

# **Biscayne Bay Coastal Wetlands (BBCW) National Park Service (NPS) Alternative Y**

**Charles W. Downer**

**John R. Klochak**

## **Executive Summary**

The National Park Service has prepared an alternative to be considered for the Biscayne Bay Coastal Wetlands project. The alternative was developed through the BBCW Project Delivery Team by Everglades and Biscayne National Park Staff. The NPS alternative was originally conceived as jointly sponsored alternative between the NPS and the Fish and Wildlife Service. This joint alternative has diverged into two alternatives. Like the FWS alternative, the NPS alternative strives to restore an estuarine coastal zone along the western boundary of BBNP by redistributing canal flows through restored and natural wetlands and transverse glades. The NPS alternative goes a step further by attempting to determine the quantity of water needed to fully meet the project goals. The NPS alternative also provides a description of what is thought the best way to distribute the currently available water in a way to maximize the area of a sustained estuarine zone along the BBNP western boundary, roughly between Turkey and Black Points. Thus the park service alternative is a phased approach. The first phase is the redistribution of the current amount of water available to the project to maximize the size of a sustained nearshore estuarine zone. This plan calls for the construction of roughly 10,000 acres of reservoirs/STAs, the re-establishment of roughly 12,000 acres of converted wetlands, and 3,000 of converted glades. The plan also calls for the re-routing water from C100, and C1 canals, to the C-102 canal. With the addition of reuse water, this plan is anticipated to establish a sustained nearshore estuarine zone between Turkey Point and Black Point, and for the area immediately north of the Black Point Jetty. In addition, this plan will eliminate direct canal discharges to the bay and hydrate the natural and restored freshwater wetlands. Ultimately, the alternative calls for the addition of 700 K-acre-ft/yr of water to be delivered to the bay. Utilizing the storage systems outlined above, approximately 1.0 to 1.4 M-acre-ft of water/yr will have to be delivered to the bay to meet the full restoration goals as outlined by the Project Delivery Team. A simple spreadsheet analysis tool was used to size alternative components and compute effects on the bay. The tool is limited in its ability to analyze detailed response from the bay and the alternative must be further analyzed and refined using the full suite of physics-based models.

Record # 18407

## Introduction

The intent of the National Park Service (NPS) sponsored Biscayne Bay Coastal Wetlands (BBCW) project alternative is to establish a nearshore estuarine zone along the western boundary of the bay between C100 and Turkey Point, approximately 30km of shoreline. As per Performance Measure 3.A, developed and adopted by the BBCW Project delivery team (PDT) and described in Appendix A of the Feasibility Scoping Meeting (FSM) document, the zone is identified by the location of the 20 ppt isohaline contour, measured perpendicular to the shore. The goal is that the 20 ppt isohaline will persist 250 m offshore during the period November through May, and 500 m offshore for the period June through October (Attachment A). It should be noted that state mandated minimum flows and levels (MFLs) are currently being developed, and may result in the NPD adopting different NPS salinity goals for the bay.

The intended goal will be met through the implementation of design features which will satisfy the primary goal and also satisfy several complementary and even competing goals of the project. The basic design features include.

| Design Feature                         | Primary PM/Constraint                                                         | Secondary PM/Constraint                                                                                                                                               |
|----------------------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Construction Features</i>           |                                                                               |                                                                                                                                                                       |
| Hydraulic structures on primary canals | 2.A - Reduce canal flows<br>C1 - Flood constraint                             | 1.C - Salinity in coastal areas<br>1.D - Seagrass community<br>3.G - Restore hydrograph<br>3.J - Canal turbidity<br>4.B Enhance FW wetlands                           |
| Storage reservoirs                     | 3.D - Hydrograph shape                                                        | 3.F - Reduce N<br>3.G - Basin response<br>4.B - Enhance FW wetlands                                                                                                   |
| STAs                                   | 3.F - Reduce N<br>3.N - Reduced nutrients<br>3.S - Reduced NO <sub>2</sub> +3 | 3.H - Sediment Toxicity<br>3.J - Canal turbidity<br>3.K - Increased groundwater flow<br>3.O - Reduced P<br>3.Q - Reduced NH <sub>4</sub><br>4.B - Enhance FW wetlands |
| Culverts under Card Sound Road         | 4.B - Enhance FW wetlands                                                     | 2.G - Reduce white zone                                                                                                                                               |
| Levee on western project border        | C1 - Flood constraint                                                         |                                                                                                                                                                       |
| <i>Restoration Features</i>            |                                                                               |                                                                                                                                                                       |
| Restore converted wetlands             | 4.A - Increase wetlands/glades<br>4.B - Enhance freshwater wetlands           |                                                                                                                                                                       |

|                                                            |                                                                   |                                                                                                                  |
|------------------------------------------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Restore natural sloughs and creeks                         | 2.B - Restore freshwater creeks<br>4.A - Increase wetlands/glades | 1.C - Salinity in coastal areas<br>1.D - Seagrass community<br>2.C - Oyster                                      |
| <i>Removal/modification of existing features</i>           |                                                                   |                                                                                                                  |
| L31-E canal, road, levee removal (hydraulically invisible) | 4.B Enhance freshwater wetlands                                   |                                                                                                                  |
| Remove secondary drainage features                         | 4.B Enhance freshwater wetlands                                   |                                                                                                                  |
| FPL road                                                   | 4.B Enhance freshwater wetlands                                   | 2.G - Reduce white zone                                                                                          |
| Tallahassee road                                           | 4.B Enhance freshwater wetlands                                   | 2.G - Reduce white zone                                                                                          |
| <i>Operational Features</i>                                |                                                                   |                                                                                                                  |
| Diversion of canal flows                                   | 3.D - Hydrograph shape                                            | 1.C - Nearshore salinity<br>1.D - Seagrass community<br>3.J - Canal turbidity<br>4.B Enhance freshwater wetlands |
| Inter-basin transfers                                      | 3.D - Hydrograph shape                                            | 3.G - Basin response                                                                                             |
| Provide maintenance water for STAs and wetlands            | 4.B - Enhance FW wetlands                                         | 3.K - Increased groundwater flow                                                                                 |
| Define water needed to meet target                         | 3.A - Nearshore salinity                                          | 3.B - Reduce hypersalinity                                                                                       |

The park service design philosophy is to maximize the use of historical natural features, converted wetlands, glades, tidal creeks, etc., and remove artificial impediments to flow to restore the natural distribution of water in both time and space. To this extent, the restoration of natural features will be maximized. Due to the loss of available storage, or even potential storage, constructed storage features, reservoirs, will be required. To meet water quality requirements treatment will be required. For the purposes of this analysis, Stormwater Treatment Area wetlands (STAs) are specified, but other options (i.e. treatment plants) could be explored. Canal discharges will be diverted into the combination of reservoir, STA, and wetland systems. Water requirements for the STA and wetland areas are determined.

### **Flows Required to Meet Biscayne Bay Estuarine Zone Goals**

A simple, quasi steady state advection/dispersion model was developed help analyze project alternatives for the BBCW. This model is used to estimate the amount of water needed, on a monthly basis, to satisfy the estuarine salinity Performance Measure 3.4, Attachment A. The amount of water is computed on a monthly basis, for the BBCW Alternative Y Regions 2a through 3b, Figure 1. This area extends from approximately C100, below Deering Estate, to just north of Turkey Point, and comprises approximately

18.6 miles of shoreline. Region 1, not included in the analysis, encompasses another 5.8 miles of shoreline, and is exposed to wind and currents, and inclusion of this area would be expected to significantly increase the volume of water required to keep this sub-zone within the required estuarine range of salinities.

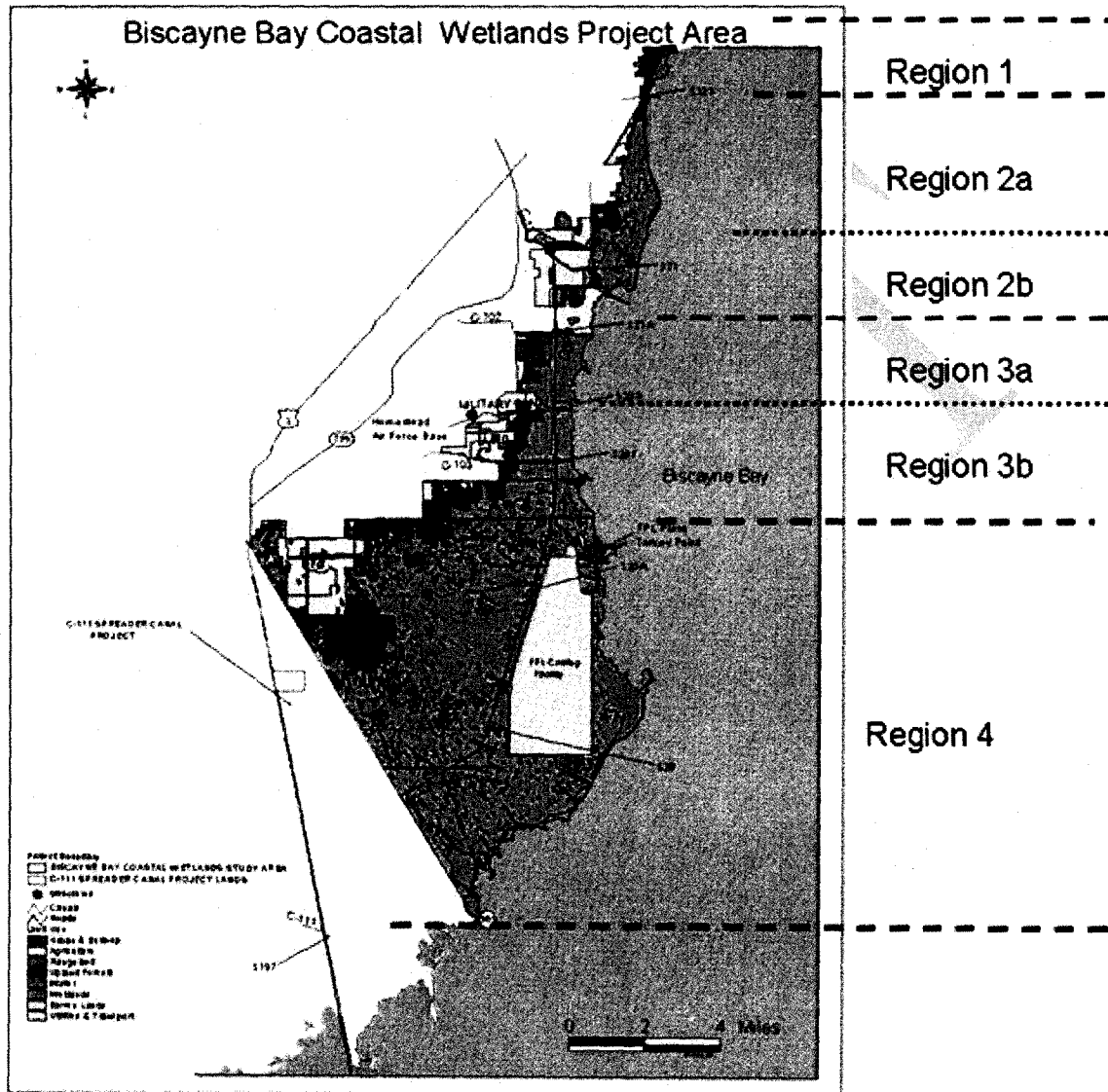


Figure 1 – Sub-regions in BBCW project Alternative Y

Assuming salinity in the region is related to distance from the shoreline and flow, the salinity ( $S$ ) at any distance,  $x$ , from specified boundary salinity ( $S_0$ ) can be estimated from (Thomann and Mueller, 1987):

$$S = S_0 e^{(Ux/E)} \quad (1)$$

where:  $U$  is the velocity in the longitudinal direction (L/T) and  $E$  is the dispersion coefficient ( $L^2/T$ ), which accounts for all forms of mixing, including diffusion, shear, lateral currents, wind, etc.

The dispersion coefficient was estimated using monthly values collected in Biscayne Bay by the Southeast Environmental Research Center (SERC) (Jones and Boyer, 2001), database from 01/01/1990 to 12/31/2004, available from the South Florida Water Management District (SFWMD). Canal data supplied the information needed to compute the velocity,  $U$ . Daily canal data were assembled from SFWMD DBHYDRO database (DBHYDRO, 2004) for structures S21, S21a, S20g, and S123. All data were assembled in support of the Biscayne Bay Alternative Analysis and Screening Tool (BBAAST) (Nuttle, 2005). The dispersion coefficient was calculated by regression of the average salinity values from stations 101, 102, 103, 109, 110, 122, and 123, Figure 2. The station locations are shown in Figure 3.

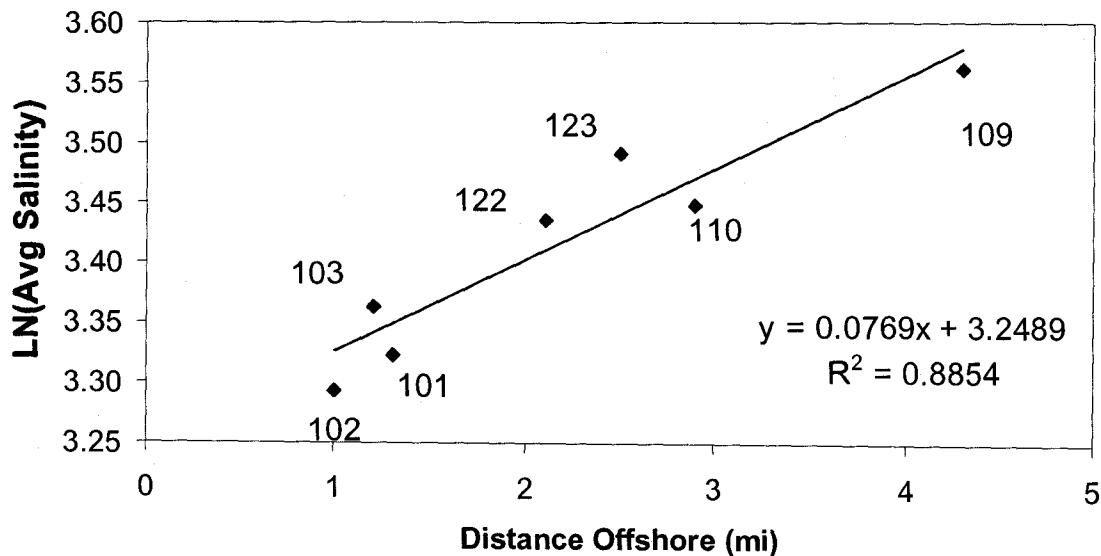


Figure 2 – Regression of average salinity values to compute mid Biscayne Bay dispersion coefficient.

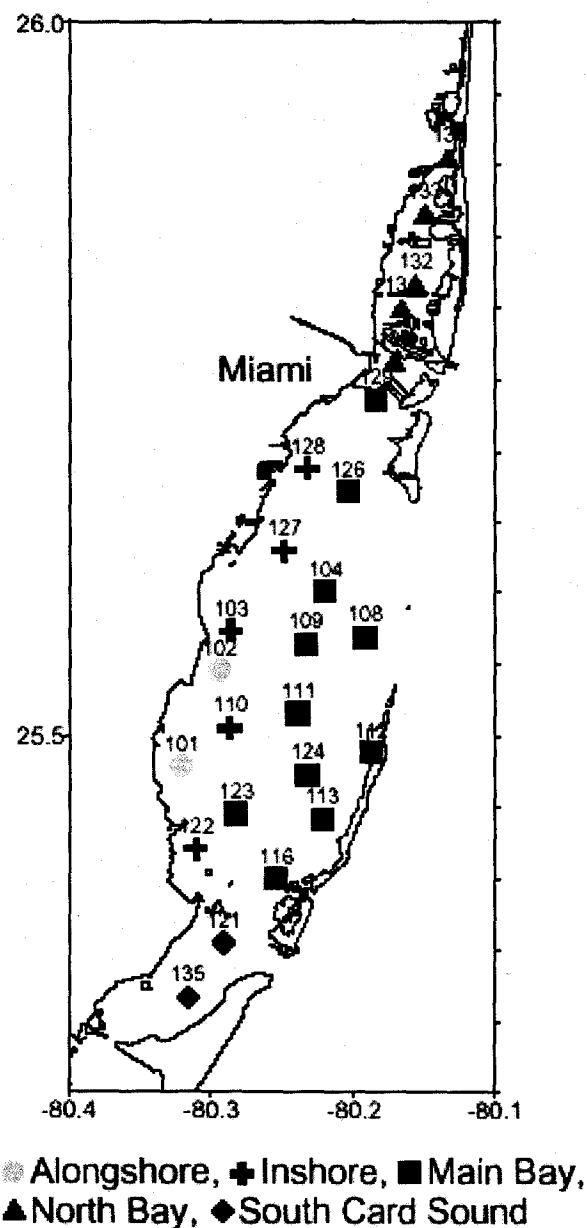


Figure 3 - Monitoring sites for monthly salinity data (from Nuttle, 2005, as modified from Jones and Boyer 2001)

Assuming an average nearshore depth of 3 ft (Richardson, 2003), and an average annual flow of 420 K-acre-ft/yr, 580 cfs, the mean velocity along the 18.5 miles of coast is 0.0322 miles per day (mpd), and the computed dispersion coefficient,  $E$ , is 0.4147 square miles per day (smpd), or  $12.55 \text{ m}^2/\text{s}$ . This value is higher than measured values reported by Wang et al. (1978), who used dye and drogue studies to estimate the dispersion

coefficient near the mouths of Mowry Canal, Black Creek, and Snapper Creek. In their study, they estimated dispersion coefficients of  $5 \text{ m}^2/\text{s}$  for the more open area of Snapper Creek, and  $0.5 \text{ m}^2/\text{s}$  for the area protected within the Black Creek channel. As noted by the authors, these values are subject to conditions, flow, wind, and tides, at the time the tests were conducted.

In application of the model the best fit to observed salinities came from averaging the current monthly and previous monthly flows to compute the velocity  $U$ . In comparison to stations 101, 102, 103, 110, 122, and 123, the statistics, for the prediction of monthly salinity are:

- Root Mean Square Error – 4.07 ppt
- Mean Absolute Error – 3.09 ppt
- Nash Sutcliffe Forecast Efficiency – 46%

Thus, the model correctly predicts salinity in the region approximately 1 mi from the shore, within about 3-4 ppt. Results from Station 101, Figure 4, are typical.

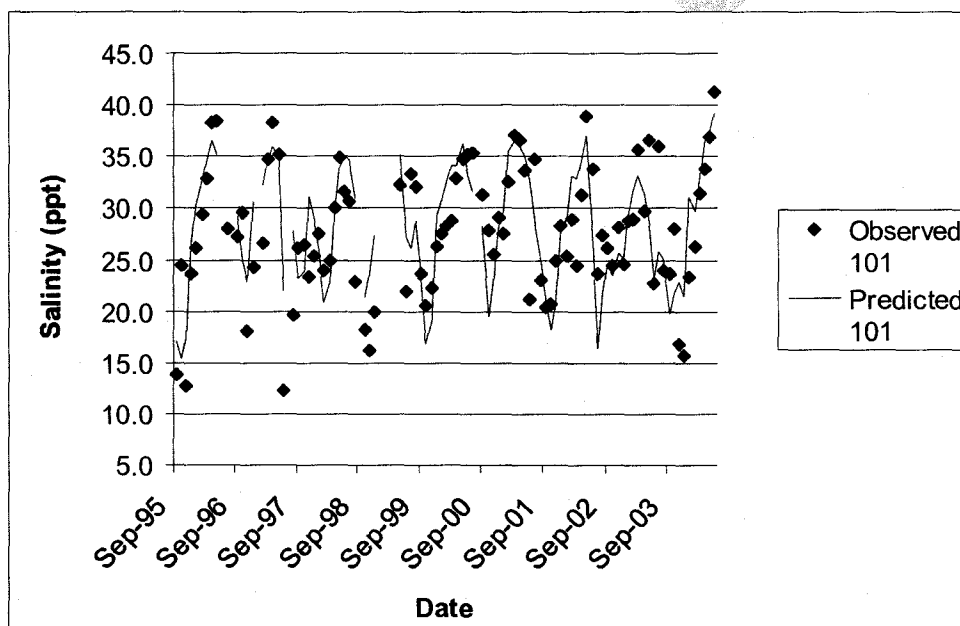


Figure 4 – Observed verses predicted monthly salinities for Station 101

Rearranging Equation 1, the distance from the shoreline, km, to a target salinity ( $S_T$ ) can be computed assuming the measured salinity at Station 109 is an appropriate boundary salinity, located 4.3 miles from the shore, as:

$$x = 1.609 \left[ \frac{E \ln(S_T / S_{109})}{U} - 4.3 \right] \quad (2)$$

with  $E$  in smpd and  $U$  in mpd. The monthly discharge,  $Q_i$ , from all canals, required to meet the target salinity is:

$$Q_i = U_i d L \quad (3)$$

where  $d$  is the depth, 3 feet, and  $L$  is the shoreline length, 18.57 mi. The monthly velocity (mpd) ( $U_i$ ) can be computed using the previous monthly velocity ( $U_{i-1}$ ) as:

$$U_i = 2 \left[ \frac{E \ln(S_T / S_{109})}{x - 4.3} - 0.5 U_{i-1} \right] \quad (4)$$

Using this model, the average annual discharge required to meet the target salinities outlined in PM 3.4 is 763 K-acre-ft/yr. The discharge for the period simulated is shown in Figure 5.

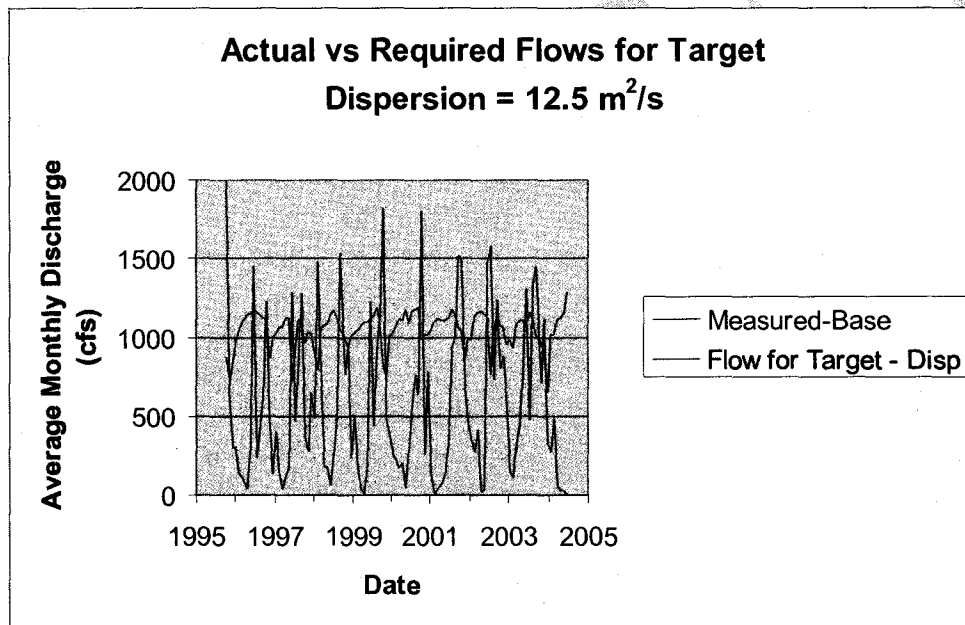


Figure 5 – Measured verses required discharges to meet salinity target for PM 3.4.

Reducing the dispersion coefficient reduces the amount of water required to meet the target. A value of 5 m<sup>2</sup>/s results in 310 K-acre-ft/yr, Figure 6. Reducing the dispersion target to 0.5 m<sup>2</sup>/s results in only 40 K-acre-ft/yr being required, Figure 7.

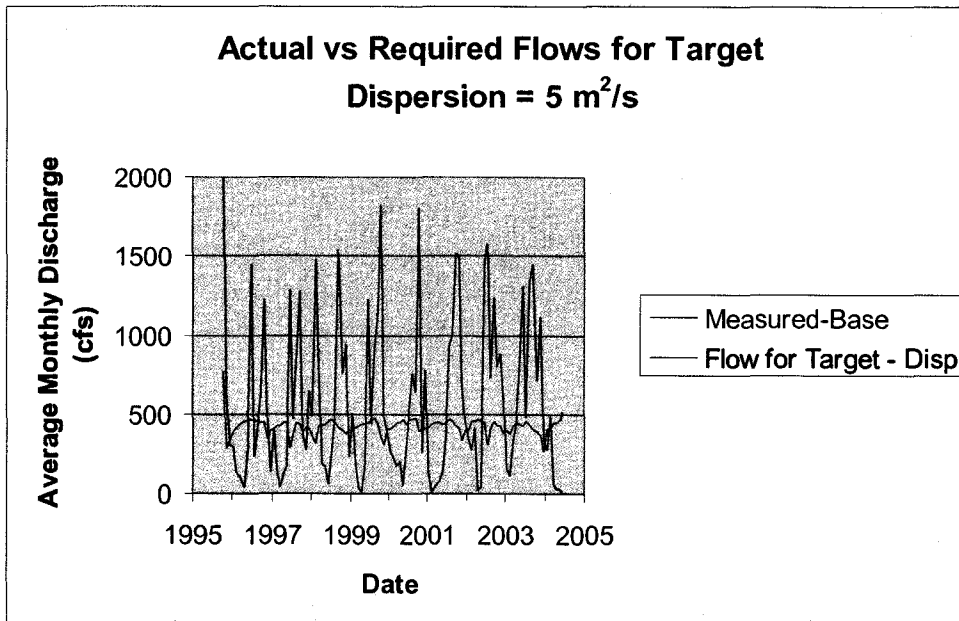


Figure 6 – Observed versus required flow to meet salinity target PM 3.4 with a dispersion coefficient of 5 m<sup>2</sup>/s.

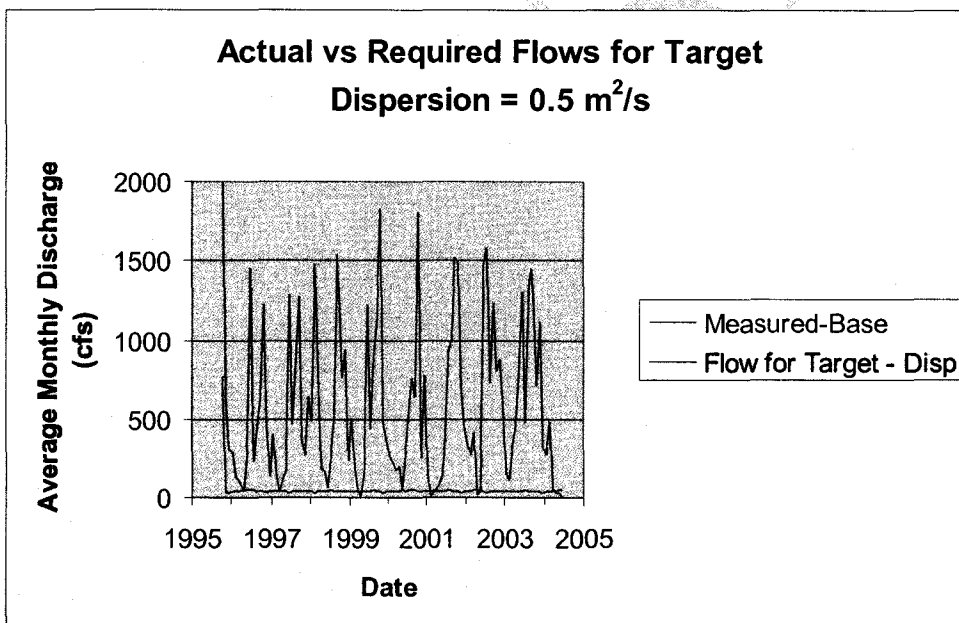


Figure 7 – Observed versus required flow to meet salinity target PM 3.4 with a dispersion coefficient of 0.5 m<sup>2</sup>/s.

Adjusting this figure to include Region 1 would require approximately 1 M-acre-ft/yr. It is likely that the actual amount of water required to meet PM 3.4 for Regions 2b through 3b is somewhat less than the estimated 762 K-acre-ft/yr. Additional water would be required in order to maintain wetland hydration in Region 4. The assumptions in the

simple estuary model that: 1) a substantial increase in flows to the bay does not reduce the salinity at Station 109; along with 2) the dispersion coefficient most suitable in the 1-4 mile offshore range is also best for the nearer shore areas are conservative, and the number can be viewed as an upper bound on the amount of water required achieve the PM 3.4 for regions 2b-3b. For comparison Brown (Richardson, 2003) used the TABS-MDS hydrodynamic model to estimate the amount of water needed to establish a nearshore estuarine zone of 100-200m in the same region of the bay, Areas 1-3. His analysis resulted in an estimated 517 K-acre-ft to meet the target used in that modeling effort. It should be noted that the salinity regime was not the same as the one now specified for PM 3.4. Table 1 summarizes estimates of current, historic, and flows required for restoration from a variety of sources and methods. Moreover, according to discussions within the PDT, the currently proposed CERP0 base condition to be used for alternative modeling allocates only 307 K-acre-ft to BBCW. Regardless of the amount of water required, it is clear that to establish a permanent estuarine zone requires a steady flow of water to the bay. Comparing the required flows to the actual flows, Figure 5, clearly shows a large discrepancy between the way the water is currently delivered and the way the water is required.

| Method                            | Estimated Flow<br>K-acre-ft/yr | Regions/Area                | Shoreline Distance<br>(mi) | Source of Calculations/Data   |
|-----------------------------------|--------------------------------|-----------------------------|----------------------------|-------------------------------|
| Measured, 1991-2004               | 427                            | S123, S20f, S20g, S21       | 24.34                      | DBHYDRO, 2004                 |
| Dispersion Modeling to Meet PM3.4 | 763                            | 2a-3b                       | 18.57                      | Downer, 2005<br>Nuttall, 2005 |
| TABS Modeling*                    | 540                            | 1-3b                        | 24.34                      | Brown, 2003                   |
| BBAAST Modeling to Meet PM3.4**   | 1054-1,366                     | 2a-3b                       | 18.57                      | Nuttall, 2005<br>Downer, 2005 |
| Rainfall from Contributing Area   | 779                            | Miami Canal to Turkey Point | 26                         | Downer, 2005                  |
| Groundwater Seepage               | 800                            | 2a-3b                       | 18.57                      | Downer, 2005<br>Chen, 2004    |
| Groundwater Seepage               | 1,400                          | Miami Canal to Turkey Point | 26                         | Downer, 2005<br>Chen, 2004    |
| Mass Balance to meet PM3.4        | 466                            | 1-3b                        | 24.34                      | Meeder, 2003                  |

Table 1 – Summary of annual flow totals for mid Biscayne Bay

Notes: \* - The TABS modeling did not fully incorporate PM3.4

\*\* - Includes losses due to project storage features, reservoirs, STAs and wetlands.

## **Design of National Park Service Sponsored Alternative (Y)**

As described above, the National Park Service developed Alternative Y with the intent of:

- Maximize suitable nearshore estuarine habitat in as much of the bay as possible utilizing currently available and estimated wastewater reuse water
- Eliminate, or greatly reduce, point canal discharges into the bay
- More evenly distribute flows in both time and space
- Restore and enhance freshwater wetlands
- Develop estimates of freshwater deliveries and storage requirements for the water required to fully meet the project salinity regime as outlined in PM 3.4

The alternative (Figure 8) is developed utilizing an altered version of the BBAAST model (Nuttle, 2005) that incorporates the simple advection-dispersion model described above, on a sub basin basis. This allows the effects of the project to be analyzed on a sub-basin basis. While the currently available amount of water is insufficient to establish a nearshore estuarine zone along the entire project areas, as described by Richardson (2003) there is great potential to establish estuarine zones in selected parts of the bay. The availability of the wastewater reuse water, providing a continuous flow of treated water at a rate of 200 cfs, 144 K-acre-ft/yr, greatly enhances this potential.

The BBAAST model allows users to design or analyze a project alternative by specifying the size and characteristics of storage elements, reservoirs, STAs, and wetlands, for each sub-basin, Figure 1. Measured canal flows for the period 1991 through 2004 are distributed into the storage elements according to the rules defined at the end of this section. Additional water, representing wastewater reuse or other sources of water, can be added to the canal as well. The model calculates the percent of time that the target salinity is met in each basin using the advection-dispersion model, and the domain as a whole using the regression formulation described in attachment B. The model also gives vital information on water budgets, amount of canal water diverted, and treated with STAs. As BBAST is a simple spreadsheet model, a nearly unlimited number of configurations can be investigated rapidly and simply.

Storage elements are used to eliminate harmful canal discharges, treat the canal flow before releasing it to the bay, redistribute water in time and space, smooth out the flows to bay, and hydrate the restored/enhanced wetlands. The alternative is designed to maximize these additional functions, while greatly sacrificing the effects on near shore salinity with the current amount of available water.

The amount of area available to place storage elements is largely controlled by the availability of farmland. The availability of farmland, as determined from SFWMD GIS products, is listed in Table 2. As shown in the table, land is generally available in the southern portion of the study area, Basins 3 and 4, much less available in Basin 2, and generally unavailable in Basin 1. The location of wetland areas, in the form of both enhanced natural wetlands, as well as converted and restored farmlands, was selected by BNP staff. The location, size and shape of the restored glades are estimated from an



orthorectified 1903 US General Lands Office Dade County Map, from Meeder (2003), and from the LIDAR elevation data (Figure 9). The wetland areas were then fixed and represent a water demand in each basin based on the net loss of water from wetland areas as calculated by BBAAST. Subtracting the area of the converted wetlands and the glades west of L31E leaves the approximate amount of land available in each sub-basin to be utilized for additional storage elements, i.e. reservoirs and STAs.



Figure 9 – Location of glades, as determined by LIDAR elevation coverage and a 1903 GLO map.

| Sub-basin    | Available<br>Idle/Farmland | Converted Farmland<br>Wetlands | Glades | Remaining |
|--------------|----------------------------|--------------------------------|--------|-----------|
| 1            | 0                          | 0                              | 0      | 0         |
| 2a/2b border | 287                        | 0                              | 293    | 0         |
| 2b           | 1,670                      | 0                              | 0      | 1,670     |
| 3a           | 2,710                      | 149                            | 776    | 1,785     |
| 3b           | 9,070                      | 2,655                          | 798    | 5,617     |
| 4            | 10,977                     | 9,101                          | 1,261  | 615       |
| Total        | 24,714                     | 11,905                         | 3,128  | 9,678     |

Table 2 – Available areas for sub-basins

As can be seen, the available storage is located in the southern portion of the domain. The available area in southern 2b, 3a and 3b, about 10,000 acres, will be dedicated to providing storage for these basins, i.e. C-102 and C-103.

### Water Routing

As discussed above, the estimated amount of water required to meet the nearshore estuarine salinity target for all sub-areas is greater than 1 M-acre-ft/yr. Given current water levels, 427 K-acre-ft/yr, plus reuse water, 145 K-acre-ft/yr, or 572 K-acre-ft/yr total, is approximately half of the required amount. Spreading this amount of water equally among the project basin will likely result in the establishment of no sustained nearshore estuarine zone. It is therefore proposed that if only 572 K-acre-ft of water is available, then this water be appropriated to maximize the area of nearshore estuarine habitat expected to always meet the requirement of PM 3.4. Due to the location of available storage, along with results of both TABS-MDS and BBAAST modeling, the majority of the water available should be discharged in sub-areas 3a and 3b, with targeted flows in 2b behind the Black Point jetty to establish a small estuarine zone in that region. A minimum of water will be discharged into sub areas 1 and 2a, essentially enough to keep the wetlands hydrated. There will be no estuarine zone established in basins 1 and 2a, with a minimum estuarine zone established in basin 2b. Flows in the C100 and C1 canals will be rerouted to the reservoirs designed for basins 3a and 3b. Either the L31E canal, or other canal, can be used as conveyance of this water. Reuse water will be used to satisfy the wetland demands in sub-basins 1 and 2a. A small portion of the flow in C1, along with reuse water, will be discharged into 2b, with the intent of both hydrating the wetlands and establishing a small estuarine zone behind the Black Point jetty. The remaining canal flows, and reuse water, will be diverted into storage reservoirs in sub areas 3a and 3b. The reservoirs will discharge to either STAs or wetlands, according to the configuration, as described below. Target discharges are approximately 600 and 700 acre-ft/d for areas 3a and 3b, respectively. Excess canal water is discharged to the STA and/or wetlands. Table 3 shows the proposed distribution of water. The WASH123D and RMA models will be used to refine these estimates of flow to ensure that the wetlands stay hydrated and the nearshore estuarine zone is established and maintained.

| Sub-basin | Canal    | Structure | Current Canal Flow<br>% | Reuse<br>cfs | Total Basin Flow<br>K-acre-ft/yr |
|-----------|----------|-----------|-------------------------|--------------|----------------------------------|
| 1         | C100     | S123      | 0                       | 5            | 4                                |
| 2a        | C100     | S123      | 0                       | 15           | 11                               |
| 2b        | C1       | S21       | 0                       | 40           | 30                               |
| 3a        | C102     | S21a      | 300                     | 0            | 258                              |
| 3b        | C103     | S20f      | 100                     | 100          | 272                              |
|           | Military | S20g      | 100                     | 40           |                                  |
| Total     |          |           |                         | 200          | 572                              |

Table 3 – Distribution of flows

## Expected Results

It is expected that NPS Alternative Y will ultimately provide for 100% of targeted estuarine zone along western Biscayne Bay shoreline. This expectation is contingent on the additional water being made available in the future. CSOP and C111 projects are likely sources of water to be provided to BNP. Proper utilization of the water will require additional, off-site, storage to provide for the correct timing of these flows, as described above. Table 4 contrast the required amount of discharge into each basin with the current discharge, and the proposed discharge for Phase 1, current discharge plus reuse water.

| Sub-basin | Required Discharge<br>K-acre-ft/yr | Current Discharge<br>K-acre-ft/yr | Phase 1 – NPS Alt<br>Discharge<br>K-acre-ft/yr |
|-----------|------------------------------------|-----------------------------------|------------------------------------------------|
| 2a        | 188                                | 31                                | 14                                             |
| 2b        | 224                                | 138                               | 30                                             |
| 3a        | 313                                | 86                                | 258                                            |
| 3b        | 327                                | 171                               | 272                                            |
| Total     | 1034                               | 427                               | 572                                            |

Table 4 – Required flows for each basin compared to current and NPS Alt Phase 1

As the amount of water currently available is estimated to be far less than the amount required to meet the project goals, the BBCW project should be developed in phases, with Phase 1 utilizing the amount of water currently considered available to maximize the area that meets PM3.4, along with other project goals. Using all available space for reservoir storage, the following percentages of times that the target is met for each sub-basin, calculated using the advection-dispersion model, and the entire area, calculated using the BBAAST Regression model, are shown in Table 5 below. Although Table 5 indicates that the target salinity will be met approximately 80 percent of the time in 3a and 3b, it is expected that PM3.4 will be met 100% of the time, allowing for the conservative nature of the salinity analysis. This project also results in 100% of canal flows being diverted into either the reservoirs, or wetlands. Water budget for sub-areas 3a and 3b are shown in Figures 10 and 11.

| Region | Baseline            |                   | With Project        |                   |
|--------|---------------------|-------------------|---------------------|-------------------|
|        | Avg. Distance<br>km | meets target<br>% | Avg. Distance<br>km | meets target<br>% |
| 1      | n/a                 | n/a               | n/a                 | n/a               |
| 2a     | 0.10                | 6                 | 0.00                | 0                 |
| 2b     | 0.60                | 29                | 0.00                | 0                 |
| 3a     | 0.23                | 13                | 1.85                | 80                |
| 3b     | 0.71                | 30                | 1.28                | 83                |
| 4      | n/a                 | n/a               | n/a                 | n/a               |
| all    | 0.15                | 11                | 0.15                | 10                |

Table 5 – Expected results for NPS alternative using all available area for reservoirs

If STAs are utilized to treat the canal water, but not the reuse water, the percent of time that the nearshore estuarine goal is met will be reduced because of increased ET and seepage losses. The amount of these losses and resulting effect on meeting the target, as shown in tables 6 and 7 below, depends upon the seepage from the STAs and the fate of this seeped water. Water budgets for sub-basins 3a and 3b are shown in Figures 12 and 13.

As the seepage loss and fate of the seeped water depends on the interaction of the STA with the groundwater system, BBAAST cannot be used to make this calculation. The WASH123D and RMA models must be used to calculate the seepage losses, fate of the seeped water, and the resulting effect on the nearshore salinity. This analysis will be used to determine whether the benefit of nitrogen removal with the STAs justifies any reduction in nearshore salinity benefits.

| Region | Baseline      |              | With Project  |              |
|--------|---------------|--------------|---------------|--------------|
|        | Avg. Distance | meets target | Avg. Distance | meets target |
|        | km            | %            | km            | %            |
| 1      | n/a           | n/a          | n/a           | n/a          |
| 2a     | 0.10          | 6            | 0.00          | 0            |
| 2b     | 0.60          | 29           | 0.00          | 0            |
| 3a     | 0.23          | 13           | 1.38          | 53           |
| 3b     | 0.71          | 30           | 1.03          | 53           |
| 4      | n/a           | n/a          | n/a           | n/a          |
| all    | 0.15          | 11           | 0.14          | 8            |

Table 6 – Expected results for NPS alternative providing for 75% STA treatment of canal water assuming seeped water is lost

| Region | Baseline      |              | With Project  |              |
|--------|---------------|--------------|---------------|--------------|
|        | Avg. Distance | meets target | Avg. Distance | meets target |
|        | km            | %            | km            | %            |
| 1      | n/a           | n/a          | n/a           | n/a          |
| 2a     | 0.10          | 6            | 0.00          | 0            |
| 2b     | 0.60          | 29           | 0.00          | 0            |
| 3a     | 0.23          | 13           | 2.21          | 72           |
| 3b     | 0.71          | 30           | 1.50          | 65           |
| 4      | n/a           | n/a          | n/a           | n/a          |
| all    | 0.15          | 11           | 0.23          | 13           |

Table 7 – Expected results for NPS alternative providing for 75% STA treatment of canal water, assuming seeped water is not lost

Utilizing storage elements increases the amount of water required to meet the ultimate project goal. Estimates of the total amount of water required with the described project elements results are shown in Table 8.

| Scenario                        | Total Flow Required<br>K-Acre-ft/yr | Water Deficit<br>K-Acre-ft/yr |
|---------------------------------|-------------------------------------|-------------------------------|
| All Reservoir                   | 1,034                               | 462                           |
| With STAs and 100% seepage loss | 1,336                               | 764                           |
| With STAs and 0% seepage loss   | 1,216                               | 644                           |

Table 8 – Estimated required flows to reach 100% of target salinities for basins 2 and 3, PM 3.4

The alternative configurations, from BBAAST, with and without STAs are shown in Tables 9 and 10 below.

| Sub-Basin | Canals<br>& Structures | Areas (acres) and Volumes (acre-ft) |         |      |     |          |         |       |
|-----------|------------------------|-------------------------------------|---------|------|-----|----------|---------|-------|
|           |                        | Reservoir                           |         | STA  |     | Wetlands |         |       |
|           |                        | Area                                | Vol     | Area | Vol | Con      | Enhance | Glade |
| 1         | C100/S123              | 0                                   | 0       | 0    |     |          | 50      | 144   |
| 2a        | C100/S123              | 0                                   | 0       | 0    | 0   | 263      | 1,011   | 473   |
| 2b        | C1/S21                 | 0                                   | 0       | 0    | 0   | 139      | 838     | 786   |
| 3a        | C102/S21a              | 5000                                | 50,000  | 0    | 0   | 211      | 310     | 1,637 |
| 3b        | C103/S20f&g            | 5000                                | 50,000  | 0    | 0   | 2000     | 649     | 1,247 |
| 4         | Florida City           | 500                                 | 5,000   | 0    | 0   | 9,216    | 34,646  | 1,261 |
| Totals    |                        | 10,500                              | 105,000 | 0    | 0   | 12,000   | 37,500  | 5,548 |

Table 9 – Alternative Y storage elements with no STAs

| Sub-Basin | Canals<br>& Structures | Areas (acres) and Volumes (acre-ft) |        |       |        |          |         |       |
|-----------|------------------------|-------------------------------------|--------|-------|--------|----------|---------|-------|
|           |                        | Reservoir                           |        | STA   |        | Wetlands |         |       |
|           |                        | Area                                | Vol    | Area  | Vol    | Con      | Enhance | Glade |
| 1         | C100/S123              | 0                                   | 0      | 0     |        |          | 50      | 144   |
| 2a        | C100/S123              | 0                                   | 0      | 0     | 0      | 263      | 1,011   | 473   |
| 2b        | C1/S21                 | 0                                   | 0      | 0     | 0      | 139      | 838     | 786   |
| 3a        | C102/S21a              | 3,000                               | 30,000 | 3,400 | 10,200 | 211      | 310     | 1,637 |
| 3b        | C103/S20f&g            | 2,400                               | 24,000 | 2,200 | 6,600  | 2000     | 649     | 1,247 |
| 4         | Florida City           | 500                                 | 5,000  | 500   | 1,500  | 9,216    | 34,646  | 1,261 |
| Totals    |                        | 5,900                               | 59,000 | 6,100 | 18,300 | 12,000   | 37,500  | 5,548 |

Table 10 – Alternative Y storage elements with STAs included

**Region 3A - Summary Water Budget**  
(fluxes in 1000 acre-feet/year; 1991-2003)

|                        |       |
|------------------------|-------|
| Canal inflow           | 228.3 |
| Rainfall minus evap    | -2.2  |
| Seepage                | -3.2  |
| Makeup*                | 0.3   |
| Storage change         | 3.8   |
| Discharge to Bisc. Bay | 219.3 |

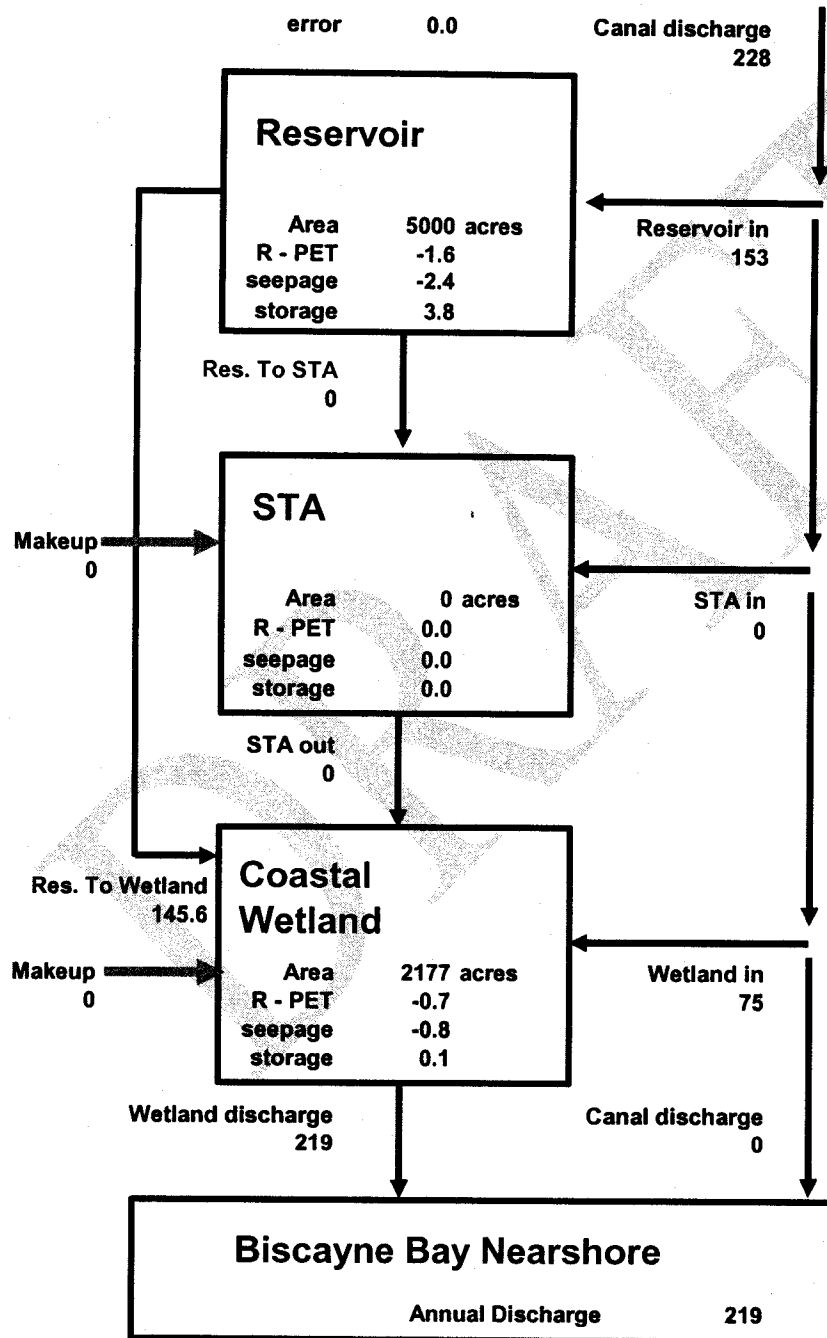


Figure 10 – Sub-area 3a water budget, with no STAs

**Region 3B - Summary Water Budget**  
(fluxes in 1000 acre-feet/year; 1991-2003)

|                        |       |
|------------------------|-------|
| Canal inflow           | 272.5 |
| Rainfall minus evap    | -3.2  |
| Seepage                | -4.4  |
| Makeup*                | 0.0   |
| Storage change         | 3.6   |
| Discharge to Bisc. Bay | 261.4 |

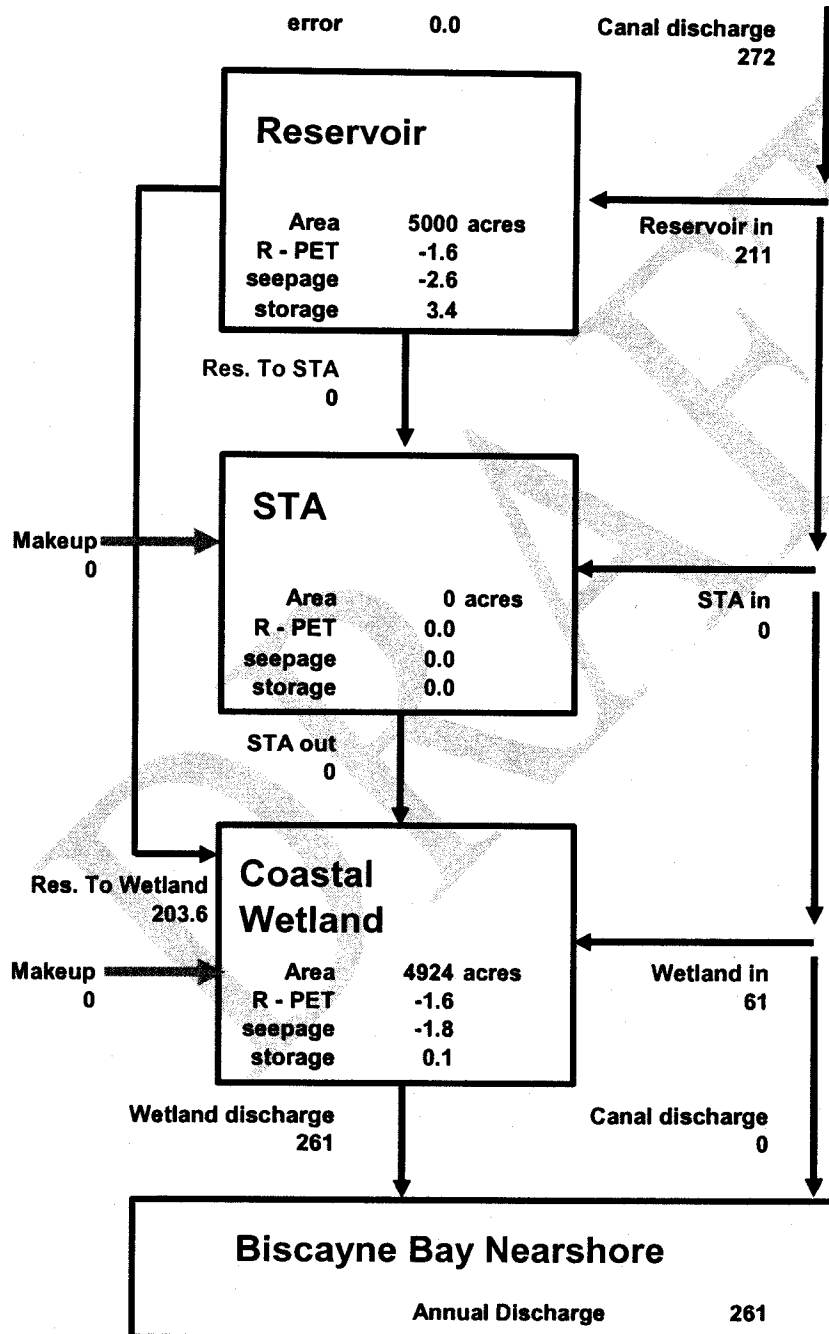


Figure 11 – Sub-area 3b water budget, with no STAs

**Region 3A - Summary Water Budget**  
(fluxes in 1000 acre-feet/year; 1991-2003)

|                        |       |
|------------------------|-------|
| Canal inflow           | 258.4 |
| Rainfall minus evap    | -2.4  |
| Seepage                | -94.5 |
| Makeup*                | 6.0   |
| Storage change         | 1.4   |
| Discharge to Bisc. Bay | 166.1 |

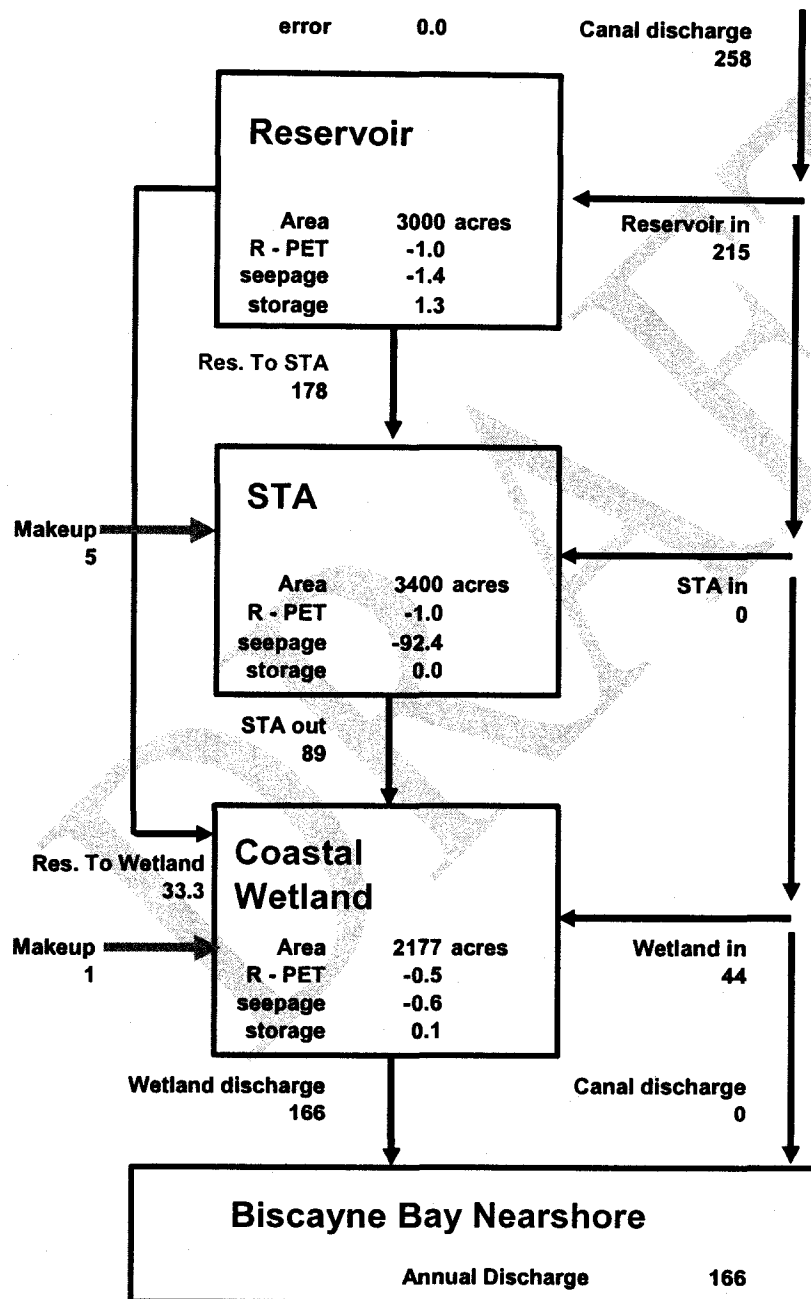


Figure 12 – Sub-area 3a water budget, with STAs

**Region 3B - Summary Water Budget**  
(fluxes in 1000 acre-feet/year; 1991-2003)

|                        |       |
|------------------------|-------|
| Canal inflow           | 272.5 |
| Rainfall minus evap    | -2.9  |
| Seepage                | -65.8 |
| Makeup*                | 0.1   |
| Storage change         | 1.0   |
| Discharge to Bisc. Bay | 202.8 |

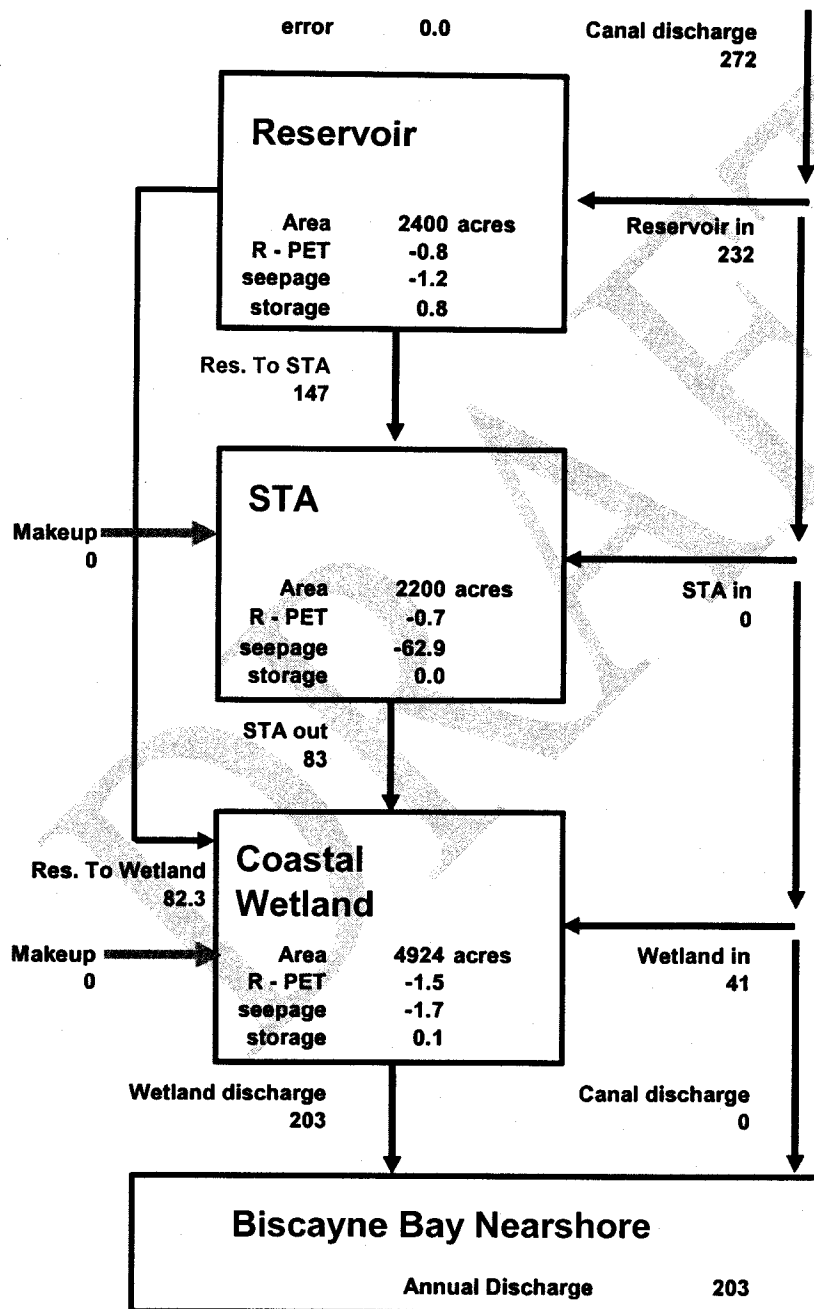


Figure 13 – Sub-area 3b water budget, with STAs

## **Basin By Basin Description**

For this alternative, regions are specified according to location and the inclusion of major canals. The regions include:

- Region 1 - Deering Estate
- Region 2a - C100
- Region 2b - C1
- Region 3a - C102
- Region 3b - C103
- Region 4 - Model lands

Specific features for each region include:

### Sub Region 1

Restore Deering Estate wetland as per Yellow Book description

### Sub Region 2a

Restore 259 acres of converted wetland areas along 2a/2b Border

Restore 134 acres of glades along 2a/2b Border

Divert canal flows (C100 and Saga Bay, S123) to 3a reservoir/STA/wetlands using L31E

Discharge 20 cfs wastewater reuse into historic creeks

Backfill secondary drainage features

### Sub Region 2b

Restore 259 acres of converted wetlands along 2a/2b border

Restore 134 acres of glades along 2a/2b border

Divert canal flows (C-1/S21) to 3a reservoir/STA/wetlands using L31E

Requires hydraulic structures in canal

Hydrate glades/wetlands using 40 cfs of wastewater reuse water

Backfill secondary drainage features

### Sub Region 3a

Construct 5,500 acre STA and reservoir system

Restore 149 acres of converted wetlands

Restore 776 acres of glades west of L31E and 861 acres east of L31E

Divert canal flows (C102/S21a) to reservoir/STA/wetlands

Requires hydraulic structures in canals

Backfill secondary drainage features

Make L31E, levee, & road hydraulically transparent by removal, culverts or other means

Move levee to western side of project features for flood protection and reduction in hydraulic barriers

Hydraulically connect sub-areas 3a and 3b to allow inter-basin transfers of water

#### Sub Region 3b

Construct 5,500 acres STA and reservoir system

Restore new value acres of converted wetlands

Restore 798 acres of glades west of L31E and 582 acres east of L31E

Divert canal flows (C-103/S20f, Military canal/S20G, North canal) to reservoir/STA/wetlands

Requires hydraulic structures in canals

Discharge 140 cfs of wastewater reuse into reservoir/STA/wetlands

Backfill secondary drainage features

L31E, levee, & FP&L road removed or otherwise hydraulically transparent

#### Sub Region 4

Construct 500 acre STA and 200 acre reservoir system

Restore 9101 acres of converted wetlands

Restore Long Slough, 1261 acre glades

Divert Florida City canal flows to reservoir/STA

Requires hydraulic structures in Florida City canal

Backfill secondary drainage features

L31E, levee, & road removed or otherwise hydraulically transparent

Culverts under Card Sound Road

#### **Storage Elements**

##### **STAs**

STAs are designed based upon average current loadings of  $\text{NO}_{2+3}$  for C102 and C103, applied to all canals. Based upon previous analysis, see attached spreadsheet – Size\_of\_STA\_Biscayne.xls, and a decay rate of 50/d (Kadlec, 2005), the required retention time is approximately 27 days, and the hydraulic loading rate (HLR) is approximately 0.11 ft/d. The HLR may be increased if the STA is losing water, primarily to seepage. Increasing the HLR reduces the STA size needed. It was deemed desirable to treat 75% of the total canal flows in each sub-basin. Seepage rates estimates are based on the assumption that the STAs will be located in marl areas. According to a soil classification, marl could be considered clay or silty-clay with vertical hydraulic conductivities assigned as 0.047 and 0.078 ft/d, respectively (Rawls et al., 1993). Other estimates may be obtained from field observations, (Reese and Cunningham, 2000) <0.1 ft/d (horizontal), and from various model applications, such as 2.46 ft/d (vertical) used for soils classified as neither peat nor limestone SICs (Langevin, et al. 2004), 0.24 ft/d (vertical) for surficial materials in WASH123D (Lin et al., 2004), and 1 ft/d (horizontal) for marl in MODBRACH-P-D-M (Evans, 2003). The effects of these different seepage

rates on the required size of STA required to treat 75% of flows for each basin is shown in Figure 14. This STA size is determined based on no reservoir storage. The total area, STA plus reservoir, can be reduced through the use of properly sized reservoirs.

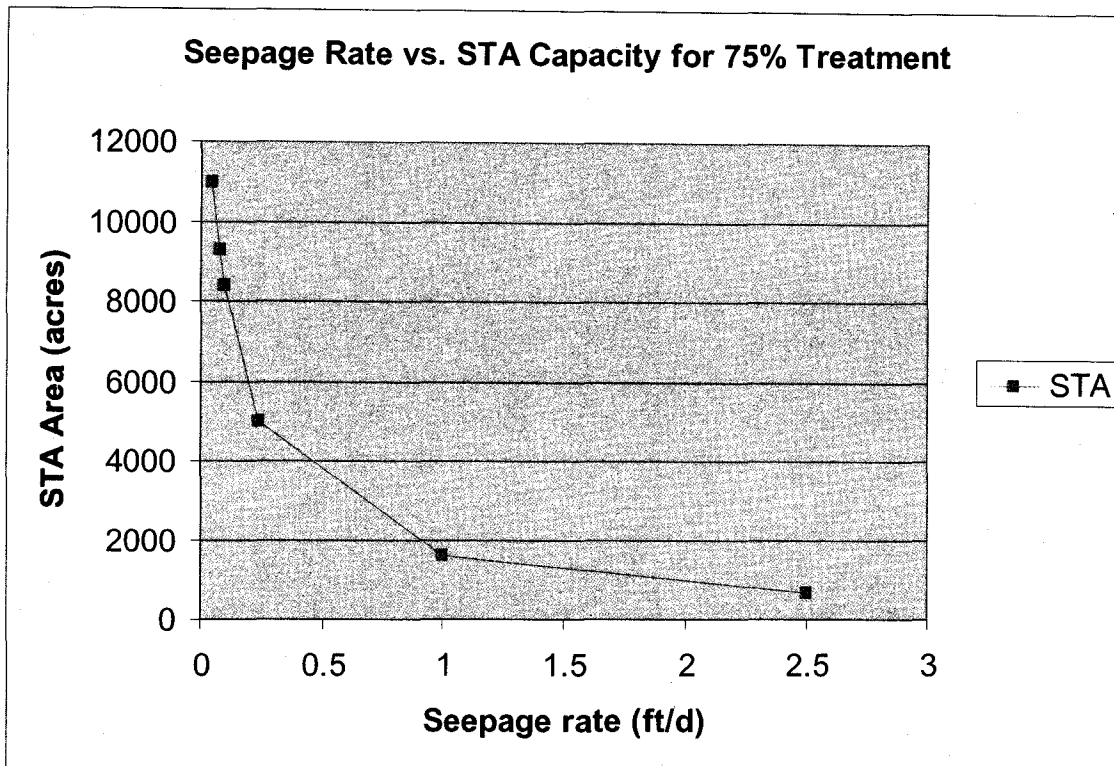


Figure 14 – Required STA size verses seepage rates for 75% treatment

For the purpose of this analysis the rate for silty-clay, 0.0789 ft/d, is assumed appropriate, in relative agreement with most estimated field and model values, assuming 10/1 horizontal/vertical hydraulic conductivity applies.

### Wetlands

Wetlands are designed based on the area, and HLR, and outflow. The outflow is estimated from a overland roughness equation, See Nuttle (2005). The alpha parameter used in the attached spreadsheet is calculated as:

$$\alpha = \frac{1.49}{n} LS^{0.5} \quad (5)$$

where:  $n$  is the Manning friction coefficient,  $L$  is the shoreline length of the wetland, and  $S$  is the overland slope at the coast. The values for each subsection are shown in Table 11. The value of  $n$  is representative of values used in the SICS model (Swain et al., 2004). The slope is the approximate slope estimated from the SFWMM elevations. The BBAAST model is not sensitive to the alpha value.

| Sub-basin | Wetland Shore Length (ft) | Roughness | Slope  | Alpha |
|-----------|---------------------------|-----------|--------|-------|
| 1         | 9,144                     | 0.4       | 0.0002 | 480   |
| 2a        | 21,480                    | 0.4       | 0.0002 | 1131  |
| 2b        | 26,570                    | 0.4       | 0.0002 | 1400  |
| 3a        | 21,495                    | 0.4       | 0.0002 | 1100  |
| 3b        | 28,475                    | 0.4       | 0.0002 | 1500  |

Table 11– Wetland alpha parameter calculations

The HLR rate of the wetlands was adjusted based on the existence or non-existence of STAs to keep the discharge rate to bay approximately 600 cfs for 3a and 700 cfs for 3b, as previously mentioned.

### Description of Storage Design Elements

#### Reservoir

##### Specifications

- active storage volume
- 3/1 side slopes should be subtracted from volume
- pumping in and out
- gains – rainfall
- losses – ET, seepage rate

##### Inputs

- Area
- Maximum depth – 10 feet
- Seepage rate - 0

##### Operating Rules

- Pump into reservoir any time storage is below maximum and water is available in canal
  - Count water that could have been stored but is not available
- Feed water to STA if STA is below minimum level
- Feed water to STA if desired treatment can be met and maximum depth is not exceeded
- Feed water to wetlands if they are dry

#### STA

##### Specifications

- active storage volume
- ignore side slopes in volume
- pumping inflow
- weir outflow
- gains – rainfall
- losses – ET, seepage

##### User Inputs

- Area

- Maximum depth – 3 feet
- Outflow weir height – 2.5 feet
- Outflow weir length – 2000 feet, vary as needed
- Seepage rate – calculated based on surficial materials (calibrated WASH vertical hydraulic conductivity values)
- Desired detention time – 27 days (HLR = 0.11 ft/d without seepage)
- Minimum depth – 0.5 feet

#### Operating Rules

- Feed water to STA if STA is below minimum level
  - First from reservoir
  - Second from canal
  - Third from make-up water
- Feed water to STA if desired treatment can be met
  - First from reservoir
  - Second from canal
- Feed water to wetlands if they are dry
  - Use reservoir first

#### Wetland

##### Specifications

- Parabolic shape
- Overland outflow
- Inflows –
  - STA overflow
  - reservoir pumping
  - canal pumping
- gains – rainfall
- losses
  - ET
  - seepage calculated from surficial materials (calibrated WASH values)

##### User Inputs

- Area
- Maximum depth – 3 feet
- Roughness coefficient – (calibrated WASH values for wetlands)
- Desired HLR

#### Operating Rules

- Put maximum water through wetland
  - Pump excess canal flow through wetland
  - Pump from reservoir to satisfy desired HLR, after satisfying STA demands
- Put water into wetland if is dry
  - First from STA
  - Second from reservoir
  - Third from canal

#### General Discussion

- There is a preference to have the water flow

1. from the canal to the reservoir
  2. from the reservoir to the STA, and
  3. from the STA to the wetlands.
- Direct canal discharges to the bay are to be avoided.
  - The STAs minimum levels must be maintained
  - The STAs should not be flooded (Maximum depth should not be exceeded.)
  - The wetlands should not go completely dry
  - The wetlands should not be flooded (Maximum depth should not be exceeded.)
  - Need to account for amount of water missing to keep STAs and wetlands alive

#### **Needed Output**

1. % Reduction in canal flow for each subarea
2. % Canal flow treated with STA
3. Amount of additional water needed to keep STA and wetlands alive

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## Attachment A – BBCW Estuarine Zone Performance Measure

| Evaluation Criterion Number and Name (PM)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3.A. Nearshore salinity patterns exhibit a broader area and extended duration of mesohaline conditions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Criterion Target and Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <p>In the area from Shoal Point to Turkey Point the targets are as follows:</p> <p>Wet season (June-October) - Create a persistent positive salinity gradient from freshwater wetlands into the bay with an average bottom salinity of 20 ppt in a zone extending 500 meters from shore. Meeting the wet season salinity target requires total wet season flows of 321,000 acre-feet (ac-ft) during the period November-May. This is an average daily flow of 2,104 ac-ft (1,051 cubic feet per second [cfs]).</p> <p>Dry season (November-May) - Create a persistent positive salinity gradient from freshwater wetlands into the bay with an average bottom salinity of 20 ppt in a zone extending 250 meters from shore. Meeting the dry season salinity target requires total dry season flows of 146,000 ac-ft during the period June-October. This is an average daily flow of 687 ac-ft (346 cfs).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Justification and Current Condition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <p>Historically, the Biscayne Bay coastal wetlands and nearshore areas supported a diverse assemblage of estuarine faunal communities, including oyster reefs, estuarine fish and crocodiles. The remains of oyster reefs have been found in association with relic coastal creeks that once dispersed fresh water to the bay through coastal wetlands (Meeder et al. 1999). Prior to construction of the South Dade Conveyance System, estuarine conditions in lower Biscayne Bay were maintained by the flow of fresh water through a series of creeks, as identified through historic photographs, satellite imagery and soil analyses (Meeder et al. 1999). As many as 48 historic creek beds have been identified between Shoal and Convoy points (Meeder et al. 2001). Major creeks drained surface water passing through the transverse glades of the coastal ridge and were distinct from the shorter, more numerous tidal creeks and creeks that originated at local springs. Redfish and other species of sciaenids that rely upon estuarine areas were “abundant at all seasons” during the late Nineteenth Century (Smith 1896). Prior to the early part of the Twentieth Century, Miami-Dade County was at the core of the American crocodile geographic range in the United States (Kushlan and Mazzotti 1989) and coastal wetlands along the western shore of Biscayne Bay provided important habitat.</p> <p>Historic oyster beds are presently inactive due to habitat changes associated with the loss of freshwater discharge into the wetlands through creek systems. Estuarine fishes and shellfish have precipitously declined in abundance due to the loss of estuarine habitat along the bay’s southwestern edge (Serafy et al. 2001). The diversity of estuarine species is very low in southern Biscayne Bay today. Restoration of red drum to the bay through stocking failed due in large part to the release of juveniles into areas that were no longer consistently estuarine (Serafy et al. 1996). Abrupt canal-driven salinity fluctuations have deleteriously affected aquatic plants and fish populations in the western part of the bay (Montague and Ley 1993, Serafy et al. 1997). In southern Biscayne Bay the salinity of marine waters (30-35 parts per thousand [ppt]) downstream of canal water control structures frequently drops 20 ppt within 60 minutes and returns almost as rapidly (Wang et al. 1988). As the system is currently operated, these dramatic salinity fluctuations can occur several times per day during the wet season (June - October) when water is released through control gates. The higher salinities that now characterize the western bay and adjacent wetlands have severely reduced the suitability of this area for juvenile crocodiles,</p> |

which require relatively low salinities for proper growth and development.

Salinity requirements for oysters, estuarine fishes and crocodiles are very similar. For oysters, ideal salinity ranges in South Florida are 5-15 ppt during the wet season and 10-19 ppt during the dry season (J. Meeder, FIU, pers. comm.). Target salinity for estuarine fishes is 5-15 ppt from June through October, with higher salinities during the remainder of the year. Ideal salinity for juvenile crocodiles is 0-20 ppt in the mangrove wetlands and coastal creeks during the wet season and several months into the dry season (approximately June through January; Mazzotti et al. 2002).

The original number of major creek systems in each watershed management unit should be recreated in both general location and estimated freshwater flows between Shoal Point and Turkey Point. It is anticipated that by redirecting canal flows through these creek systems, the positive salinity gradient characteristic of estuaries will be restored, creating fresh and oligohaline wetlands, mesohaline conditions in nearshore waters, and polyhaline conditions in shallow waters beyond. Restoration of mesohaline conditions along the mangrove shoreline of western Biscayne Bay will provide suitable habitat for oysters, new essential estuarine fish habitat, and better quality juvenile crocodile habitat, and will allow estuarine dependent species to complete their life cycles. The sawfish, newly listed by the National Marine Fisheries Service, is one of many estuarine species that may benefit from restoration of mesohaline habitat in nearshore southern Biscayne Bay. Reestablishing a broader, more stable polyhaline zone in shallow waters further offshore should provide more suitable nursery habitat for pink shrimp. Shrimp densities in the northern part of the restoration area (between Shoal Point and Black Point) appear robust (Diaz, pers. comm.). However, shrimp densities in the southern area (between Black and Convoy points) are very low (Diaz, pers. comm.), possibly because of the widely fluctuating salinities that now prevail in the southern area.

#### Evaluation Method/Approach

The method developed by Meeder et al. (2003) was used to determine the freshwater flow required to reestablish and maintain freshwater wetlands and a positive salinity gradient, with an average bottom salinity of 20 ppt, 500 meters into the bay from shore during the wet season and 250 meters into the bay from shore during the dry season:

| 1                                                                  | 2                                                | 3                                                           | 4                                  | 5                                          | 6                 | 7                                            |
|--------------------------------------------------------------------|--------------------------------------------------|-------------------------------------------------------------|------------------------------------|--------------------------------------------|-------------------|----------------------------------------------|
| Scenario<br>(zone width)<br>Wet season: 500 m<br>Dry season: 250 m | Evapo-<br>transpiration<br>replacement<br>volume | Wet Season Daily<br>Input for Full<br>Replacement<br>Volume | Estuarine<br>Zone<br>Creek<br>Flow | Daily Marsh and<br>Estuarine Zone<br>Total | Days in<br>Season | Seasonal<br>Requirement<br>(total acre-feet) |
| Wet season (cfs)                                                   | 67.50                                            | 34.08                                                       | 949                                | 1,051.00                                   |                   |                                              |
| Dry Season (cfs)                                                   | 67.50                                            |                                                             | 279                                | 346.41                                     |                   |                                              |
| Wet season (ac-ft/day)                                             | 134.08                                           | 89.06                                                       | 1,881                              | 2,104.00                                   | 153               | 321,912                                      |
| Dry season (ac-ft/day)                                             | 134.08                                           |                                                             | 588                                | 686.77                                     | 212               | 145,595                                      |

Calculations were based on a combined wetland-stormwater treatment area of 23,618.5 acres, which includes all of the area east of the proposed new spreader system. Note that the upper two rows in the table above are in terms of cfs) and the bottom two rows are in terms of ac-ft per day, except that the last column is in terms of total ac-ft per season. The required total annual flow is 467,507 ac-ft (321,912 + 145,595).

Daily flow requirements were calculated as follows:

Dry season:  $[(Aw + Asta) \times (ET)] + [(SL \times Z \times (E-P) + SL \times Z \times Dm) \times 0.5 \times R]$

Wet season:  $[(Aw + Asta) \times (ET) + (Aw \times Dw + Asta \times Dsta)/WSD] + [SL \times Z \times (E-P) + SL \times Z \times Dm \times 0.5 \times$

R]

where  $A_w$  = wetland area,  $A_{sta}$  = STA area,  $ET$  = daily evapotranspiration,  $D_w$  = wetland depth,  $D_{sta}$  = STA depth,  $WSD$  = number of days in wet season (5 months = 153 days),  $P$  = daily precipitation,  $SL$  = shoreline length,  $Z$  = nearshore mesohaline zone width,  $E$  = daily evaporation,  $D_m$  = outer depth of mesohaline zone,  $R$  = estimated daily exchange rate.

The calculations provide rough estimates. As they are based on several simplifying assumptions, there is some associated uncertainty. The flow estimates used with the salinity targets are similar to those derived by other methods. The seasonal flows correspond well with those determined by Alleman (2003) based on average (across years) observed flows during months in which average (across years) monthly salinities measured in Biscayne Bay produced salinity patterns approximating those specified in the Meeder analysis. His seasonal totals were 248,200 ac-ft for the wet season (based on September) and 137,700 ac-ft for the dry season (based on February). Wet and dry season total volumes in both analyses were based on the number of days from June through October and November through May, respectively. Meeder's estimates are slightly higher than Alleman's primarily because they account for  $ET$  losses in the marshes and STAs (columns 2 and 3 in above table). Without the marshes and STAs, the Meeder figures would be 287,793 ac-ft (a daily average of 1,881 ac-ft, corresponding to 949 cfs) for the 5-month wet season and 124,656 ac-ft (a daily average of 588 ac-ft, corresponding to 279 cfs) for the 7-month dry season (column 4 above). The above flow values used in relation to salinity targets are also supported by recent simulations of the TABS hydrodynamic model.

The required volumes must be diverted into a spread system from the canals discharging into southern Biscayne Bay; therefore, in the evaluation, simulated daily flows at the following structures will be summed to determine whether targets are met: S-123, S-21, S-21A, S-20G and S-20F. Flows should total 321,000 ac-ft in the wet season (June-October) and 146,000 ac-ft in the dry season (November-May). Evaluation will depend upon flows simulated by the 2-by-2 model (SFWMM, Version 5.0) until more accurate models become available. Required volume values have been rounded to reflect estimated degree of precision.

Requested graphic output from 2-by-2 model runs include histograms of the summed daily wet season and dry season flows of the structures (S-123, S-21, S-21A, S-20G and S-20F) compared to the target, as has been produced for other areas of Biscayne Bay and average daily flow by month for the modeled period, with a 95% confidence interval, compared to the target daily flow (column 5 above).

#### Source/Contact Information

Rick Alleman, [ralleman@sfwmd.gov](mailto:ralleman@sfwmd.gov), 11/14/03  
Joan Browder, [j\\_browder@bellsouth.net](mailto:j_browder@bellsouth.net), [joan.brwoder@noaa.gov](mailto:joan.brwoder@noaa.gov)  
Patrick Pitts, [patrick\\_pitts@fws.gov](mailto:patrick_pitts@fws.gov)

#### Comments/Notes

Salinity concentrations should also be reduced in Manatee Bay in a similar fashion, but will not likely be below 20 ppt frequently. Any stable reduction in salinity is believed to improve productivity of targeted species, as long as salinity does not fall below 5 ppt for more than two days.

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