A Water Level Performance Measure for Everglades Restoration – Integrating Everglades and Florida Bay Restoration Requirements

Donald R. Deis[1], Frank E. Marshall[2], Patrick A. Pitts[3], Andrew D. Gottlieb[1]
[1]Atkins, Jacksonville, FL, USA; [2]Cetacean Logic Foundation, New Smyrna Beach, FL, USA; [3]U.S. Fish & Wildlife Service, Vero Beach, FL, USA

Abstract

Water levels in the southern Everglades are determined by freshwater flows (overland and groundwater), rainfall, and evaporation. Therefore, freshwater stage integrates and reflects the recent hydrologic activity. Because of the interconnection of freshwater, brackish, and marine waters in the Everglades, freshwater stage (water level) is an important factor in determining salinity regimes in the estuaries along with the uncontrollable effects of wind and oceanic influence. The goal of the Comprehensive Everglades Restoration Program (CERP) is to restore water levels in the wetlands of the Everglades which will achieve established salinity restoration targets in the southern estuaries. The original salinity performance measures in the Restudy (U.S. Army Corps of Engineers 1999) for the estuaries in Everglades National Park used relationships generated between salinity and upstream freshwater stage data. The water levels required for salinity restoration targets are also the water levels required for resumption of sheet flow and related patterns of hydroperiod and water depth. These water levels could significantly help to restore and sustain the microtopography, directionality, and spatial extent of ridges and sloughs and improve the health of tree islands in the ridge and slough landscape in the Everglades.

A new water level performance measure (PM) has been proposed to provide the integration of freshwater water depth requirements and the stage required to attain salinity restoration targets. The focus of this current work is on the salinity/aspect of the stage PM, not the Everglades stage aspect.

Desired Restoration Condition

Water level (stage) in the freshwater Everglades, particularly the downstream reaches of the Everglades wetlands, is an important driver for the salinity regimes in Florida Bay and the southwest Florida coast. Because of this interconnectivity, achievement of salinity performance measure targets means that average freshwater stage levels in the Everglades must be increased and historic variability restored. The purpose of this performance measure is to tie estuarine salinities to upstream stage. Attaining stage targets in the wetlands that have been established with consideration of the natural climatic variability of South Florida should result in the desired restoration condition in downstream estuaries, which is to:

- Restore salinity patterns that are typical of the natural system where freshwater flows often extend beyond the end of the rainy season,
- Reduce the frequency, duration, magnitude, and extent of hypersaline conditions where they occur, especially in summer and early fall,
- Increase the frequency and extent of lower salinity conditions, and
- Restore oligohaline and mesohaline salinity patterns in the nearshore environment.

Based on the above, the desired stage condition in the freshwater Everglades to achieve desired salinity conditions in the southern estuaries is to:

- Restore the natural pattern of seasonal deliveries of freshwater to Everglades National Park (ENP; i.e. appropriate timing of flow volumes), and
- Increase both the wet season and the dry season stage levels that were typical of the natural system.

Background

Embayment	Salinity Value (ppt)	P33 Gage Elevation (ft NGVD29)
	5	7.0
Joe Bay	15	6.2
	15	7.1
Little Madeira Bay	25	6.3
	25	7.1
Terrapin Bay	35	6.3
	25	7.3
Garfield Bight	35	6.3
	5	7.1
North River Mouth	15	6.2

The original salinity performance measure used in 1999 for the Restudy for the estuaries in ENP used relationships generated between salinity and upstream freshwater stage data. Linear regression models were developed with a one-month lag between stage at P33 and salinity estimated monthly at station locations in Florida Bay for the Restudy period of record (1965-1995).

Contact Information: Donald R. Deis, Atkins, 7406 Fullerton Street, Suite 350, Jacksonville, Florida 32256 USA, Tel: (904) 363 8442, Fax: (904) 363 8811, Email: don.deis@atkinsglobal.com

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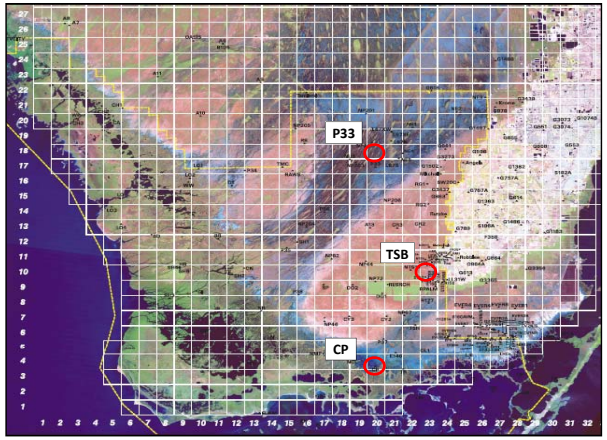


Figure 1. Location of the significant water level stations (red open circles) within south Florida and the South Florida Water Management Model (SFWMM) grid.

Embayment	Salinity Value (ppt)	Gage Elevation (ft NGVD29)
Joe Bay	5	2.63
Based on NP67	15	2.04
Little Madeira Bay	15	2.82
Based on NP67	25	2.02
Terrapin Bight	25	2.91
Based on NP67	35	1.92
Garfield Bight	25	2.99
Based on NP67	35	1.97
North River Mouth	5	7.1
Based on P33	15	6.2

In 2002, a revision to the Restudy performance measure was recommended and implemented. Mean monthly stage values at gage NP67 in west central Taylor Slough and P33 in central Shark River Slough were used to create relations with salinity in the coastal embayments

The methods used to evaluate this Performance Measure (PM) rely on the procedure presented in Marshall et al. (2009) using paleo-based estimates of salinity to estimate the stage and flow needed in the Everglades freshwater marshes. Salinity data were daily average values from the ENP Marine Monitoring Network (MMN) stations; stage data were ENP Everglades water levels. Wind data from the National Weather Service at Key West and Miami and water level data collected at Key West from the National Ocean Service were also used. Over time, Multiple Linear Regression (MLR) salinity models were developed for all MMN sites (Marshall et al. 2011).

To summarize the modeling procedure, all independent variables are subjected to a cross-correlation analysis with salinity to identify correlated variables, determine if a lagged relationship exists, and examine the level of correlation. Lags up to 50 days were evaluated. Then a step-wise regression process was used to retain the most significant parameters in an MLR salinity model. To ensure that only the most highly significant parameters are selected, the significance level was set at 99.9% (Marshall et al. 2011).

It was observed during the model development process that several stage stations appeared frequently in the MLR salinity models. These stage stations include **CP, P33, and TSB stage** and are referred to as the primary stage stations. For some salinity models regionally significant stage stations (e.g. EVER4, EVER7, EVER1) were included in the models in addition to the primary stations (Marshall et al., 2011).

Significant Gage Station	Mid-range Overlap	Mean Offset	Low Level Frequency of Occurrence	Overall Stoplight Score
P33 - 1995	0.53	0.23	0.0	2.67
P33-1972	0	1.68	0.71	1
P33 – CERP0 (low level 6.0 ft)	0.87	0.69	0.08	2.67
P33 – CERP0 (low level 6.2 ft)	0.87	0.69	0.13	2.33

Summary of scores and stoplight evaluation for P-33 in 1995 (a "wet" year), 1972 (a "dry" year), and CERP0 (the modeled preferred restoration alternative) at two low level alternatives. Note low levels for high salinity in Table from the Restudy.

Metric and Target

The target is the "paleo-adjusted NSM stage". The NSM is an attempt to simulate the hydrologic response of a non-managed Everglades system to the climatic conditions of 1965-2000. This is obtained by initially post-processing output from the Natural System Model (NSM) Version 4.6.2 using the MLR statistical models described above to obtain daily salinity regimes at Whipray Basin, Little Madeira Bay, and Rankin Lake (Buoy Key MMN station). The NSM-based salinity time series values at each of the three MMN stations are then adjusted such that the average salinity for 1965-2000 equals the average paleosalinity based on the most current paleosalinity information provided by the USGS studies in Florida Bay (Wingard et al. 2007a, Wingard et al. 2007b, Marshall et al. 2009, Marshall and Wingard 2011). Next, the three paleo-adjusted NSM salinity time series values are used as input to the MLR stage models developed by Marshall and Wingard (2011) that converts the paleo-adjusted salinity into the paleo-adjusted NSM stage time series for each of the three primary gage stations.

For **evaluation** purposes, output from the SFWMM for each CERP alternative is post-processed to remove the bias and correct for datum differences at the three gage stations. The CERP alternative output time series are then compared to the paleo-adjusted NSM stage target using the metrics described below.

For **assessment** purposes, the observed water level data from the significant gage stations are used for comparison to the paleo-adjusted NSM stage values using the metrics described below.

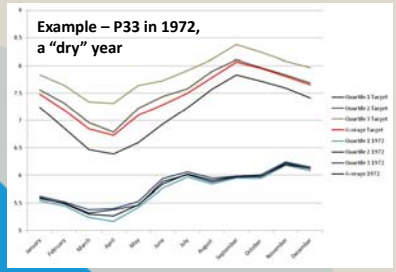
Regime metric - This refers to the water level envelope that is characteristic of a given location. The distribution of water level in the paleo-adjusted NSM record (target) condition is compared to the observed or predicted water level distribution. The distribution of paleo-adjusted NSM water levels for 1965-2000 is evaluated on an average monthly basis (i.e. the average for May is the average of all daily values in every May from 1965-2000) to address the timing and quantity aspects of water levels in the marshes upstream of the coastal embayments. These comparisons will focus on the range of water levels that occur between the 25th and 75th percentiles (see example graphic below) to minimize the confounding effects of outliers that are caused by ephemeral events such as storms.

Mean Offset metric – The mean offset metric is a measure of the magnitude that the mean value of the subject data deviates from the mean value of the paleo-adjusted NSM stage target. For assessment purposes the mean values of a particular year is compared with the mean value of the paleo-adjusted NSM stage target. For evaluation purposes, the mean values of the evaluated alternative will be compared over the full model output time period (currently, 1965-2000) with mean value of the paleo-adjusted NSM stage target. This metric should be as small a number as possible, approaching zero .

Low Level metric – Each significant gage station has a level that is reflective of an extremely low water level condition that should be avoided, especially after the normal dry season (i.e., into June and July) because it will result in elevated salinity conditions in the downstream estuaries. The metric compares the frequency of occurrence (FO) of water level below the threshold low elevation between the target and the assessment data (observed data) or CERP evaluation output (CERP alternative).

Score Regime Overlap and Low Level metrics	Stoplight Evaluation
0-0.30	Red
0.31-0.60	Yellow
0.61-1.0	Green

Score Mean Offset metric	Stoplight Evaluation
<1.0	Red
0.5-1.0	Yellow
0-0.5	Green



Conclusions

These metrics and targets allow the development of a scoring scheme. To the left are the recommended scoring for the metrics. Because two of the metrics are normalized and the other is not, an overall score cannot be obtained by aggregating metric scores. Instead, the overall stoplight score is generated by initially assigning an integer value for each stoplight color (red=1, yellow=2, green=3). Then, the three integer values for each metric for a given gage station are then summed and the mean is calculated, which becomes the overall stoplight numeric score. The overall score is then applied to the stoplight scale in the panel below. An example of scoring assessment data and modeled alternatives is located left and below.

Overall Stoplight Score	Stoplight Evaluation
1.00-1.50	Red
1.51-2.50	Yellow
2.51-3.00	Green

References

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