AM EDT), or little before the low tide at the Peanut Island. The flows are nearly at a standstill, and the concentrations do not exhibit any reductions. At 7.5 hours (See Figures 13a and 13b), the flood flow has begun and the dye concentrations are reduced to near zero in the Lake Worth Inlet and areas east and southeast of Peanut Island. At 9.0 hours (See Figures 14a and 14b), the inflow velocities have increased and most of the waters east, northeast, and south of Peanut Island are replaced with seawater. Areas northwest of the island are still made up largely of waters formerly resident to the lagoon, probably transported there from areas closer to the inlet.

It is of interest to the siting and design of the shallow habitat that at 9.0 hours, the waters closest to the south end of the island remain dye stained. The velocities in this vicinity indicate an eddy effect, as the flows are in the opposite direction of the inflowing seawater in the adjacent turning basin. Both the opposite flow direction and the poorer visibility implied by the remnant dye were observed in the field. In the model, as observed in the field, this condition tends to continue throughout most of the flood flow.

Also of interest to the shallow habitat siting and design is the split in flood tide flow direction at the east side of Peanut Island. Just north of the proposed shallow habitat site, the flood flows along the east side of the island are directed north. Immediately adjacent to the proposed site, the flows along the east shore are directed south. A dead zone is implicit in the flow split that may influence the connecting channel siting.

Continued simulation of the dye dispersion through tidal dynamic processes show the concentrations rise again in the vicinity of Peanut Island during the next ebb tide, but the maximum concentrations are less than those occurring during the previous ebb flows (i.e. <100.), particularly around the south end of Peanut Island. The model simulated advective processes associated with the tidal exchange will eventually reduce the dye concentrations throughout the lagoon to near zero. However, it should be noted that the modeling assumed no source of dye emanating from within the lagoon. In reality, there are such sources of color and suspended materials including canal discharge, groundwater inflows, and local runoff. Resuspension of lagoon bottom materials can cause increased turbidity, particularly during windy conditions. Also, the inflowing seawater made be associated with some turbidity. Under various commonly occurring conditions one or all these sources would provide a source of visibility reducing dissolved or suspended materials which would reduce the water clearing effects of tidal exchange. The analysis of the sources of suspended and dissolved materials impacting the visibility, turbidity, and color of the waters was beyond the scope of this study.

2. Proposed Improvements

a. Shallow Habitat Area

The Shallow Habitat Area is intended to attract ocean going fish that enter the inlet. It is desired to have clear water during as much of the tidal cycle as possible. The Peanut Island Model was simulated with various shallow habitat design configurations in order to determine the period that clear water can be expected. The model was run for the same time period as done for the existing conditions simulations, and dye introduced at the same time.

The shallow habitat area scenarios simulated are displayed on 1"=400' window of the PIM grid (See Figure 25). Each scenario included a 50' wide channel connection at -10' NGVD. These scenarios include the following:

Scenario SH1
2 acre rock revetment enclosed area with one channel opening toward the east. (See Figure 26)

Scenario SH2
2 acre rock revetment enclosed area with one channel opening toward the east and a second opening along the south boundary. (See Figure 27)

Scenario SH3
1 acre rock revetment enclosed area with one channel opening

toward the east. (See Figure 28)

Scenario SH4a
1 acre rock revetment enclosed area with one channel opening toward the east and a second opening along the south boundary. (See Figure 29a)

Scenario SH4b
1 acre rock revetment enclosed area with one channel opening toward the east and a second opening along the south boundary. A baffle was added to help distribute channel inflows. (See Figure 29b)

Scenario SH5
1 acre rock revetment enclosed area with one channel opening toward the south. (See Figure 30)

Scenario SH6
1 acre rock revetment enclosed area with one channel opening toward the south and a second opening toward the south at the west end. (See Figure 31)

Appendices B-H contain displays of model simulated velocities and dye concentrations on a 1"=200' window (See Figure 32) for each of the shallow habitat scenarios and the adjacent lagoon waters. Scenarios SH1, SH3, and SH5 are each associated with one 50' wide channel connection to the adjacent tidal waters. Such single connections are not conducive for rapid flushing and maintenance of clear water, especially for the proposed habitat with depths which are relatively deep compared to the tide range. The tidal exchange in such a system may be essentially limited to the tidal prism volume.

Scenarios SH2, SH4a, SH4b, and SH6 each have multiple connections to the adjacent lagoon waters, one 50' wide channel connection (-10 NGVD) and one relatively shallow opening through the rock revetment.

Scenario SH2 allows good exchange of flows into the 2 acre shallow habitat, but the larger area causes some relatively dead space at the north end. Repositioning of the entrance channel to the north end may help with the flushing but would increase the dredging required to reach the -10' NGVD contour. Also, the farther north the entrance channel is positioned, the closer it is to the region of the modeled (and observed) flow split and potential dead water zone.

Scenario SH4a allows flow through flushing during both flood and ebb flows. The east entrance channel intercepts westerly directed flood flows and the momentum is sufficient to carry through the shallow areas and prevent the inflows from the south opening. The eddy induced easterly directed flows along the south side of Peanut

Island during flood tide conditions are associated with lower visibility than the seawater from the inlet.

Scenario SH4b, a modification of Scenario SH4a was also simulated. The purpose of SH4b was to demonstrate that the inflows from the east can be better distributed throughout the shallow habitat area to reduce dead areas and produce better visibility throughout. The resulting average dye concentrations in the 1 acre shallow habitat were reduced.

Scenario SH6 experiences a strong flow through the shallow habitat area during flood flow conditions. However, the flood flows are an extension of the existing eddy flows along the south side of the island. These eddy flows appear to be enhanced by the SH6 dual openings toward the south. The problem with this flushing is that the eddy flow waters are associated with higher percentages of formerly resident lagoon waters and therefore have lower visibility. The ebb flows are directed easterly to northeasterly and are not conducive to generating flow-through in the SH6 scenario's two southerly directed inflows.

A comparison of the dye concentration time series for the two best flushing scenarios, SH4b and SH6, is presented in Figure 33. Although the ebb tide concentrations are slightly higher for Scenario SH4b, the flood tide concentrations are zero where the concentrations of the Scenario SH6 are slightly elevated, reflective of the lower visibility of the eddy waters from the south side of Peanut Island.

b. Tidal Pond

The tidal pond is proposed to be located on the west side of Peanut Island (See Figure 3). While there is no need to have clear water in the tidal pond it is important that the basin be well flushed. The ability for the tidal flows to flush the tidal pond was also evaluated using the EFDC model (See Figure 34). However, because the proposed connection is via a single channel aligned perpendicular to adjacent lagoon and ICWW tidal flows, significant interactions with the Peanut Island vicinity hydrodynamics was not anticipated. The tidal pond and adjacent mangrove areas were therefore modeled separate from the Peanut Island Model. The tide history in the PIM at the location of the entrance to the tidal pond was saved for input as the driving boundary condition in the tidal pond simulations.

Two scenarios were run for the tidal pond model. They are described as:

Scenario BB1
a 1.0 acre tidal pond, dredged to -6' NGVD, and connected to the Lake Worth Lagoon by a -6' NGVD, 30' wide channel. The tidal pond is not connected to the existing adjacent mangrove area. See Appendix I for dye and flow distributions in time.

Scenario BB2
a 1.0 acre tidal pond, dredged to -6' NGVD and connected to the Lake Worth Lagoon by a -6' NGVD, 30' wide channel. The tidal pond is also connected to the existing adjacent mangrove areas by -3' NGVD perimeter channel that allows water to flow into the mangrove areas during high tides. See Appendix J for dye and flow distributions in time.

The primary difference between the flushing simulated for the two tidal pond scenarios was the additional tidal prism volume provided by the inclusion of the perimeter ditch and mangrove areas. The flushing of the tidal pond is significantly faster if the connection to the mangroves exists (See Figure 35). The higher concentrations that persist in the mangrove areas themselves is somewhat deceptive. The way EFDC works is that a minimum water level is maintained in the overflow (mangrove) areas to prevent instabilities. This minimum water level represents a small volume of water but the associated dye concentrations remain relatively high and show up on the plotted dye map.

c. Shoaling Considerations

The simulated entrance channel velocities for the shallow habitat area are not of the magnitudes normally associated with transport of medium grain sand channel bed materials. However, the tidal flows and wave action transverse to the proposed entrance channel alignment (under all scenarios) are sufficient to transport materials into the channel. Whatever scenario chosen, the channel must be protected from sediments entering from lateral sources or provided frequent maintenance.

Very fine suspended materials can fall out and be deposited in the shallow habitat area if flushing is not adequate. The chosen alternative should have flow through flushing distributed sufficiently to avoid fine material deposition.

The tidal velocities coupled with wave action adjacent to the entrance channel to the tidal pond are sufficient to transport sand materials and finer materials along the shoreline to cause deposition in the entrance channel. It is recommended that groins be constructed to the -6' NGVD contour to protect the entrance channel from alongshore transported materials.

V. Conclusions and Recommendations

Review of the model simulated dye distributions during the tidal cycle indicates the proposed shallow habitat site, at the southeast corner of Peanut Island is at an optimal location to maintain clear water. However, the design must consider the existence of eddy flows along the south side of the island during flood tide conditions. These easterly directed eddy flows are associated with higher turbidities and poorer visibility than the waters coming from sources on the east side of the island. The SH4a and SH4b scenarios capture westerly directed flows from the inlet with sufficient momentum to flow through the shallow habitat and exit the western opening. The discharge through the western opening prevents the eddy flows from entering the shallow habitat. The SH4b scenario includes a baffle structure to distribute the inflows to the more inland parts of the shallow habitat.

Scenario SH4b is recommended for the shallow habitat design. The simulated baffle demonstrates the energy availability with a easterly directed channel to flush the system and is not intended to support a recommendation for the specific baffle modeled. It is recommended that the entrance channel be designed to distribute flow throughout the shallow habitat area and to avoid short circuiting flows to the western opening.

Simulations of the tidal pond Scenario BB1, without connection to the mangroves, demonstrated that dyed water would flush to less than 10% of it's original concentration within 48 hours (See Figure 34). The reasonably quick flushing is due to the shallow depth, and corresponding large tidal prism volume to tidal pond volume ratio.

The simulation of the tidal pond design under Scenario BB2 indicated a faster flushing (10% of original concentration in 20 hours, See Figure 34). The faster flushing is due to the larger tidal prism volume provided by the addition of the perimeter ditch and mangrove areas.

Scenario BB2 is recommended for the tidal pond design.

VI. References

1. Tomasello Consulting Engineers, Inc. et al, "Lake Worth Hydrodynamic/Salinity Model", Volumes 1 and 2, March, 1996.

2. Department of the Army, Jacksonville District, Corps of Engineers, "Palm Beach Harbor, Florida, Examination Survey 33 and 35-foot Project, Entrance Channel and Settling Basin Dredging Plan", 1994.

3. Palm Beach County Department of Environmental Resources Management, "Lake Worth Lagoon Natural Resources Inventory and Resource Enhancement Study", December 15, 1990.