Southern Estuaries Performance Measure

Everglades Water Levels

Last Date Revised: September 2008

Acceptance Status: Accepted

1.0 Desired Restoration Condition

Florida Bay - Provide less abrupt and less extreme decreases in salinity in the northeastern bay. Reduce the frequency, duration, magnitude, and extent of hypersaline conditions throughout the bay. Increase the frequency and extent of lower salinity conditions in the bay. Restoration of timing entails an increase of fresh water flows and water levels that continue after the end of the rainy season. This is associated with restoration of the wetland's function as a hydrologic buffer through re-establishment of historic hydroperiods and hydropatterns to the extent possible (or practicable).

Whitewater Bay, Harney/Shark Rivers, Broad River, Lostmans River, and Chatham River - Increase the frequency and extent of lower salinity conditions in the bay and estuarine rivers. Restoration of timing entails restoration of fresh water flows that continue after the end of the rainy season. This is associated with restoration of fresh water flows to the extent possible (or practicable) that continue after the end of the rainy season and that mimic the historic dry and wet cycle seasonality.

Mangrove Estuary - Lower salinity to oligohaline levels in coastal lakes and basins.

1.1 Predictive Metric and Target

The Natural System Model (NSM) is an attempt to simulate the hydrologic response of a pre-drained Everglades system and provides water levels that are simulations of a predrainage condition. If current management of water within the Everglades system led to hypersaline conditions in Florida Bay, management to NSM will improve the current conditions and may lead to the conditions desired in Florida Bay. However, the paleosalinity studies linking linear regression models to paleoecologic data to-date (Marshall, 2008; Marshall (draft), 2008a; Marshall (draft), 2008b) indicate that pre-drainage salinity concentrations in Florida Bay may have been lower than the levels that are estimated through the use of NSM. Because of this a minimal level of restoration requires achieving NSM water levels at the five primary water level stations—CP, P33, EVER7, P35, and PA8—which is the target for this performance measure. NSM is considered a provisional target; when the paleosalinity studies have been completed and the effects of sea level rise evaluated further the predictive measure and target should be re-evaluated by the Southern Estuaries Sub-team.

1.2 Assessment Parameter and Target

The assessment parameter is salinity as it relates to freshwater water levels within the Everglades system. Achieving the target water levels at the primary water level stations as described herein will increase the probability of lowering salinity in the southern Everglades system.

2.0 Justification

All performance measure development for Florida Bay and surrounding embayments have used relationships generated between salinity at Everglades National Park (ENP) Marine Monitoring Network (MMN) stations and stage data at ENP Physical Monitoring Network (PMN) gauge stations. Initially, the linear and logarithmic regression and correlation coefficients were monthly stage data at gauge station P33 [South Florida Water Management Model (SFWMM) cell Row17Column20] for monthly stage and salinity, with and without a one-month lag between stage and salinity. Linear regressions with a one-month lag between stage and salinity were used to estimate monthly salinity for the Restudy (U.S. Army Corps of Engineers and South Florida Water Management District, 1999) period of record (1965-1995). The regression indicated that stages of 7.3 and 6.3 feet mean sea level (msl) at P33 produced the lower and upper salinity levels, respectively, for Joe Bay, Little Madeira Bay, Terrapin Bay, Garfield Bight and North River Mouth (Table 1).

Table 1. Predicted stage at P33 for the indicated upper and lower salinity values in the coastal embayments of Florida Bay.

Embayment		**Salinity Value (ppt)**	**Gauge Elevation (ft-msl)**
Joe Bay	upper	5	7.0
	lower	15	6.2
Little Madeira Bay	upper	15	7.1
	lower	25	6.3
Terrapin Bay	upper	25	7.1
	lower	35	6.3
Garfield Bight	upper	25	7.3
	lower	35	6.3
North River Mouth	upper	5	7.1
	lower	15	6.2

These elevations at P33 became a priority measure of performance in the Restudy. Stages above 6.3 feet-msl at P33 were used to correspond to reduced frequency of undesirable high salinity events in the coastal basins. A second measure was the number of months during the period of record when stages equal or exceed 7.3 ft-msl at P33. Stages above 7.3 at P33 were used to correspond to an increased frequency of desirable low salinity events in the coastal basins.

In 2002, a revision to the Restudy performance measure was recommended and implemented where mean monthly stages at gauge NP67 in west central Taylor Slough and P33 in central Shark River Sough were used to create relations with salinity in the coastal embayments. It was recommended that NP67 (SFWMM Row7Column22) be used for the relationship to salinity in Joe Bay, Little Madeira Bay, Terrapin Bay, and Garfield Bight and that P33 be used for the relationship to North River Mouth. Comparisons of regressions of salinity as a function of stage were made using no time lags between stage and salinity, one-month lags, and two month lags. For all stations, maximum R-square values were derived from regressions that incorporated one-month lags. The predicted stages at the referenced gauges required to achieve the “threshold” salinity values for each embayment are found in Table 2. Managing NP67 between 2 and 3 ft-msl and P33 between 6.2 and 7.1 ft-msl would achieve the goals of the performance measure.

Table 2. Predicted stage at NP67 and P33 for the indicated upper and lower salinity values in the coastal embayments of Florida Bay.

Embayment		**Salinity Value (ppt)**	**Gauge Elevation (ft-msl)**
Joe Bay Based on NP67	upper	5	2.63
	lower	15	2.04
Little Madeira Bay Based on NP67	upper	15	2.82
	lower	25	2.02
Terrapin Bay Based on NP67	upper	25	2.91
	lower	35	1.92
Garfield Bight Based on NP67	upper	25	2.99
	lower	35	1.97
North River Mouth Based on P33	upper	5	7.1
	lower	15	6.2

In 2004, the first set of multivariate linear regression (MLR) models (equations) (Marshall et al. 2003; 2004) were developed and proposed to be used to relate salinities in coastal embayments to upstream water levels, wind patterns, and sea level variation. This modeling effort utilized ENP MMN salinity data that had been averaged to daily values. Water level (stage) data used were also collected by ENP and utilized as daily average values. Other time series data were included with these data to create the MLR models, including wind data from the National Weather Service (Southeast Regional Climate Center), and sea surface elevation data collected at Key West from the National Ocean Service.

To summarize the modeling procedure, all independent variables are subjected to a cross-correlation analysis with salinity to determine if the variables are correlated, to determine if a lagged relationship exists, and to examine the level of correlation. Lags up to 50 days were evaluated. Then the observed data of the correlated variables (and lagged values) were subjected to a step-wise regression process to identify the most significant parameters in a multivariate linear regression equation. To ensure that only the most highly significant parameters are selected, the significance level was set at 99.9%, a very high level. Cross-correlation effects that seemingly improve model fit and suggest the inclusion of spurious parameters were eliminated (Marshall 2004).

It was observed during this process that Craighead Pond (CP) was a water level (gauge) station that the stepwise linear regression process chose often as the most significant independent variable, or one of the most significant variables, in development of almost all of the original MLR salinity models. However, in the extreme northeast Florida Bay, EVER7 in the ENP "panhandle" was also a significant local variable, so the MLR salinity models were controlled to include EVER7 as a local hydrologic indicator, usually in concert with CP or P33 (see below) as a regional hydrologic indicator. In the original models for the stations within the Shark Slough discharge influence, the model development was controlled to include P33, and excluded CP from these MLR salinity models. Therefore, these three Everglades water level stations (CP, P33, and EVER7) are considered to be the "primary" stations for MLR salinity modeling (Marshall, 2004).

In 2007 and 2008, MLR salinity models were completed for all of the MMN stations throughout the coastal margin of ENP (Marshall, 2007; 2008). These additional models revealed the significance water level stations P35 and NP206 to the Shark River Slough and Broad River areas, usually in concert with P33. Water level station PA8 in Big Cypress National Preserve was revealed as significant in the Lostmans River and Chatham River systems.

From the work that has been done to date, managing these five water level stations to desired elevations may achieve the goal of the salinity performance measure for these areas of the southern estuaries. This performance measure is intended to be used as additional information to the other Southern Estuaries Sub-team evaluation performance measures and is not intended to replace any of the existing performance measures.

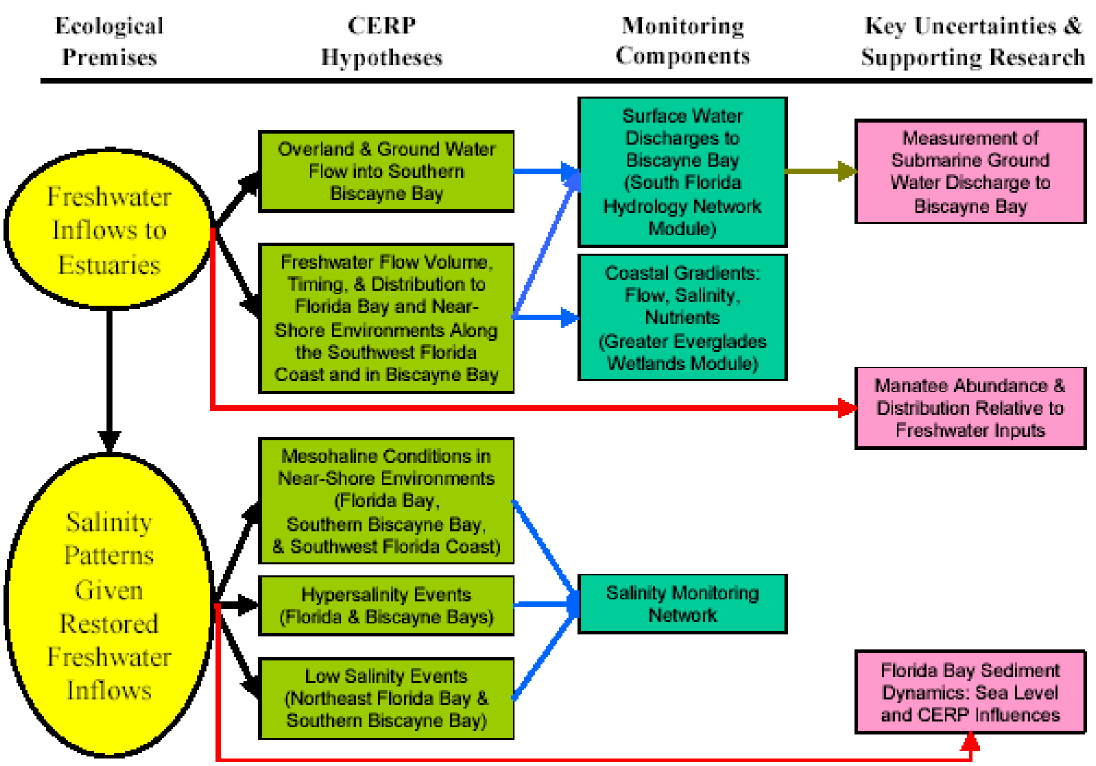
3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

The indicator for this performance measure is a stressor in the following Conceptual Ecological Models:

Regional Models (RECOVER 2004b)
Everglades Mangrove Estuaries
Florida Bay

Conceptual Ecological Models



3.2 Relationship to Adaptive Assessment Hypothesis Clusters

Ecological Premise: Prior to water management, the Natural Systems Model (NSM) and palaeoecological studies (Hunt and Nuttle, 2007) indicate that patterns of freshwater inflow to Biscayne Bay, Florida Bay, and the southwest Florida coast resulted in more sustained mesohaline salinity conditions in coastal areas with fewer high and low salinity extremes.

CERP Hypotheses: The restoration of more natural upstream hydrological conditions and the expansion and/or addition of flow pathways will result in the following:

- Provide additional overland and ground water flow into south Biscayne Bay
- Provide more natural patterns of freshwater flow volume, timing, and distribution to Biscayne Bay, Florida Bay, and the near-shore environments along the southwest Florida coast
- Expand areas of mesohaline conditions in near-shore regions of southern Biscayne Bay, Florida Bay, and the southwest Florida coast, shifting seaward and possibly expanding the polyhaline zone
- Decrease the intensity and duration of hypersalinity events in Florida Bay and Biscayne Bay
- Reduce the magnitude, duration, and frequency of pulsed, low salinity events in northeastern Florida Bay and southern Biscayne Bay

4.0 Evaluation Application

4.1 Evaluation Protocol

In the evaluation process, cells in the SFWMM that correspond to the locations of the water level stations (Table 3) will be used for analysis. The water depth outputs for those cells will be acquired from modeled simulations for each alternative. The NSM output will be modified as described in Marshall (2005, 2008) for removal of model bias before being used for performance measure applications. Period of record values will be graphically displayed. The target for this performance measure is to closely resemble the salinity values predicted by the water levels that are the output of NSM.

Evaluation Method and Target 1:

The mean and the 25th and 75th quartiles of the frequency of water depths for the CERP alternatives will be compared to the water depths of the NSM. Graphics and values (in text files) of these results are used to evaluate the success of alternative plans. Individual scores will be shown for each alternative relative to NSM. The highest summed scores will indicate the most favorable alternative.

Evaluation Method and Target 2:

The monthly average water depth for the CERP alternatives will be compared to the 90% confidence interval for the current NSM water depths. Both graphics and values (in text files) are provided for the monthly average water depths for the CERP alternatives and the 90% confidence intervals for the

NSM. Individual scores will be shown for each alternative relative to NSM. The index score is the total number of months that the water depths are within the 90% confidence interval divided by the total available months within the period of record.

Table 3. Cells in the SFWMM that corresponds to the location of the primary water level stations.

Water Level Station	Location in the SFWMM
CP	Row4Column20
P33	Row17Column20
EVER7	Row6Column25
P35	Row12Column15
PA8	Row26Column2
NP206	Row15Column21

4.2 Normalized Performance Output

A scale from 0.0 to 1.0 will be developed in the future.

4.3 Model Output

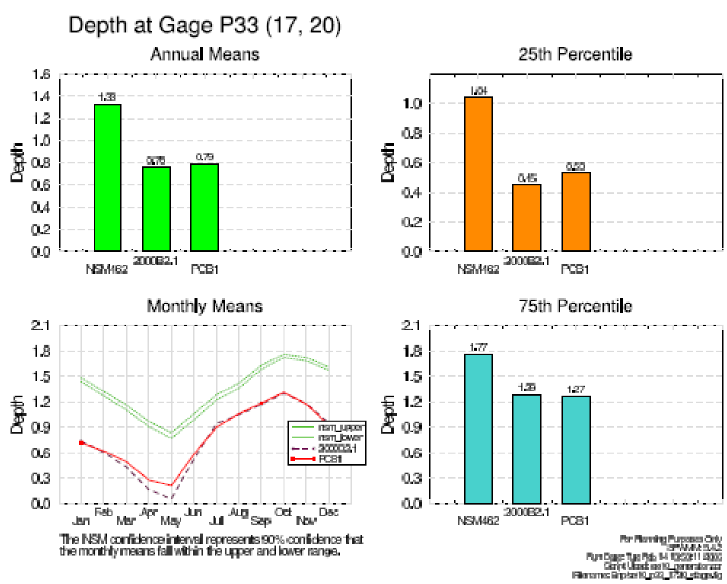
Period of record values will be graphically displayed. The target for this performance measure is to closely resemble the water levels (depths) predicted by the modified NSM output (see 4.1).

Evaluation Method and Target 1:

The mean and the 25th and 75th quartiles of the frequency of water depths for the CERP alternatives will be compared to the water depths of the NSM. Graphics and values (in text files) of these results are used to evaluate the success of alternative plans. Individual scores will be shown for each alternative relative to NSM. The highest summed scores will indicate the most favorable alternative.

Evaluation Method and Target 2:

The monthly average water depth for the CERP alternatives will be compared to the 90% confidence interval for the current NSM water depths. Both graphics and values (in text files) are provided for the monthly average water depths for the CERP alternatives and the 90% confidence intervals for the NSM. Individual scores will be shown for each alternative relative to NSM. The index score is the total number of months that the water depths are within the 90% confidence interval divided by the total available months within the period of record. In this example, the score would be zero for the PCB alternative, because water depths are never within the NSM interval.



4.4 Uncertainty

This performance measure uses data directly from the SFWMM (SFWMD, 2005). All uncertainty would be related to the results from that model and the modifications suggested by Marshall (2005, 2008).

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See *CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research* - Southern Estuaries Module section 3.2.3.6 (RECOVER 2004a).

5.2 Assessment Approach

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

6.2 Assessment Tools Needed

7.0 Notes

This Performance Measure supersedes and addresses SE-3 Water level at regionally significant gauge stations in ENP (Last Date Revised: December 3, 2004).

8.0 Working Group Members

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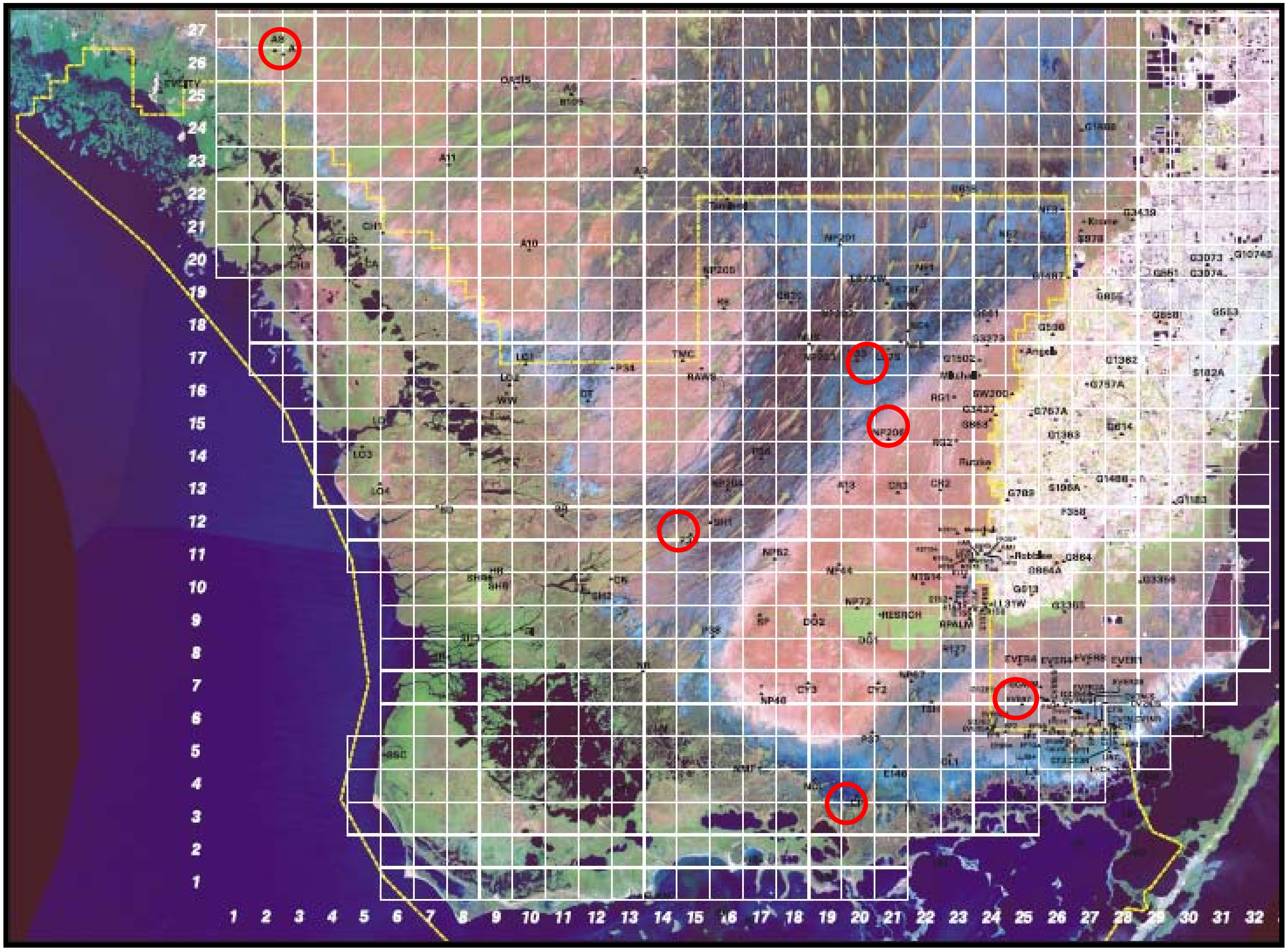

Location of the significant water level stations within south Florida and the SFWMM grid.