EFFECTS OF PROPOSED ACCESS CHANNELS FOR A DANIEL ISLAND TERMINAL ON WANDO RIVER CURRENTS, SALINITY, & SHOALING, CHARLESTON, SOUTH CAROLINA AUGUST 1999

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INTRODUCTION

The South Carolina State Port Authority is planning projects involving two marine terminals on Daniel Island in Charleston Harbor. Vessel access to the terminal on the Wando River side of Daniel Island must be provided by a new channel system. The U.S. Army Engineer District, Charleston (SAC), is performing navigation, economic and environmental analyses on alternate channel designs. At CHL, three sets of three channel designs have been evaluated with respect to navigation. The present study used numerical hydrodynamic, salinity, and sedimentation models to evaluate three channel designs which passed navigation tests. A hydrodynamic model was used to compute plan-channel currents for the navigation simulator and to evaluate flow patterns. The sedimentation and salinity models were used to predict maintenance dredging requirements and changes in salinity distributions resulting from the alternate channel designs. Sedimentation impacts were examined in the vicinity of the planned channel and wharf, and other Federal channels in the area. The salinity model was used to examine impacts on conditions at the entrance to Bushy Park at river mile 42 of the Cooper River, salinity stratification on both sides of Daniel Island, and depth-averaged salinity distribution in the Wando River near and about 2 miles upstream from the study area. The entrance to Bushy Park is nearly fresh, controls water quality in the reservoir, and affects industrial and municipal water intakes. The limit of ocean saltwater intrusion is sensitive to changes in estuarine conditions.

The sections below present background conditions, results from previous studies, modeling procedures, and results from the present study.

MODEL DESCRIPTION

The numerical model applied in this study was RMA10-WES, a modified version of the model originally developed by Dr. Ian King of Resource Management Associates. It is an implicit finite element model which solves equations of motion for shallow water waves and tides over a combination of one-, two-, and three-dimensional elements. The numerical mesh covers the entire Charleston Harbor, the Cooper River up to the Pinopolis Dam, and large parts of the Wando and Ashley Rivers. The mesh was based on a two-dimensional depth-averaged mesh developed for a previous study (Teeter et al. 1995). The previous mesh was verified to flows collected in 1992 and 1993. The new mesh has three- dimensional areas in the channel covering the Federal navigation projects from the ocean up the Cooper and Wando Rivers and in

areas adjacent to the channels. A more complete description of the model was given in the February 1999 status report.

All the plans tested in the sediment model had the approved improvements for the 45 ft Federal project, including the widened Daniel Island Reach with a new turning basin, and the straightened Rebellion, Folly, Horse, and Shutes Reaches. This made it necessary to run a base condition, in addition to the existing condition, with the approved improvements installed to serve as a gage for the plan effects.

HYDRODYNAMIC MODEL VERIFICATION

The hydrodynamic model was originally verified to tidal harmonic water levels for a previous navigation study. Flow distributions in navigation channel areas were checked against 1992 field data collected in Drum Island and Town Creek Reaches. Additional flow data were collected for this study in June 1996 at the entrance of the Wando River, Drum Island Reach, and Hog Island Reach. Inspection of those data indicated that the model needed adjustment in areas outside the navigation project. A reverification of the model mesh to measured water levels, tidal discharges, and currents was performed.

HYDRODYNAMIC MODEL TESTS OF CHANNEL PLANS

The existing channel condition includes a 40-ft-deep channel (mlw) which follows the natural channel on the southeastern side of the Wando waterway to a rectangular turning basin constructed abreast of the existing Wando Terminal. The base condition includes a 45-ft-deep channel in the Wando in the existing location and channel enlargements on the Cooper River side of Daniel Island, the removal of the dike on the southwest corner of Daniel Island, and a turning basin (Plan 2-5). The three plans involve 45-ft-deep channel areas to replace or supplement the existing channel and with connections to the existing turning basin. As mentioned earlier, the plan tests also include channel enlargements on the Cooper River side of Daniel Island, the removal of the dike on the southwest corner of Daniel Island, and a turning basin (Plan 2-5). Further details of the plans were presented in the February 1999 status report.

The model was used to simulate a time period from June 1996 when field data were collected. Six channel conditions were tested in all:

Condition	Project Depth	Project Area	Daniel Island Reach Width
Existing	40 ft	49.3e6 ft^2	600 ft
Base	45 ft	53.3e6 ft^2	875 ft
Plan 1	45 ft	59.1e6 ft^2	875 ft
Plan 1s	45 ft	59.1e6 ft^2	875 ft
Plan 2	45 ft	61.4e6 ft^2	875 ft
Plan 3	45 ft	63.4e6 ft^2	875 ft

The project area covers all the areas used to assess shoaling in the model, including Rebellion through Daniel Island Reaches and the Wando River. The difference between Plans 1 and 1s is that, in the

former,the existing Wando River channel was left in the model while, in the latter, that area was smoothed to depths similar to the surrounding area to simulate long-term sediment deposition. The smoothing was accomplished by shoaling the existing Wando Channel to 30 ft half way between the entrance and the Wando Turning Basin, and smoothing channel depths on both ends of the reach.

HYDRODYNAMIC IMPACTS

Model plan tests indicate that, as a result of greatly increased cross-sectional areas, current velocities in the Wando River abreast of the proposed Daniel Island Terminal will be appreciably reduced. In the Wando River, average current speed decreased 34 to 40 percent on ebb tidal flow and 36 to 41 percent on flood tidal flow compared to the existing condition. The slightly greater decreases on flood versus ebb tidal phase may be due to the increased cross sections in the Drum Island and Daniel Island Reaches allowing greater flow through those channels. Details of percentage decrease in the currents relative to the existing condition are:

Tidal Phase	Plan 1	Plan 2	Plan 3
Average Ebb	34	36	40
Maximum Ebb	41	43	44
Average Flood	36	37	41
Maximum Flood	31	33	36

These percentages were calculated from model output and are not meant to imply that 1 or 2 percent are important differences. Some further details of hydrodynamic impacts were provided in the February 1999 status report.

Examination of the sediment model results indicated that current speeds upstream of the Federal project on the Wando River were increased by the plans.

SALINITY IMPACTS

Increasing channel depths and channel cross-sectional areas can alter ocean salinity intrusion. Model tests were performed by “spinning up” the model with a steady freshwater inflow of 6,250 cubic feet per second (cfs) in the Cooper River at Pinopolis Dam. As indicated in our February 1999 status report, the Wando inflow is small and was set in the model at a constant 260 cfs. After 48 hours of model simulation, the inflow at Pinopolis was reduced to 140 cfs to simulate a hypothetical 48-hour “zero-flow” weekend operation of the Pinopolis hydropower station. Zero-flow periods have been found to induce greater saltwater intrusion in the vicinity of the Bushy Park Reservoir entrance.

All the plans tested included the widened Daniel Island Reach. Salinity effects appeared to come mainly from this feature, and the effects of individual plan components could not be identified. Salinity impacts were greater at the surface than at the bottom. Model results for the Wando River indicated the following plan salinity differences relative to existing condition at the surface after 6,250 cfs inflow period:

	Plan 1	Plan 3
Wando River Entrance	0.02 ppt	-0.01 ppt
Upstream of Turning Basin	-0.06 ppt	-0.06 ppt
Rathall Creek	0.09 ppt	0.09 ppt

After the zero-flow period, the model indicated the following changes at the surface:

	Plan 1	Plan 3
Wando River Entrance	0.00 ppt	-0.04 ppt
Upstream of Turning Basin	-0.19 ppt	-0.21 ppt
Rathall Creek	-0.01 ppt	-0.03 ppt

Salinity differences were calculated from model output and rounded off to indicate the magnitude of effect, though this magnitude may not be important in relation to the verification between the model and the prototype or to possible impact levels.

The effects of the plans on salinities in the Wando River were minor partly because the plan channel length is short compared to the length of salinity intrusion and partly because the freshwater inflow to the Wando River is low and the sub-estuary remains well-mixed vertically. Salinity stratification in the Wando River was not affected by the plans while stratification did increase in the Daniel Island Reach of the Cooper River as a result of the 875-ft-wide plan channel feature. Salinity stratification in the Cooper River remained below values associated with changes in fundamental estuarine characteristics as identified by Teeter (1989). Kjerfve and Magill (1990) found that most (78 percent) of the variance in the 1922-1987 salinity record at the Charleston Custom House was related to freshwater discharge.

Salinity intrusion near the entrance canal to Bushy Park was not impacted by the plans. During the zero-flow period, plan minus base salinity differences were less than 1 ppm at this location.

IMPACTS ON SEDIMENTATION AND MAINTENANCE DREDGING VOLUMES

Impacts of the Wando River Channel Plans

The reductions in plan-channel maximum and average currents described earlier indicate that sedimentation and maintenance dredging requirements will be greater as compared to the existing channel. The channel bottom areas are also appreciably greater for the plans than the existing channel area. The model was operated for the June 1996 condition and verified to suspended sediment measurements. Other data collected in the harbor indicate that suspended sediment concentrations can be about 40 times higher as a result of winter storms (Teeter 1989). These events have a great effect on sedimentation, and, for this reason, model shoaling volumes were indexed to the base condition.

It is apparent that the increased dredging volumes predicted by the model for the Cooper River and for Drum Island Reach are the result of the channel changes in those areas and not in the Wando River. Therefore,

the predicted shoaling in the Cooper and in Drum Island Reach are treated separately. It is reasonable to assume that only the Wando River shoaling volumes are associated with the Wando River plans. The following are the raw model indices for the plan tests:

Location	Existing	Base	Plan 1s	Plan 2	Plan 3
Wando River	0.9	1.0	2.3	3.0	3.7

The Wando River plans do not include the channel extension constructed in 1994. An earlier sediment model study of the extension of the Wando River channel predicted a 50 percent increase in shoaling (Teeter 1993). The extension was constructed in 1994, and, because of the short history, the dredging records are inconclusive. However, assuming that the dredging predicted for August 1999 is accurate, the 1996-1999 actual volumes will be 333,000 cyds/yr for the Wando, an increase of 67 percent. The 1988-1994 average Wando River maintenance dredging was about 200,000 cubic yards per year.

Impacts of Daniel Island Improvements

The shoaling volumes for the Cooper River side of Daniel Island and Drum Island Reach did not vary with plan changes in the Wando River. Raw shoaling indices for the tests were:

Location	Existing	Base	Plan 1s	Plan 2	Plan 3
Seaward Reaches	0.9	1.0	1.0	1.0	1.0
Drum Island Reach	0.7	1.0	0.9	0.9	0.9
Cooper Side	0.6	1.0	1.0	1.0	1.0

The seaward reaches included Rebellion, Folly/Horse/Shutes, Custom House/Tidewater/Lower Town Creek, And Hog Island Reaches.

The Cooper Side is the Shipyard River and Daniel Island Reach. The shoaling in the Drum Island Reach decreased by 10 percent due to the Wando River Channel Plans.

One check on the model is to compare results to the previous model. The present model predicted 444,000 cyds/yr for Daniel Island Reach after the 45-ft-deep improvements, whereas the 1995 model study predicted 230,000 cyds/yr. The earlier model study used a depth-averaged model. The present model is three-dimensional and predicts that salinity and density stratification will increase in the Daniel Island Reach as a result of the widening and deepening. For the reasons given in the last paragraph, it is reasonable that the present model would predict greater shoaling volumes than the earlier study. Both model verifications were low for Shipyard River, but the present model verification for Shipyard River plus Daniel Island Reach (302,000 cyds/ys) was much closer than the previous model to the prototype average (335,000 cyds/ys). For this reason, the index was calculated base on the combination of the Shipyard River and Daniel Island Reach.

Discussion of Shoaling Impacts

The model predictions indicate that shoaling in the reaches downstream from the Cooper and Wando Rivers will not decrease in the base and plan conditions even though shoaling may increase appreciably in the Cooper and Wando River channels. This is to be expected since the main sediment source for the estuary is not the rivers. The sources of sediments to the Charleston Harbor were extensively debated and studied during the 1960's and 1970's. Several studies found that the main source was the coastal ocean, and in 1983 the USGS estimated that 59 percent of the shoal material came from the ocean for the 1966-1982 period. Under post-rediversion inflow conditions (4,500 cfs weekly average), Teeter (1989) estimated that the inflow at Pinopolis would contribute 17 percent of the total shoal material, with about 36 percent coming from the ocean. The Cooper River was indirectly causing the earlier heavy shoaling through estuarine gravitational circulation (caused by freshwater inflow). Gravitational circulation pulls ocean water and suspended material in at the bottom of the entrance channel and transports it upstream. The effect of the rediversion project was not so much to eliminate the suspended sediment as it was to eliminate the freshwater from the Cooper River inflow. Based on stratification and estuarine trap efficiency considerations, a prediction was made at the time of the rediversion that harbor channel shoaling volumes would decrease to 1.4e6 cyds/yr exclusive of the entrance channel. In fact, the 1988-1994 total average harbor channel shoaling was 1.37e6 cyds/yr, exclusive of the entrance and Navy channels.

The large volume indices for the Wando River are caused by a combination of increased channel area and increased sedimentation rate per unit area. These factors can be broken down by plan as follows:

Wando River	Base	Plan 1s	Plan 2	Plan 3
Area Index	1.0	1.7	2.0	2.3
Shoaling Rate Index	1.0	1.4	1.5	1.6

In other words, plan 3 has 2.3 times the area of the base channel and is predicted to shoal at 1.6 times the rate per unit area on average.

As mentioned earlier, currents increased upstream of the projects on the Wando River. This caused areas which were stable in the base test to become erosional and contribute sediment to the plan channels. Even though the erosional thickness averaged only about 0.25 inches, over a wide area, it amounted to an eroded volume that was an appreciable fraction of the plan channel shoaling volumes in the Wando. With time such areas would adjust to the flow and sedimentation in the Wando River channel would decrease by perhaps 10 percent.

The uncertainty in the sediment model predictions is difficult to define. The quality of the verification is one consideration. However, model response or sensitivity to system change may be better than the verification if the boundary conditions are not well defined, as is the case here. The ability of similar models to predict sedimentation effects for channel alterations, such as those discussed earlier, is also a consideration. Still, it may be more appropriate to round indices to the nearest 0.5. The indication that the model was not run

long enough to allow a new equilibrium balance between erosion and deposition is also a consideration, as indicated in the last paragraph. Thus, a reasonable summary of the expected shoal volume indices for the Wando are:

Location	Base	Plan 1s	Plan 2	Plan 3
Wando River	1.0	2.0	2.5	3.5

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