CEERD-HC-ES 20 Dec 2003

MEMORANDUM FOR Commander, U. S. Army Engineer District, Jacksonville,
ATTN: CESAJ-EN-HI (Mr. Mitch Granat), (Prudential Building)
701 San Marco Blvd., Jacksonville, FL 32207

SUBJECT: Report on the results of preliminary scenario runs for the Biscayne Bay Coastal Wetlands project. These runs are intended to yield rough estimates of the relationship between freshwater discharge distribution and volume, and the near-shore salinity regime of Biscayne Bay in the Coastal Wetlands study area.

1. Enclosed please find the Memorandum for Record that consists of a report detailing the findings of the preliminary scenario runs for the Biscayne Bay Coastal Wetlands project.

2. If you have questions concerning the information provided, please contact Mr. Gary Brown at 601-634-4417.

Encl

THOMAS RICHARDSON
Director
Coastal and Hydraulics Laboratory

Background

1. The purpose of the preliminary scenario runs is to ascertain some general information about the relationships between freshwater inflows to Biscayne Bay, and the near-shore salinity regime in the Biscayne Bay Coastal Wetlands project area (see Figure 1). These preliminary scenario runs were done using an existing hydrodynamic/salinity model and model mesh that had been developed for a previous study of the entire Bay (see Brown, et. al. 2003)). Although this existing mesh is not appropriate for use in the final scenario analyses for the Biscayne Bay Coastal Wetlands project, it can be used to ascertain some general information about the system, which in turn could be used as guidance for selecting final design alternatives to be simulated in the final scenario runs. These final scenario runs will be run with a modified model and model mesh that are appropriate for use in this study.

2. The computer code used in this study is the TABS-MDS finite element numerical model. It is an ERDC modified version of the RMA10 numerical model (King, 1988). It has been used extensively in previous studies of multiple estuaries.

Preliminary Scenario Runs Boundary Conditions and Specifications

A. Simulation period

3. The model simulation period extends from August, 1997- July, 1998. July, 1997 is used as spin-up, i.e. the model is allowed to run for this month so that the hydrodynamics and salinity can circulate long enough for the system to achieve dynamic equilibrium.

B. Boundary Conditions

4. The model boundary conditions and the sources of the boundary condition data are given as follows:

- Flows at 16 coastal structures: taken from the South Florida Water Management District (SFWMD) DBHYDRO database, recently updated by Dr. Mahatel Ansar to account for the influence of the tide on the discharge equations at the structures.
- Tide: taken from Coastal and Hydraulics Laboratory (CHL)/Biscayne National Park (BNP) data gathered at CTD 9 (located in the Safety Valve). The data was missing for Jul 98, so data taken from the NOAA gage at Virginia Key was used to replace this missing data.
- Ocean Salinity: taken from measured monthly averaged ocean salinity at Alina's Reef.
- Wind: Taken from CHL/BNP data gathered at Convoy Point. This was then corrected for wind gage elevation and for shoreline effects on the wind.
- Rainfall: taken from CHL/BNP data gathered at Convoy Point. The data was missing for July 98, so data taken by the SFWMD at S-21 was used to replace this missing data.
- Evaporation: taken from SFWMD data collected at Hialeah, Florida.
- Groundwater Inflow: estimated values supplied by Dr. Chris Langevin at USGS (Langevin, 2000).

C. Preliminary Scenario Run Configurations

5. There are a total of 10 preliminary scenario runs that were conducted. Preliminary scenario runs 1- 9 were designed to determine the impacts on the near-shore salinity regime of making various independent adjustments to the spatial and temporal distribution of fresh water inflow to the Bay, as well as adjustments to the total volume of inflow to the Bay. The 10th preliminary scenario run represents an inverse modeling approach. That is, the spatial and temporal distribution of the inflow is regulated such that the target near-shore salinity is always achieved. This approach is designed to estimate the both the total volume and the temporal and spatial distribution of inflow required to maintain the desired salinity regime in the near-shore.

6. Table 1 shows a matrix of the various adjustment parameters investigated in preliminary scenario runs 1-9. The following discussion gives definitions and descriptions of these parameters.

Table 1: Preliminary Scenario Run Matrix

Scenario	Flow in existing canals	Flow in 21 tidal creeks	Flow in 8 primary tidal creeks	15K Ac-ft of additional storage	120K Ac-ft of available water	15K Ac-ft of additional storage and 120K ac-ft of available water
Ps1	X					
Ps2		X				
Ps3			X			
Ps4		X		X		
Ps5			X	X		
Ps6		X			X	
Ps7			X		X	
Ps8		X				X
Ps9			X			X

Figures 2 – 6 depict the existing coastal canals, the 21 tidal creeks, and the 8 primary tidal creeks discussed below.

Flow in Existing Canals: the inflows are directed to the Bay via the existing coastal canals. These canals are C-100, C-1, C-102, Military Canal, and C-103. The corresponding discharge control structures at each of these canals are: S-123, S-21, S-21A, S20G, S20F.

Flow in 21 Tidal Creeks: the inflows in the canals in the study area are directed to the Bay via 21 historic tidal creeks. The inflows are distributed as follows: The flow from C-102, Military Canal, and C-103 is combined and distributed evenly among 15 creeks located between Convoy Point (just south of C-103) and Black Point (located at the C-1 outfall) (see Figures 2-4). The flow from the C-1 canal is distributed evenly among 4 creeks located just north of the C-1 Canal (see Figures 4 and 5). The flow from C-100 is distributed evenly between 2 creeks located to the north of C-100 (see Figure 6).

Flow in 8 Primary Tidal Creeks: the inflows in the canals in the study area are directed to the Bay via 8 historic tidal creeks. These creeks were selected from among a set of creeks identified by Dr. Jack Meeder of the Southeastern Environmental Research Center as creeks that show evidence of relatively high historical discharges. The inflows are distributed as follows: The flow from C-102, Military Canal, and C-103 is combined and distributed evenly among the 5 primary creeks located between Convoy Point (just south of C-103) and Black Point (located at the C-1 outfall) (see Figures 2-4). The flow from the C-1 canal is distributed evenly between 2 primary creeks located just north of the C-1 Canal (see Figures 4 and 5). The flow from C-100 is routed to 1 primary creek located to the north of C-100 (see Figure 6).

15K Ac-Ft of Additional Storage: the inflows in the canals in the study area are routed through a storage basin with 15K Acre-feet of capacity. The storage basin is regulated as follows:

If the storage basin is less than half full, the total discharge from the storage basin to the Bay is set at 420 ac-ft/day. This figure is based on estimates given by Dr. Jack Meeder of the required volume of water to maintain the desired near-shore habitat in the study area (Meeder, et. al. 2003). This total volume corresponds to 20 ac-ft/day/creek for the 21 creek simulations, and 52.5 ac-ft/day/creek for the 8 creek simulations.

If the storage basin is more than half full, the discharge increases linearly from 420 ac-ft/day at half the basin capacity, to 1260 ac-ft/day at full basin capacity. If the basin exceeds capacity, then the water is routed directly into the coastal creeks without any attenuation in the storage basin.

Note that all of the water at the 5 coastal structures is routed through the basin, and the outflow from the basin to the Bay is distributed evenly among all of the coastal creeks (i.e. 21 tidal creeks, or 8 primary tidal creeks, depending on the scenario).

120K Ac-Ft of Available Water: the inflows in the canals in the study area are routed through the coastal creeks. The flows are routed according to the rules established for each set of creeks (see Flow in 21 Tidal Creeks and Flow in 8 Primary Tidal Creeks above). If the discharge to the Bay is high, then the inflow hydrograph is unaltered: the flow is merely redistributed to the Bay according to the groupings described above. However, if the discharge falls below a specified minimum threshold, then water is taken from the available 120K ac-ft of storage and is used to maintain the discharge at the specified minimum threshold until the incoming discharge increases above the threshold again.

This specified minimum threshold is the same as the minimum flow established above for the 15K ac-ft of additional storage, i.e. 20 ac-ft/day/creek for the 21 creek simulations, and 52.5 ac-ft/day/creek for the 8 creek simulations.

15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water: this configuration functions very much like the 15K ac-ft of additional storage configuration. The difference is that the supplemental water is used to maintain the minimum discharge threshold if the water in the storage basin is completely exhausted. Hence, the outflow is never allowed to drop below the specified minimum threshold value.

Since the storage basin stores the water from all 5 coastal canals, the outflow from the basin to the Bay is distributed evenly among all of the coastal creeks (i.e. 21 tidal creeks, or 8 primary tidal creeks, depending on the scenario).

Figure 7 shows the cumulative inflow hydrographs that result from each of these configurations. Note that the 120K Ac-Ft of available water actually adds to the total volume of inflow, whereas the 15K Ac-Ft of storage merely redistributes the timing of the inflow, storing water during the wet season and releasing it during the dry.

7. The 10^{th} preliminary scenario run is designed to force the model to supply whatever amount of freshwater is needed to maintain a stable mesohaline environment in the Coastal Wetlands study area. The following describes how this was implemented in the model.

Based on conservation of mass principles, an equation has been developed that can be used to prescribe the inflow to Biscayne Bay. The equation is as follows:

$$q_{IN} = \frac{q_{BAY}}{C_{TARGET}}\left(C - C_{TARGET}\right) \qquad (1)$$

Where:

q_{IN}	=	The freshwater inflow, per unit shoreline length (ft2/sec)
q_{BAY}	=	The net contribution of water from the Bay, per unit shoreline length (ft2/sec)
C_{TARGET}	=	The target salinity concentration at a selected near-shore location (ppt)
C	=	The salinity concentration measured in the model at the selected near-shore location (ppt)

This equation is used to prescribe the inflows to the Bay. The C values are measured values at a distance of 100 to 200m from the shoreline. The shoreline is broken into segments that correspond to natural groupings of the coastal creeks. For this scenario, the 21 tidal creek configuration is used. The creeks are divided into 5 separate groups. Each group is assigned a unique location in the near-shore where the salinity is measured. The total inflow for that group is then adjusted to drive the measured salinity towards the target salinity (using Equation 1). The inflow is evenly divided among the all the creeks associated with that group. Figures 8-12 show the groupings and the corresponding near-shore salinity measurement locations.

In order to solve Equation 1, an estimate of the average flux of water from the Bay to the near-shore is required. The following approximate values were obtained by examining model results and field data from the Biscayne Bay Phase 1 study:

Average net velocity towards the near-shore (v)= 0.2 ft/sec

Average depth (d)= 3 ft

q_{BAY} = vd = 0.6 ft^2/sec

Note that this is merely a gross approximation of this flux. It is not necessary to know the exact value of this flux, because the model will be continuously adjusting the inflows to drive the measured salinity toward the target salinity value.

Results

8. Figure 13 is useful for showing the effect of distributing the fresh water inflow amongst 21 tidal creeks and 8 primary tidal creeks. The figure depicts the average Bay salinity from August 97 – October 97 for flow distributed via 3 different mechanisms: the existing canals, the 21 creek configuration, and the 8 creek configuration. Note that distributing the flow to the creeks does indeed tend to spread the fresh water longitudinally along the shoreline. Specifically, the high flow observed in the existing configuration at C-103 is effectively distributed along the shoreline. This results in a more efficient use of the available fresh water, with respect to nearshore habitat restoration goals.

9. The 21 creek configuration is somewhat more efficient at distributing the flow along the shoreline. In most locations the difference is negligible; diffusion in the Bay tends to obscure the difference in salinity impacts at a given location between 1 large creek and several closely spaced smaller creeks. However, there are some locations, such as at the C-103 canal and in the embayment just north of the C-1 canal, where there is no creek in the 8 creek configuration discharging to the Bay. In these locations, the differences between the 2 distribution configurations are the most pronounced.

10. Figures 14-19 are given in order to determine the impacts of the various preliminary scenario inflow configurations on the salinity of the Bay. Figures 14-16 show average salinity plots over 3 separate time intervals: August 97 – October 97, November 97 – May 98, and June 98 – July 98. The analysis was divided up this way because the 97 –98 flow year was atypical with respect to seasonal rainfall and runoff. Specifically, the dry season months (November 97 – May 98) were actually relatively wet, and the later wet season months (June 98 – July 98) were exceptionally dry.

11. Figure 17 shows the percent of time (over the course of 1 year) that the model salinity falls outside of the mesohaline range (here defined as 5 – 20 ppt). Figure 18 shows the maximum continuous time that the salinity is outside of the mesohaline range. The contour interval is from 0 to 28 days, (28 days is an estimate given by Greg Graves, Florida Department of Environmental Protection, of the maximum continuous time that the salinity can be outside of the mesohaline range in a viable estuarine habitat).

12. In Figures 14-18 there are 5 images. They represent values computed for each of 5 preliminary scenario configurations. In each of these figures, the 21 creek configuration simulations have been chosen for demonstration purposes; however, the 8 creek configuration simulations show the same trends as do the 21 creek configuration simulations, and could have been used instead. (see, for example, Figure 19, which shows the similarity of the impacts observed in the 8 creek and 21 creek scenarios for a given fresh water discharge configuration)

13. The 5 preliminary scenario configuration simulations shown in Figures 14 –18 are as follows:

- Existing flows [Ps2]
- 15K ac-ft of additional storage [Ps4]
- 120K ac-ft of available water (85 K is actually utilized) [Ps6]
- 15 ac-ft of additional storage and 120K ac-ft of available water (7K is actually utilized) [Ps8]
- Target nearshore environment [Ps10]

14. For each of these configurations, the preliminary scenario number that corresponds to the run shown is given in brackets. Also, note that, although 120K Ac-Ft of water is available for use in scenarios Ps6 and Ps8, the total volume is not used in the either simulation, due to the rules of operation that govern the simulations. The actual amount utilized in each simulation is given in parenthesis.

15. By examining these images, it can be seen that the scenarios where additional water is supplied to the Bay show the most promise in yielding a viable estuarine habitat. This tendency can be most readily observed in Figure 18. The reason for this is that the additional water is supplied during the dry season, when it is needed most. If this water is not available, the salinity quickly exceeds the mesohaline limit of 20 ppt.

16. The scenarios with 15K ac-ft of available storage do permit some fresh water to be stored during the wet season and released during the dry. However, the storage volume alone is not sufficient to store the amount of water needed to maintain mesohaline salinity levels throughout the dry months. At least some supplemental water is necessary to maintain these levels.

17. Figure 20 is identical to Figure 7, except that the cumulative inflow hydrograph resulting from preliminary scenario 10 has been added to the plot. This plot represents an estimate of the minimum volume of fresh water inflow required to maintain mesohaline conditions in the coastal wetlands study area for 1 year. There are several things to note about this plot. First, note that the total volume of water required (517 K ac-ft) exceeds the volume of water available from the original inflow hydrograph (400 K ac-ft) by about 120 K ac-ft. Hence, this additional volume of water is required to maintain mesohaline conditions throughout the study area. Also note that the rate of release that is required is relatively constant. This is due partly to the fact that the Bay tends to buffer the variability of the inflow, and hence the rate at which water is required to maintain the desired conditions is mostly a function of such slowly varying trends as seasonally averaged ocean salinity concentrations and seasonally averaged wind speed and direction.

18. Figure 21 is useful for investigating the variability of the fresh water requirements for each of the 5 natural groupings of creeks that are investigated in preliminary scenario 10. The figure shows the average daily volume of fresh water required for each group, given as the total volume required for that group and as the volume required per creek. The most significant trend observed in this figure is that the volume of water required for each group is inversely proportional to the degree of physical confinement at each group location, as dictated by the shoreline morphology. So, for example, the volume of water required for group 3, which is 1

creek discharging into a well-confined embayment, is only about 13 ac-ft/day. However, the volume of water required for group 4, which discharges to a region of the shoreline directly influenced by currents in the Bay, is about 545 ac-ft/day.

19. Another way to state this phenomenon is that the volume of fresh water required for a given location is inversely proportional to the residence time for that location. Hence, if the required volume of water needed for restoration of the entire coastal wetlands study area is unavailable, a targeted restoration effort could be designed to focus on regions that require the least volume of water to achieve restoration. Alternatively, the nearshore residence time of the more exposed regions of the study area could be increased by the construction of groins and other structures.

Conclusions

20. The following general conclusions can be stated for this study. Note again that these runs are intended to be preliminary, and hence the exact quantities required to achieve the desired goals for the Biscayne Bay Coastal Wetlands project should not be taken from this report. Rather, these runs are intended for use as guidance for the selection of the final alternatives to be examined in future final scenario runs.

- The 21 creek configuration is slightly more efficient at distributing the flow along the shoreline than is the 8 creek configuration, but the observed salinity trends are the same for both configurations. The most pronounced differences are observed in confined locations where the 21 creek configuration has a discharge location and the 8 creek configuration does not.

- Scenarios where additional water is supplied to the Bay show the most promise in yielding a viable estuarine habitat.

- The scenarios with 15K ac-ft of available storage do permit some fresh water to be stored during the wet season and released during the dry. However, the storage volume alone is not sufficient to store the amount of water needed to maintain mesohaline salinity levels throughout the dry months. At least some supplemental water is necessary to maintain these levels.

- Approximately 120K ac-ft/yr of additional fresh water is required to maintain mesohaline conditions throughout the study area.

- The required rate of fresh water release is relatively constant. This is due partly to the fact that the Bay tends to buffer the variability of the inflow, and hence the rate at which water is required to maintain the desired conditions is mostly a function of such slowly varying trends as seasonally averaged ocean salinity concentrations and seasonally averaged wind speed and direction.

- The volume of fresh water required for a given location is inversely proportional to the residence time for that location.

- If the required volume of water needed for restoration of the entire coastal wetlands study area is unavailable, a targeted restoration effort could be designed to focus on regions that require the least volume of water to achieve restoration. Alternatively, the nearshore residence time of the more exposed regions of the study area could be modified by the construction of groins and other structures.

References

Brown, G. L., McAdory, R. T., Nail, G. H., Sarruff, M. S., Berger, R. C., and Granat, M. A. (2003) "Development of Two-Dimensional Numerical Model of Hydrodynamics and Salinity for Biscayne Bay, Florida" Technical Report ERDC/CHL TR-03-10, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

King, I.P. (1988) "A Finite Element Model for Three-Dimensional Hydrodynamic Systems" report prepared by Resource Management Associates, Lafayette California, for U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Langevin, C. D. (2000). "Simulation of Ground-Water Discharge to Biscayne Bay, Southeastern Florida" Draft Report, United States Geological Survey, 2000.

Meeder, J., Harlem, P. and Renshaw, A. "Paleoecological Determination of the Western Biscayne Bay Coastal Zone Salinity Regime Prior to Anthropogenic Alterations to the System and Estimates of Freshwater Discharge Required to Reproduce an Estuarine Condition" (2003) Power Point Presentation, Southeastern Environmental Research Center
Florida International University, Miami,

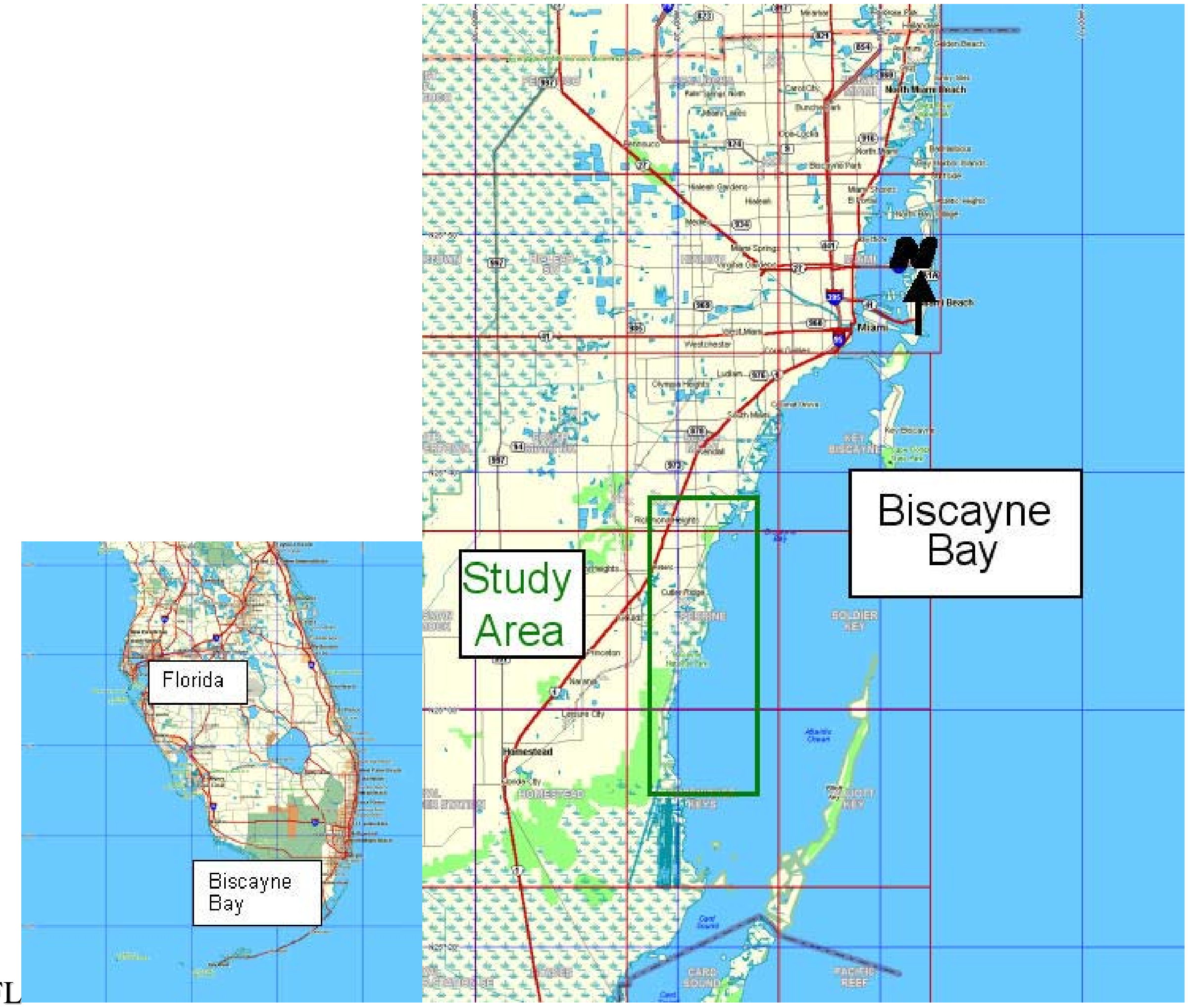

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Figure 1: Location Maps

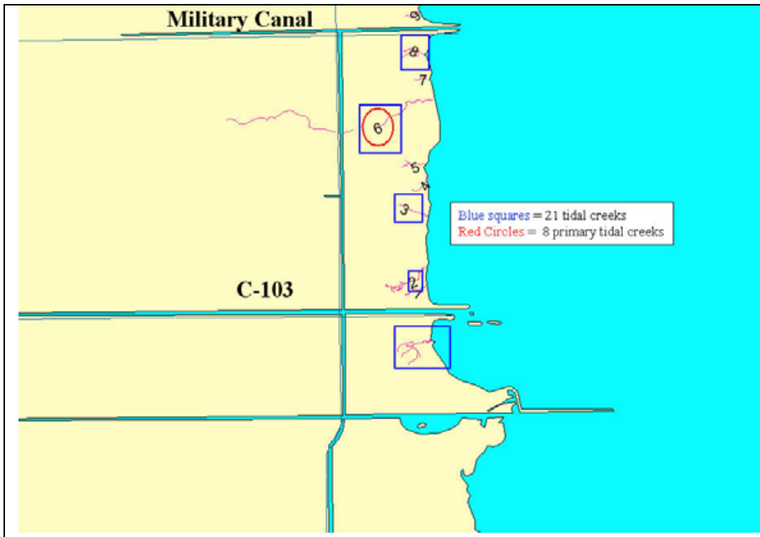


Figure 2: Creek Location Map #1

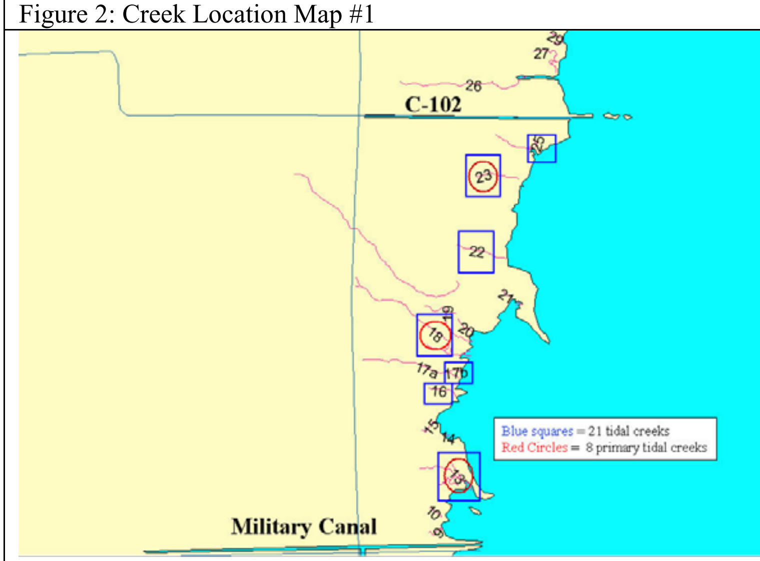


Figure 3: Creek Location Map #2

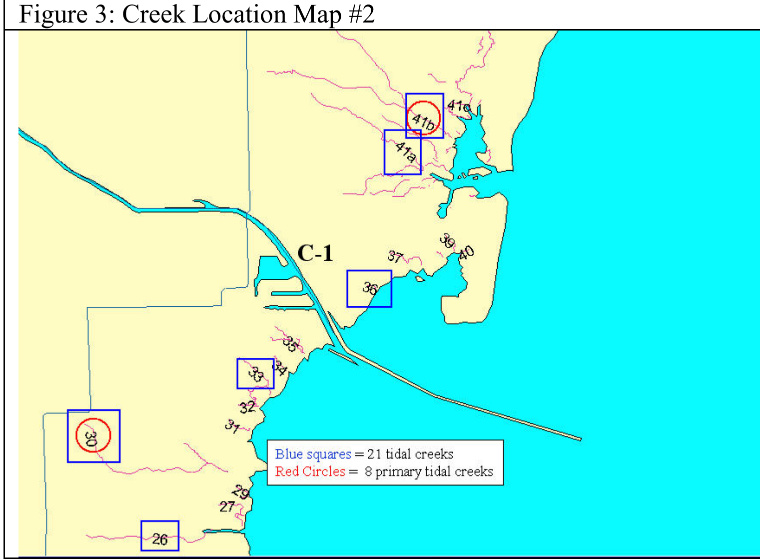


Figure 4: Creek Location Map #3

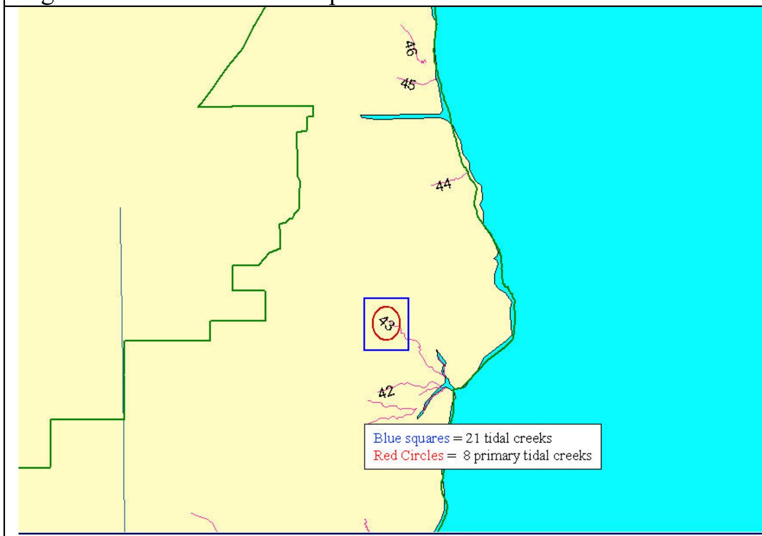


Figure 5: Creek Location Map #4

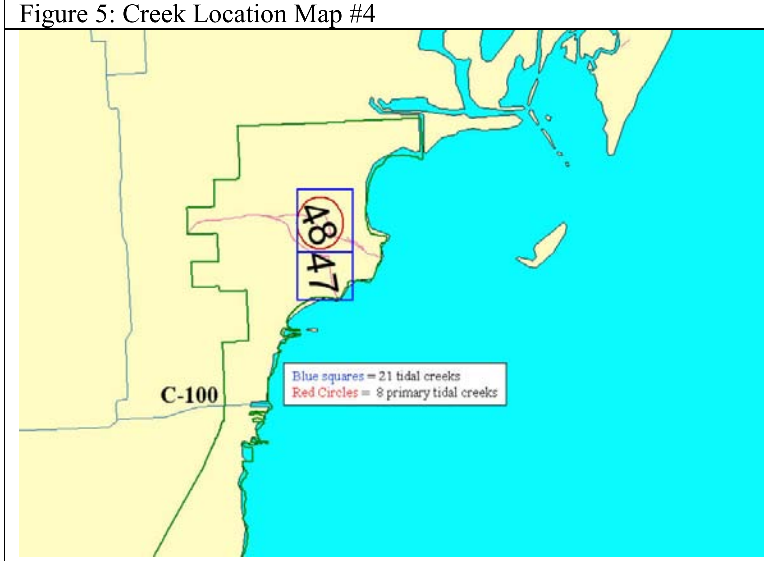


Figure 6: Creek Location Map #5

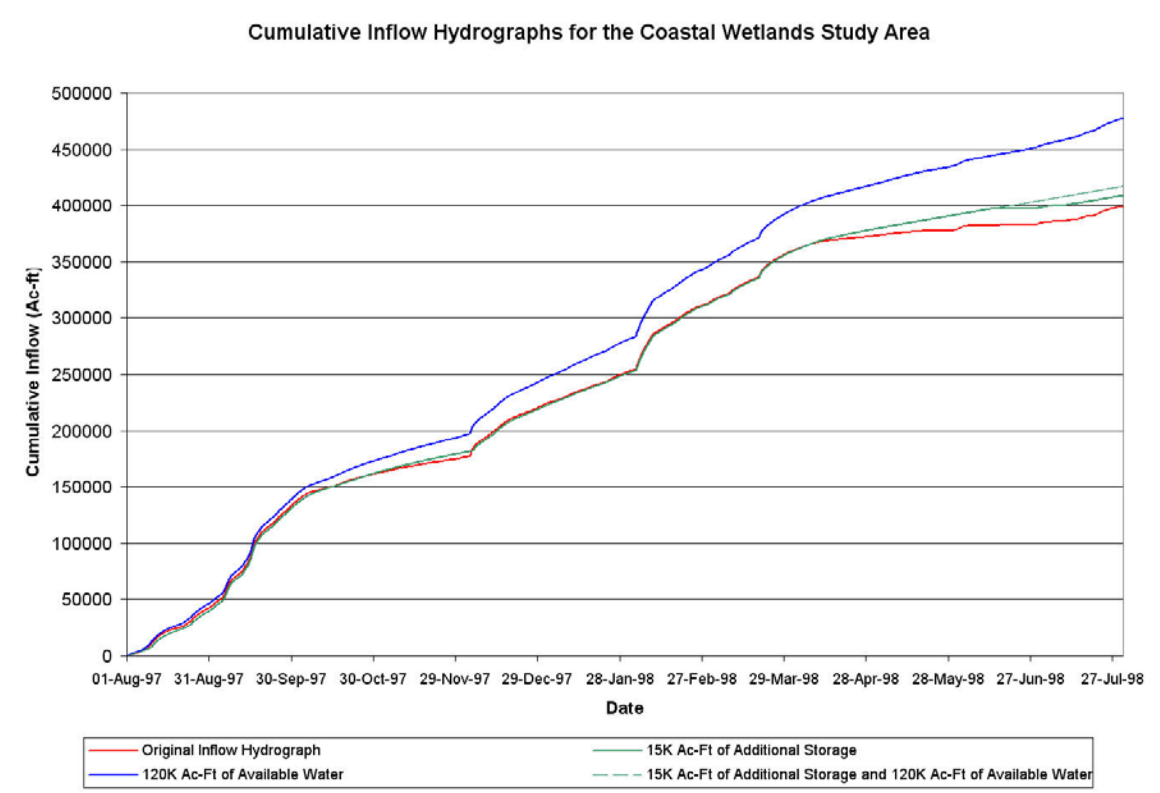


Figure 7: Cumulative Inflow Hydrographs for the Coastal Wetlands Study Area

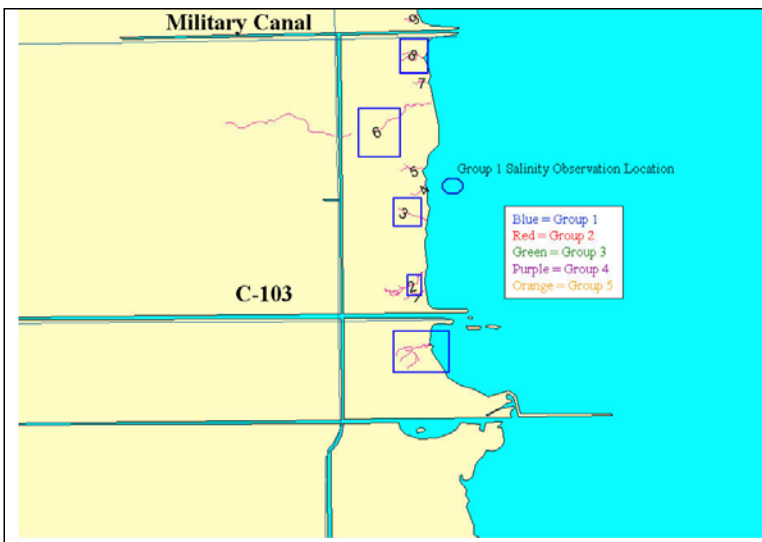


Figure 8: Preliminary Scenario 10 Grouping Map #1

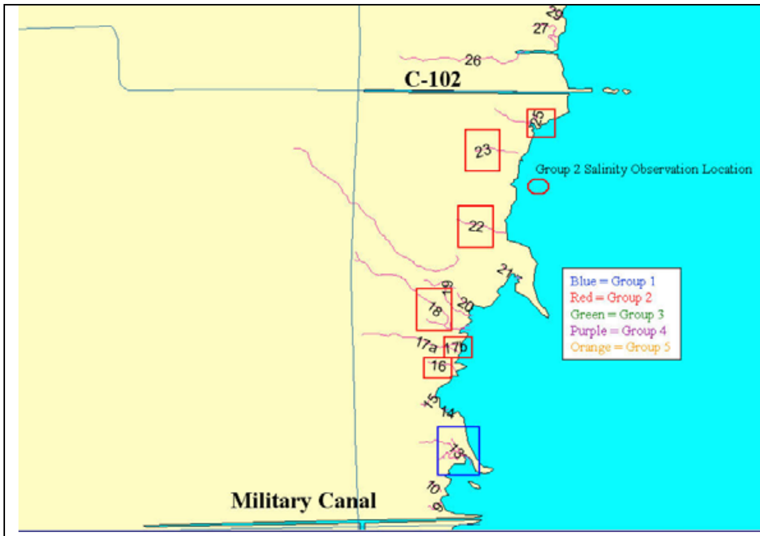


Figure 9: Preliminary Scenario 10 Grouping Map #2

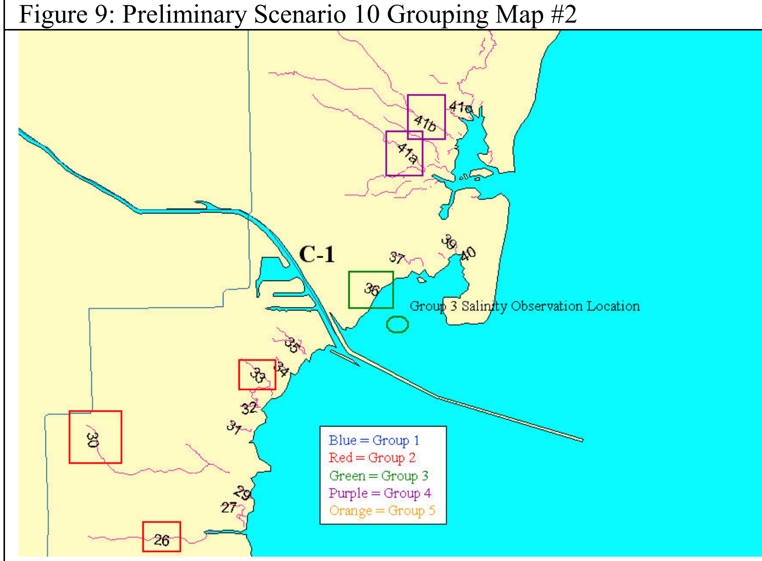


Figure 10: Preliminary Scenario 10 Grouping Map #3

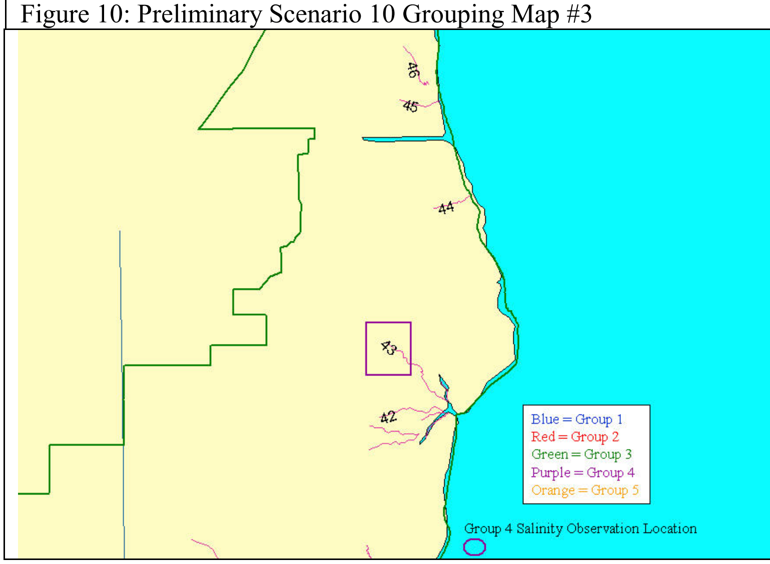


Figure 11: Preliminary Scenario 10 Grouping Map #4

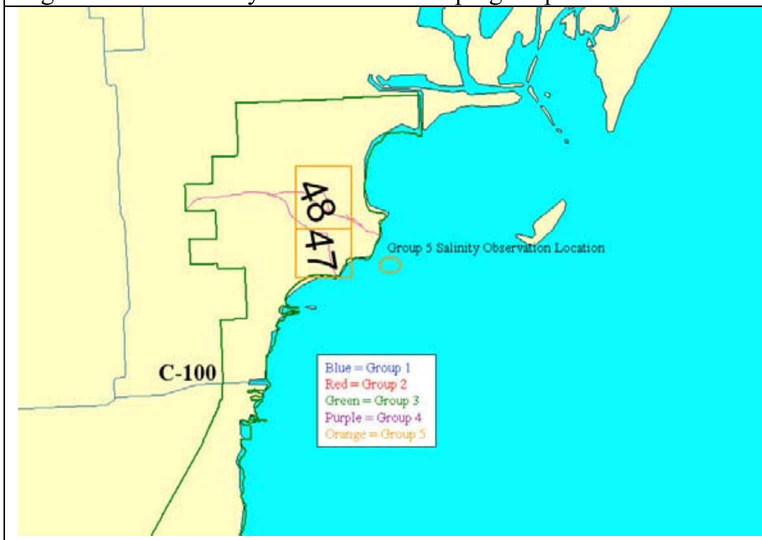
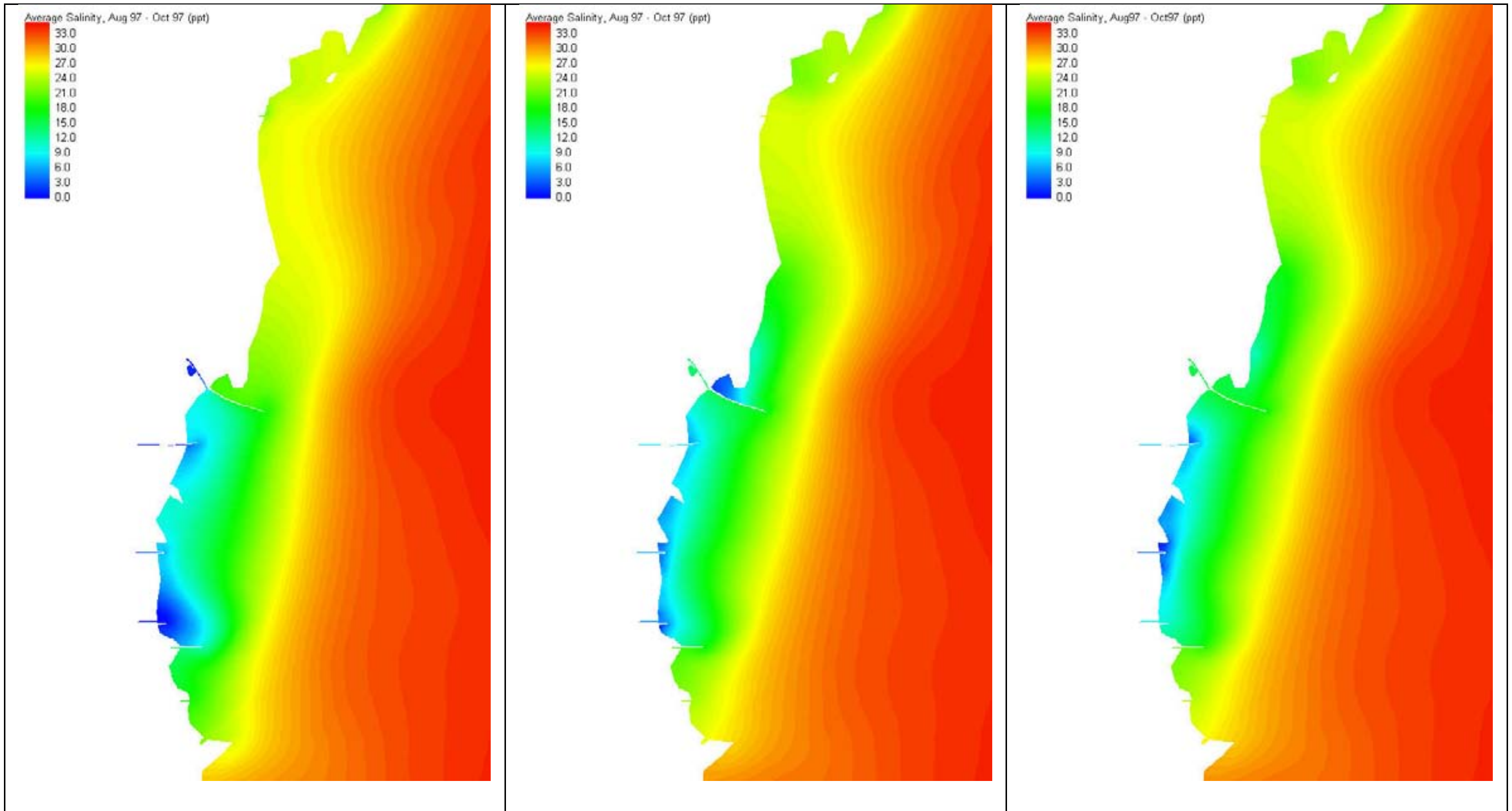
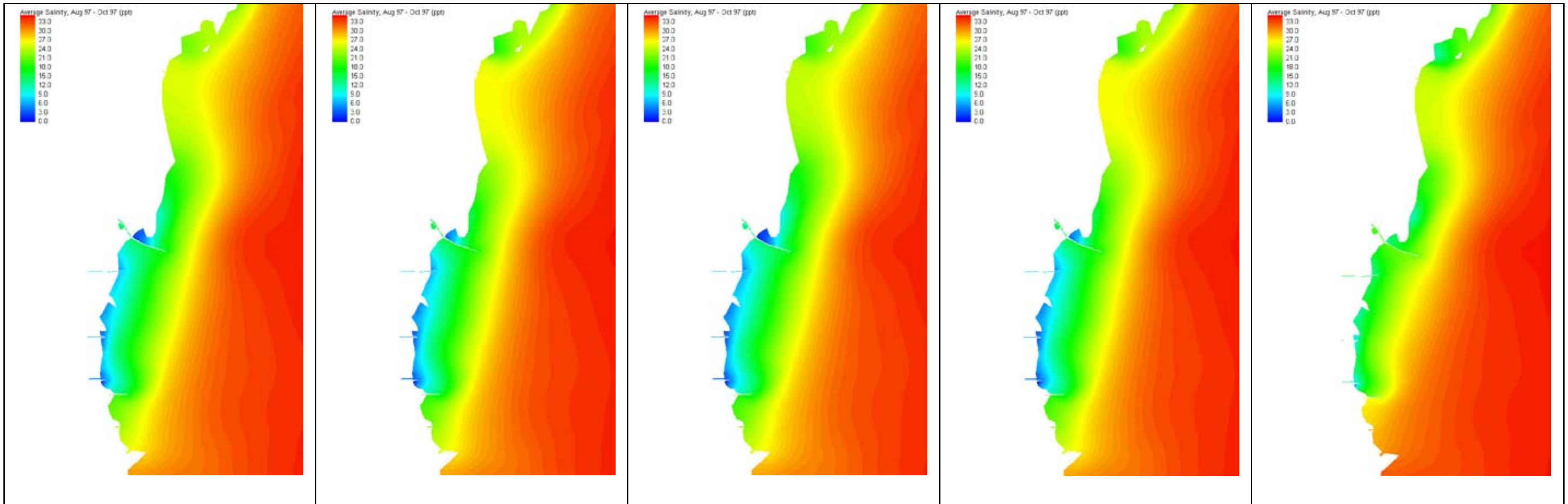


Figure 12: Preliminary Scenario 10 Grouping Map #5



Existing Configuration	21 Creek Configuration	8 Creek Configuration

Figure 13: Inflow Distribution Configuration Comparison: Average Salinity, August 97 – October 97



Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 14: 21 Creek Simulation Comparison: Average Salinity, August 97 – October 97

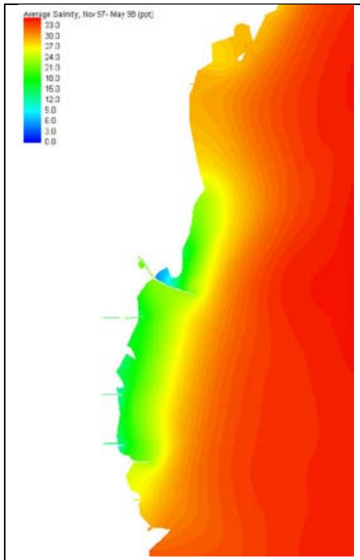
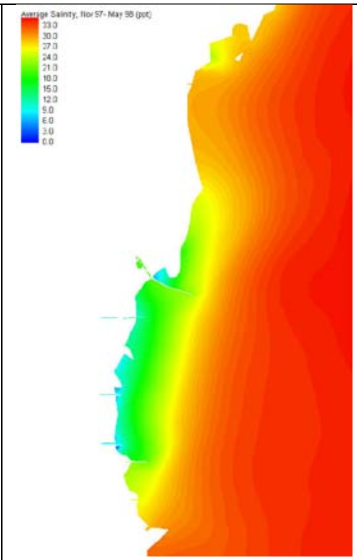
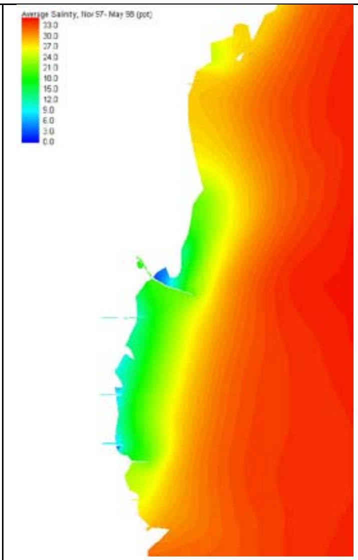
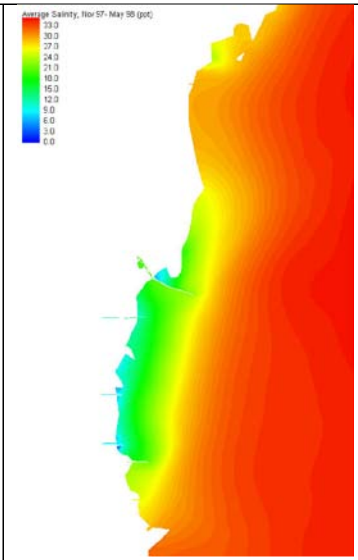
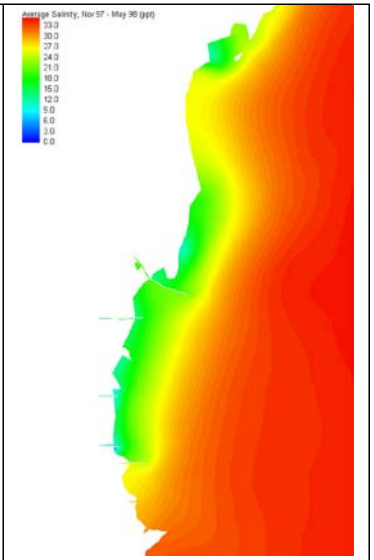
				
Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 15: 21 Creek Simulation Comparison: Average Salinity, November 97 – May 98

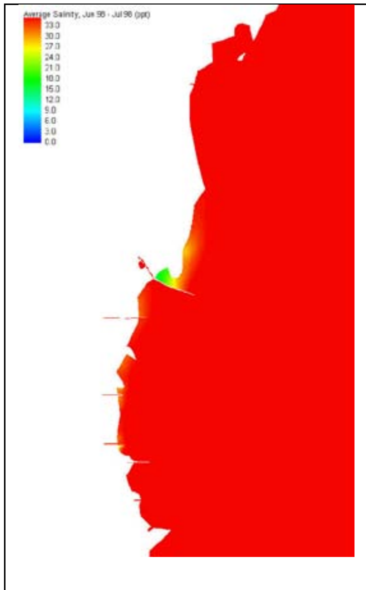
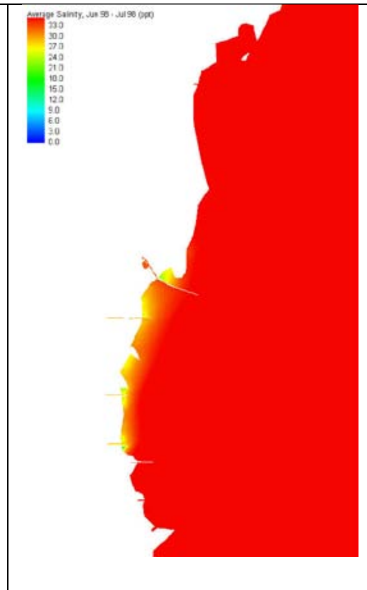
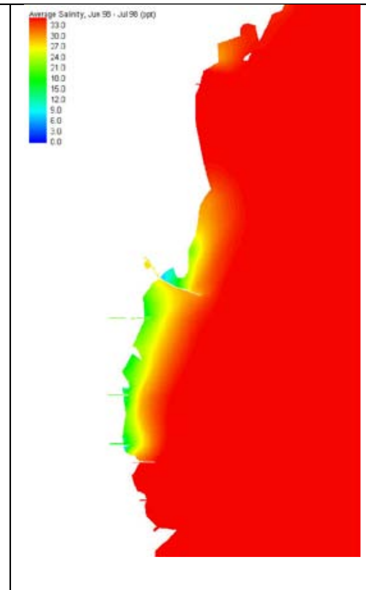
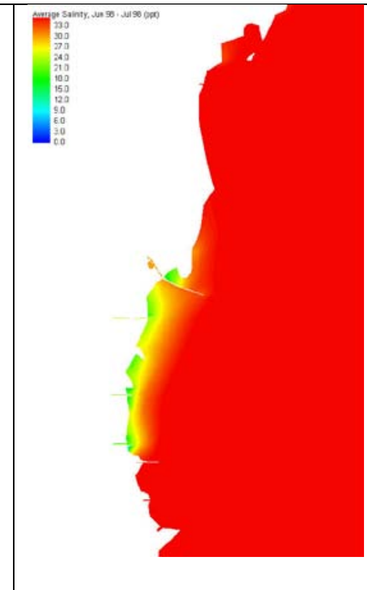
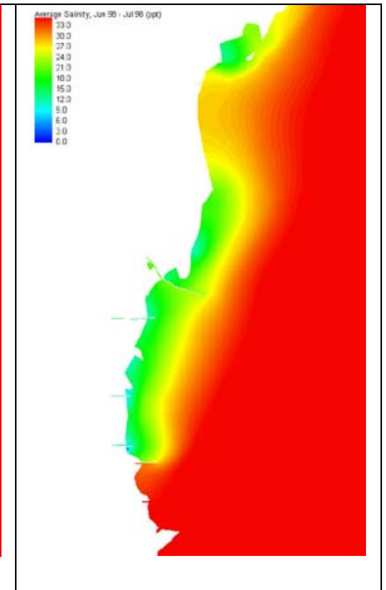
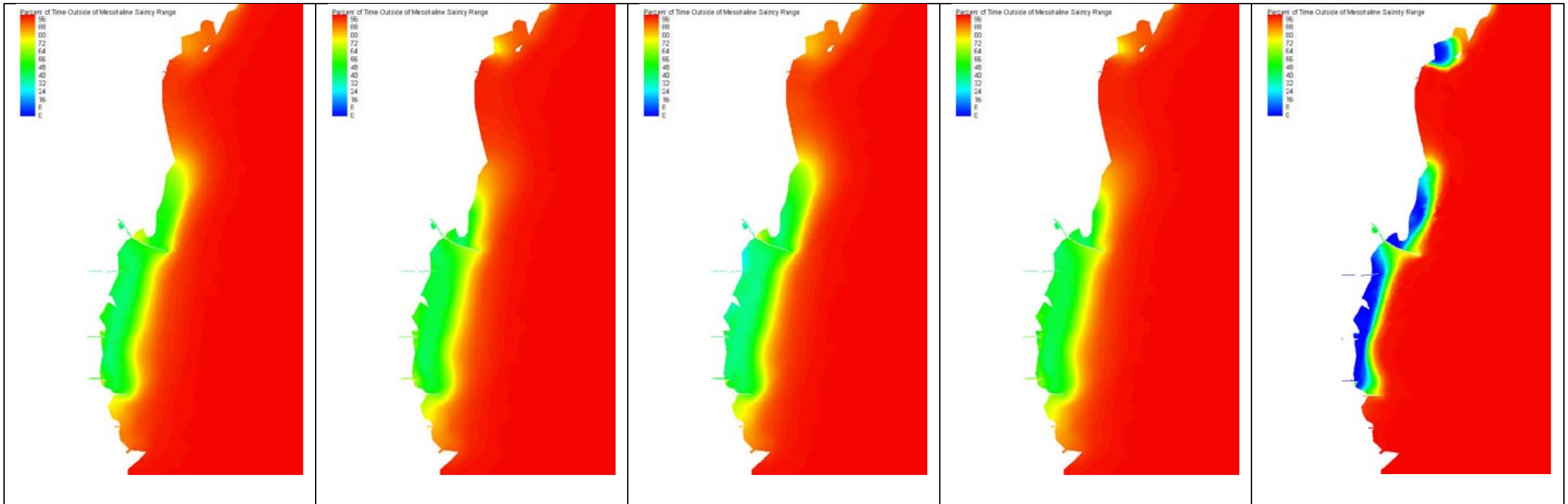
				
Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 16: 21 Creek Simulation Comparison: Average Salinity, June 98 – July 98



Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 17: 21 Creek Simulation Comparison: Percent of Time Outside of Mesohaline Range

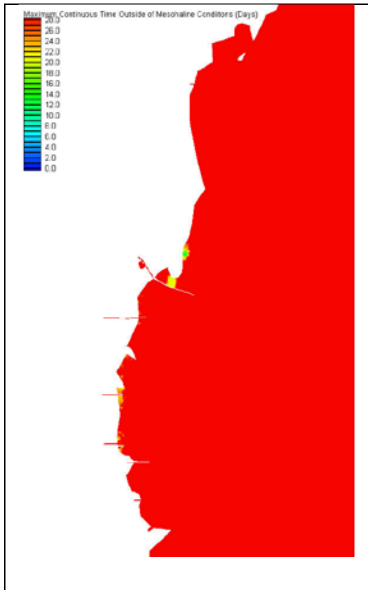
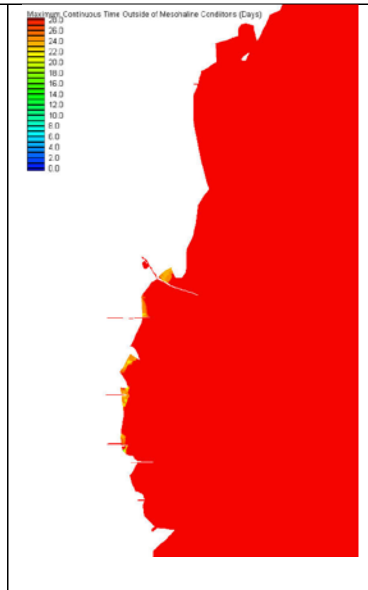
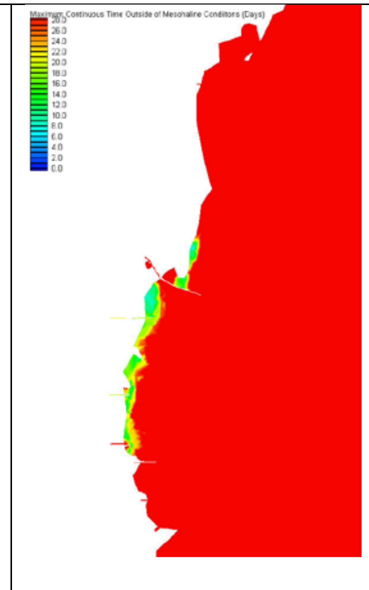
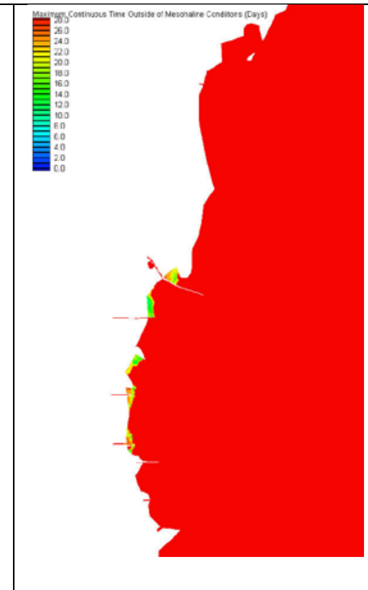
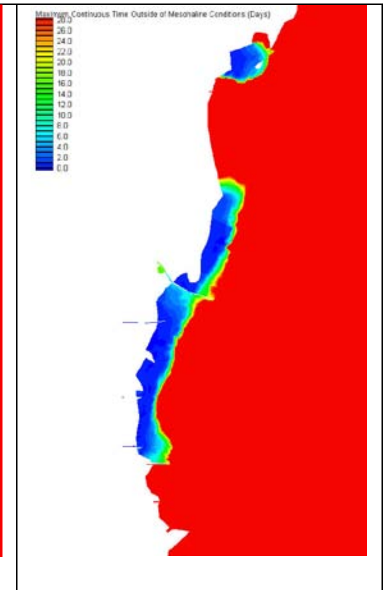
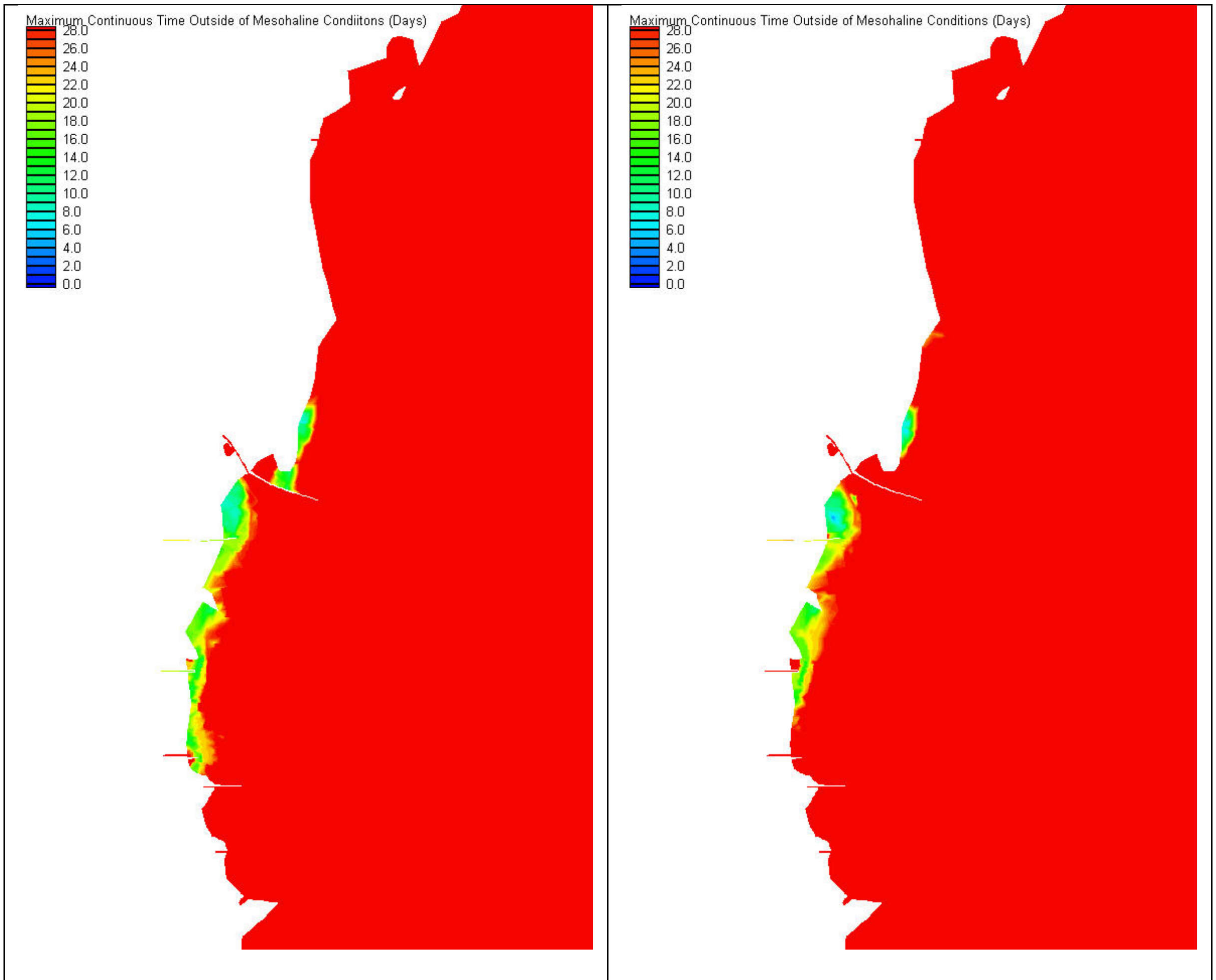
				
Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 18: 21 Creek Simulation Comparison: Maximum Continuous Time Outside of Mesohaline Range (Days)



21 Creek Configuration, 120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	8 Creek Configuration, 120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)

Figure 19: Comparison of 21 Creek Configuration and 8 Creek Configuration: Maximum Continuous Time Outside of Mesohaline Range (Days)

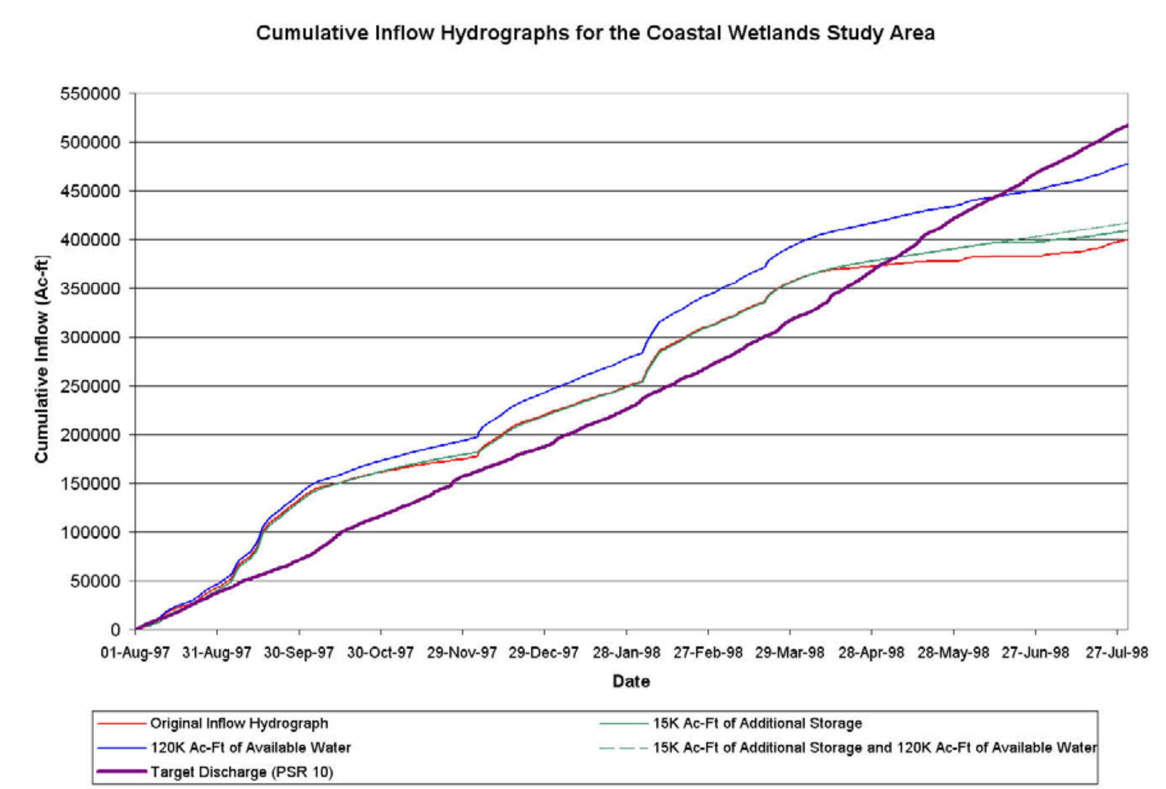


Figure 20: Cumulative Inflow Hydrographs for the Coastal Wetlands Study Area With Target Discharge Shown

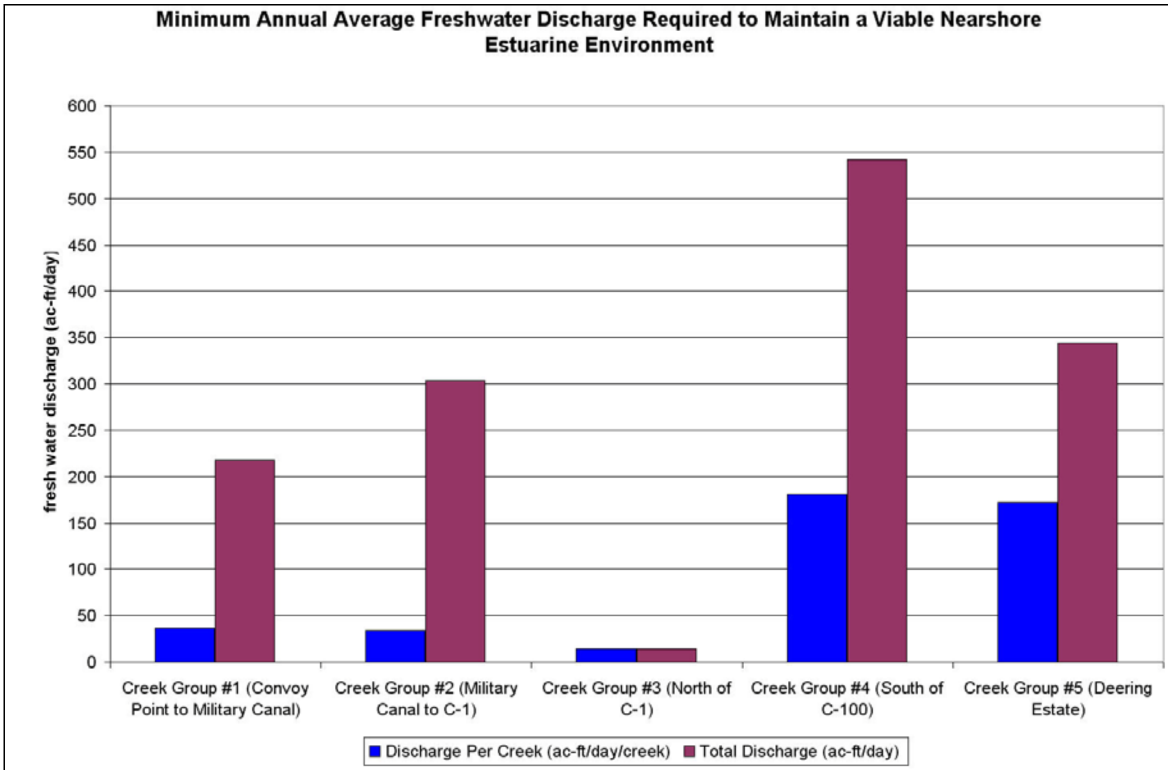


Figure 21: Minimum Annual Average Freshwater Discharge Required to Maintain a Viable Nearshore Estuarine Environment for Each of the 5 Creek Groupings in Preliminary Scenario #10