Greater Everglades Performance Measure

Extreme High and Low Water Levels in Greater Everglades Wetlands (previously GE-3)

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1.0 Desired Restoration Condition

Restore Natural System Model (NSM) (version 4.62) target envelopes throughout the Greater Everglades wetlands, except in areas where deviations from NSM have been deemed to be environmentally beneficial.

1.1 Predictive Metric and Target

There are two metrics used in predicting alternative plan performance in this performance measure: 1) Frequency, Duration, and Percent Period of Record of Extreme Events and 2) Peat Exposure Due to Droughts.

1.1.1 Frequency, Duration, and Percent Period of Record of Extreme Events

The ecological target is the recovery of the predrainage patterns of multiyear hydroperiods in each indicator region (IR). The NSM version 4.62 is used to develop target envelopes for the number and duration of extreme high and low water depth events except where deviations from NSM are deemed ecologically beneficial. These areas are the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Water Conservation Area [WCA] 1), Water Conservation Area 2, and areas in WCA 3 that have experienced significant subsidence (Figure 1 and Table 1), and the marl marshes.

Number and duration of events are used to calculate percent period of record (PPOR) of extreme high and low events by determining the duration of events relative to the full period of record. This metric is applied in all of the Greater Everglades IRs.

Table 1. Indicator Regions (IR), the landscape types they contain, and the explicit target for extreme high and low events in the IR.

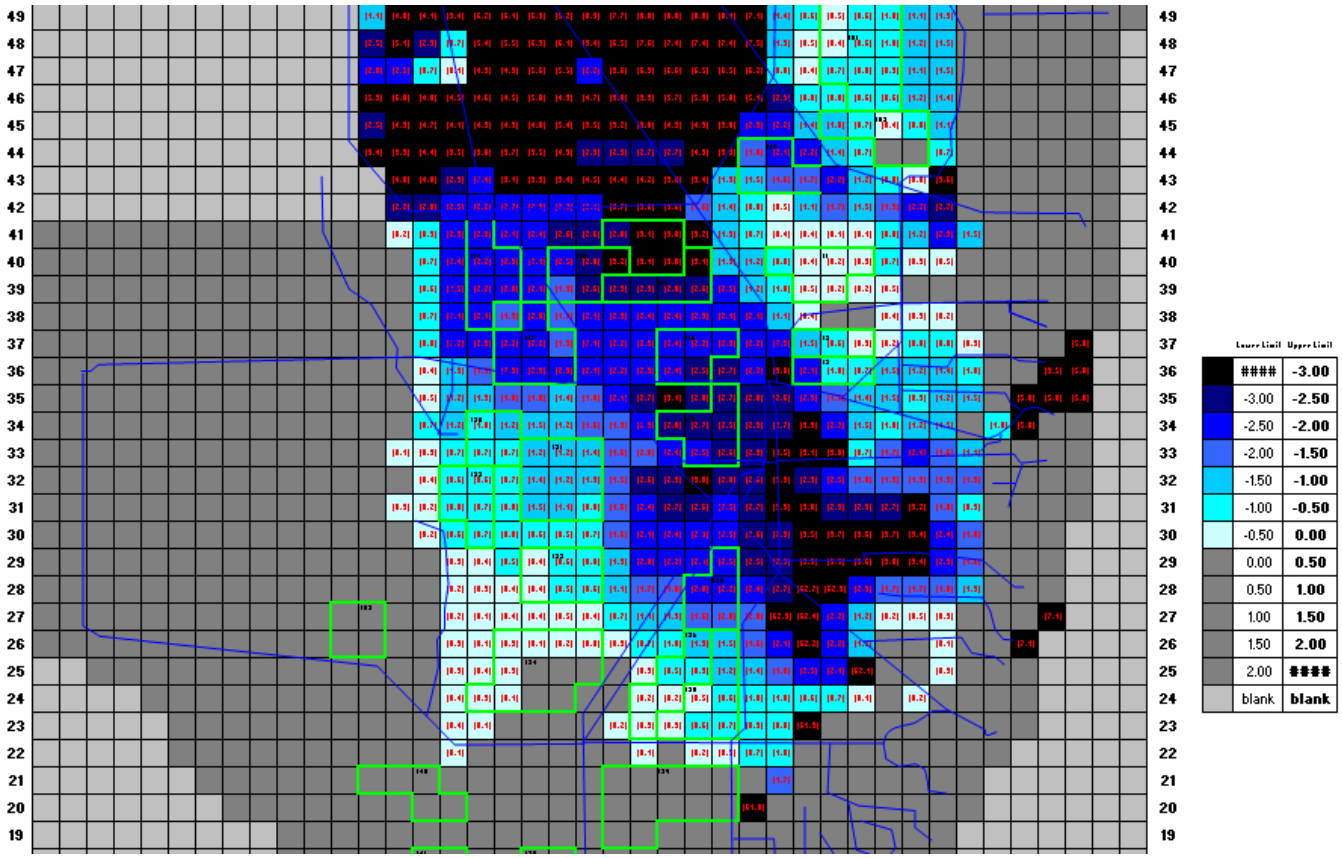
Indicator region	Landscape Type	High and Low Targets
IR 100	Ridge and Slough	6-34 high events >2.5 feet of 0-5 weeks average duration and no more than one low event <-1.0 foot of no more than 2 weeks duration
IR 101	Ridge and Slough	6-34 high events >2.5 feet of 0-5 weeks average duration and no more than one low event <-1.0 foot of no more than 2 weeks duration
IR 102	Ridge and Slough	20-36 high events >2.5 feet of 10-25 weeks average duration and no more than one low event <-1.0 foot of no more than 2 weeks duration
IR 110-114,117, 118-126 and 128-133	Ridge and Slough	No more high events >2.5 feet than NSM 4.6.2. Minimize low events <-1.0 foot. Except: for IR 129, the NSM number of high events is considered too large.
IR 115, 116, 127, and 190	Sawgrass Plains	No more high events >2.0 feet than NSM 4.6.2. Minimize low events <-1.0 foot
IR 143-145 and 148	Marl Marsh	No more than 7 high events >1.5 feet and >2 weeks duration. Minimize low events <-1.5 foot[1]
IR 140, 141, 146 and 147	Marl Marsh	No more than 7 high events >2.0 feet and >2 weeks duration. Minimize low events <-1.5 foot[1]
IR 150 and 151	Mixed	Not evaluated; targets remain under development
IR 160 and 170[2]	Sawgrass Plains	No more high events >1.75 feet than NSM 4.6.2. Minimize low events <-1.0 foot[1]

[1] These targets are a high priority for alteration based on a comprehensive review of literature and experimental approaches that are designed to determine empirical agreement with the target. Current guidance to minimize the number of events, or consider a number of events to be too large should be made more specific.

[2] Rotenberger and Holey Land (IR 160 and 170) are currently isolated from the system and managed by pumping activities based on a Memorandum of agreement with the SFWMD. While RECOVER accepts this interim policy decision, it is our expectation that the trend of management and evaluation of these areas will be eventually based upon and consistent with the changes that are expected by the Long Term Plan which is founded on a system-wide analysis of health.

Indicator region map is available at:
http://www.evergladesplan.org/pm/recover/recover_docs/et/082704_et_maps_ind_regions.pdf

Figure 1. Map of Greater Everglades Wetland areas that have demonstrated significant subsidence compared to estimates of historical elevation contained in NSM. South Florida Water Management Model (SFWMM) 2X2 cells are color coded with respect to the degree of subsidence at 0.5 ft. intervals.



1.1.2 Peat Exposure Due to Drought

The intensity of drying events that occurred in a pre-drained system yielded a state of homeostatic equilibrium between the processes of Everglades' organic soils (accretion and loss/compaction) and Florida's hydrologic conditions (inundation and drying). The unit of measure chosen to describe cumulative drought intensity for this metric is calculated by multiplying depth to water table from ground surface (ft) by the duration (days) of belowground water levels to yield a ft-days below land surface summary variable for each cell in the SFWMM 2X2 grid. This value is used as a surrogate for cumulative annual dry-event intensity and is computed for each year in the simulation. Yearly dry-event intensity values for each cell are summed across the 36-year period of record and directly compared the cumulative dry-event intensity values obtained from NSM to gauge the cumulative impact of project alternatives on the intensity of dry conditions experienced by each location in the Everglades where peat soils are present.

1.2 Assessment Parameter and Target

1.2.1 Frequency, Duration, and Percent Period of Record of Extreme Events

The Everglades Depth Estimation Network (EDEN) is an integrated multi-agency network of real-time water level monitoring, ground elevation modeling and surface water modeling (SSR 2007). EDEN is currently active and will be used for field assessments and comparisons to model projections. Depth and hydroperiod characterizations are based on field stage gauge readings. Provisional targets have been set (see Table 1), and empirical targets are preferred and under development.

1.2.2 Peat Exposure Due to Drought

Assessment of depth to water table is currently not directly detectable by EDEN, but surrogate measures of soil moisture content may be developed in the future. Water table monitoring wells utilized by the South Florida Water Management District and United States Geological Survey are available for assessment, but a formal strategy for their use has not yet been developed.

2.0 Justification

The predrainage Everglades was a single, hydrologically integrated system, with water depth and distribution determined by the seasonal and annual interplay of fairly high-contrast weather patterns, vegetation and the underlying topography. The depth, distribution, and duration of surface flooding in the three central Everglades landscape types (ridge and slough, the adjacent southern marl prairies, and Big Cypress wetlands) largely determined the vegetation patterns, as well as the distribution, abundance, seasonal movements and reproductive dynamics of all of the aquatic and many of the terrestrial invertebrates and vertebrate animals in the Everglades. The central Everglades (present day Water Conservation Area 3A), and Shark River Slough were once an uninterrupted flow path. The topography of the system combined with its size and volume of water flowing through it led to the formation of extensive peat soils that developed uninterrupted for millennia. The hydropattern exhibited by the historical system contributed directly to the development of the emergent properties that were characteristic of the historical Everglades such as expansive areas of peat soils, high density seasonal concentrations of an aquatic prey base, wading bird super colonies, and a mosaic of plant communities. The resultant system was both resistant to and resilient from extreme disturbance events such as floods, droughts, fires, hurricanes, and outbreaks of pests and pathogens.

The Central & Southern Florida (C&SF) Project compartmentalized the system such that water could be stacked in the WCAs in order to provide urban and agricultural areas with protection from flooding during the wet season, and with deliveries of water supply during the dry season. Operation of the natural system as a series of impoundments resulted in excessive depth-durations (water too deep and/or deep for unnaturally long periods) across hundreds of square miles of the ridge and slough environment during wet seasons and wet years whenever the water storage capacity required for flood control exceeded the spatial extent of remaining natural wetlands (and of man-made water storage areas). During these periods of excessive depth the tree islands flood (Van der Valk et al. 1998, Sklar et al. 2000), shallow feeding habitat for wading birds is lost, periphyton communities are stressed (Browder et al. 1994), alligator nests flood and feeding conditions are reduced (Jacobsen and Kushlan 1984, Kushlan and Jacobsen 1990), and the species composition and size classes of fishes are altered. The C&SF project made efficient drainage of the ecosystem possible, but the unintended result has been increased stress on the receiving estuaries in wet seasons and wet years and a reduction of the total amount of water stored in the system. Reducing total water quantity stored by the ecosystem has

exaggerated the dry seasons and dry years that can follow. The result is increased rates of organic soil loss (Stober et al. 1996, Sklar et al. 2000), spread of woody vegetation, reduced survival of aquatic species, altered periphyton communities (Browder et al. 1994), reduced alligator nesting (Jacobsen and Kushlan 1984, Kushlan and Jacobsen 1990), and sawgrass expansion into slough communities (Davis and Ogden 1994, Sklar et al. 2000). These biological responses can be considered symptoms of cascading ecological effects that are the consequence of the reduction of the availability of essential ecological resources (sensu Ryan et al. 2007) that were caused by large scale structural and operational modifications to the ecosystem.

Peat loss can occur as either a multi-decadal impact associated with gradual shifts in the relationship between organic matter accumulation and soil respiration caused by changes in hydropattern, or as an immediate effect of rare and intense peat soil consuming fires. The intent of the drought intensity component of the performance measure is to use a quantitative graphical display of cumulative desiccation intensity (magnitude and duration of drying event) to allow evaluators to determine whether alternative project designs are likely to increase or decrease the potential for further unnatural loss of organic soils. It has been observed throughout the northern Everglades that peat loss is associated with changes in water deliveries that reduce water depth and hydroperiod duration. The goal is to reduce the risk of further loss of soil elevations due to excessive drying of organic soils.

In the predrainage marl prairie and rocky glades wetlands bordering Shark River Slough, water normally fell below ground surface each year. However, dry season water levels were high enough to provide remnant pools of standing water in solution holes and alligator holes critical to the survival of aquatic and amphibious fauna such as fish, crayfish, and herpetofauna (Dalrymple 1987, Loftus et al. 1992, Mazzotti and Brandt 1994, Diffendorfer et al., in prep.). In the current system, developed areas within the former eastern marl prairies and rocky glades wetlands depend on a system of canals and pump stations to provide urban and agricultural flood control at the cost of excessively draining adjacent wetlands. The function of the dry season refugia in the remaining wetlands is diminished or eliminated when dry conditions are prolonged and water levels fall below the bottoms of the solution and alligator holes. Loss of vegetation heterogeneity associated with the micro-topography of alligator holes (Craighead 1968), and woody plant invasion of the graminoid communities (Armentano et al. 1995) have accompanied shortened hydroperiods and lowered water tables. Extreme droughts can result in tree island burn-outs (Hilsenbeck et al. 1979, Loope and Urban 1980, Hofstetter and Hilsenbeck 1980).

The predrainage Big Cypress region was characterized by a forested mosaic of species instead of the primarily herbaceous communities found in the central Everglades. A very gentle topographic slope supports a gradient of vegetation types from upland pinelands, to marshes, to long-hydroperiod cypress forests on lower elevations (Davis 1943, Klein et al. 1970, Craighead 1971, Duever 1984). Under current conditions in the Big Cypress ecosystem, agricultural and residential developments have dealt with the seasonally high water tables by constructing an extensive system of small ditches connected to larger and larger canals to assure that water levels remain below ground throughout the year. The drainage system lowers water tables and shortens hydroperiods for considerable distances in neighboring wetlands, causing shifts in wetland plant composition to more upland species. More frequent and severe fires, typical of the upland pinelands have hastened the decline of wetland vegetation. Native amphibian, fish, and crayfish populations, dependent on at least some wet or moist

substrate, have declined as well. Tropical species capable of surviving winter freezes if buffered by standing water also have declined.

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

http://www.evergladesplan.org/pm/recover/recover_docs/et/pm_report/pm_rpt_4_3_ge_cem.pdf (RECOVER 2006)

In each of the hypothesis clusters and conceptual ecological models (CEMs), alternate terminology for extreme high and low depths such as hydroperiod, water depth, dry down or inundation pattern may be used. Extreme depth is a stressor in the following Conceptual Ecological Models:

Greater Everglades Regional Conceptual Ecological Models (RECOVER 2004b). Manuscript documentation for the four Greater Everglades landscape-type CEMs can be found at http://www.evergladesplan.org/pm/recover/cems.aspx

1) Everglades Ridge and Slough (Ogden 2005)
2) Southern Marl Prairies (Davis et al. 2005)
3) Big Cypress (Duever 2005) Regional Ecosystem

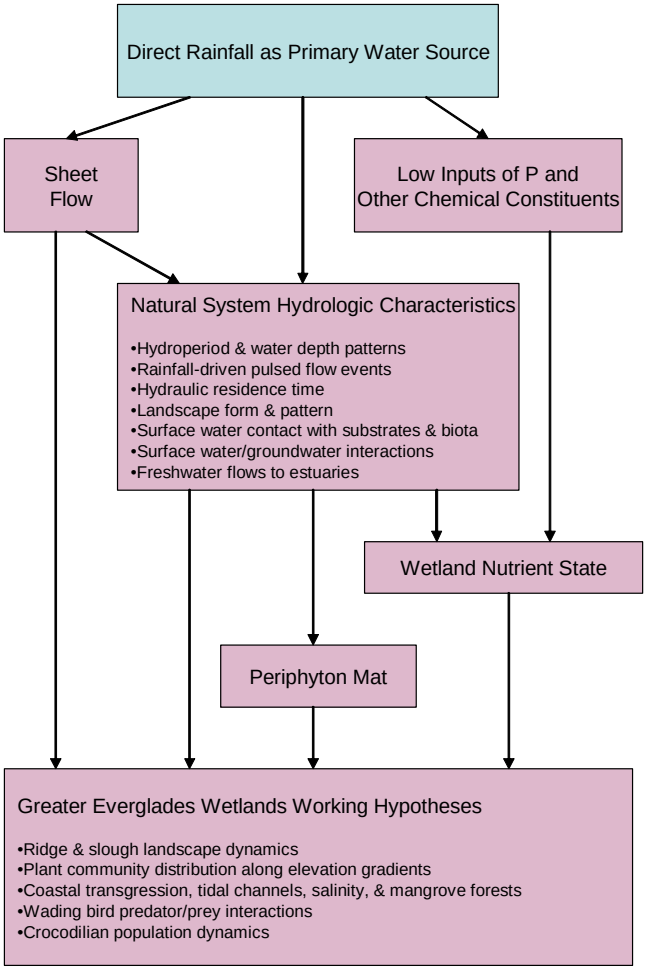
Simplified Conceptual Ecological Models (RECOVER 2006b). The following list identifies which of the ten Greater Everglades simplified CEMs are directly related to number of drydowns, their duration, and the cumulative intensity of drydown events.

1) Integrated Hydrology and Water Quality Hypothesis Cluster
2) Ridge and Slough Landscape Dynamics
3) Plant Communities along Elevation Gradients
4) Predator-Prey Interactions of Wading Birds and Aquatic Fauna Forage Base
5) Linkage of Periphyton to higher Trophic Levels
6) Everglades Crocodilian Populations

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

For detailed information regarding each of the hypothesis, including additional CEM diagrams, please see the Monitoring and Assessment Plan, Part 2. A subset of figures and hypothesis descriptions are provided below for justification and general theory.
http://www.evergladesplan.org/pm/recover/recover_docs/et/060507_pm_report/hypothesis_clusters_ge.pdf

Integrated Hydrology and Water Quality Hypothesis Cluster (RECOVER 2006b, Section 9.2.3)



Hypothesis 1: Rainfall and Sheet Flow as Determinants of Natural System Hydrologic Characteristics in the Everglades.

The volume, timing, and distribution of sheet flow, in combination with direct rainfall, produced fundamental hydrologic and landscape characteristics of the pre-drainage Everglades that can be described by the following parameters:

- Hydroperiod and water depth patterns
- Rainfall-driven pulsed flow events

- Hydraulic residence time
- Landscape form and pattern
- Surface water contact with substrates and biota
- Surface water/groundwater interactions
- Freshwater flows supporting beneficial salinity patterns in the mangrove estuaries of Florida Bay and the Gulf of Mexico

Decompartmentalization, combined with resumption of natural volume, distribution, and timing of freshwater delivery is expected to restore sheetflow and predrainage hydrologic and landscape characteristics to an undivided ecosystem encompassing much of Water Conservation Area 3A, Water Conservation Area 3B, eastern Big Cypress, and Everglades National Park.

Rationale: Specific hydrologic restoration targets associated with the resumption of sheetflow and related hydrologic characteristics include:

- Multi-year hydroperiods in ridge and slough landscape
- Conditions conducive to peat formation in ridge and slough landscape
- Hydropatterns that sustain co-existing sloughs and sawgrass ridges in the ridge and slough landscape
- No distinct or persistent changes in water levels across boundaries such as canals, levees, or roads
- Large-scale surface water flow directions that follow the historic landscape directionality
- Hydropatterns that support the long-term stability of tree islands in ridge and slough landscape
- Hydroperiods from two months to less than one year conducive to marl formation and muhly grass (Muhlenbergia filipes) community persistence in Southern marl prairies
- Persistent pools of fresh to oligohaline water along the interface of the freshwater Everglades and the mangrove ecotone of Florida Bay and the Gulf of Mexico
- Dry season water recession patterns conducive to successful wading bird foraging
- Multi-year flood and drought cycles supporting formation of wading bird super-colonies
- Absence of harmful regulatory releases of excess fresh water to the Greater Everglades
- Freshwater flow discharges to Florida Bay and the Gulf estuaries that maintain a near shore salinity gradient characteristic of predrainage conditions
- Stage levels that allow for continued sheet flow through the system given the amount of subsidence that has occurred in the water conservation areas

This performance measure is also directly related to hypotheses 1-3 in the Wetland Landscape and Plant Community Dynamics hypothesis cluster of the Assessment Strategy (RECOVER 2006b).

4.0 Evaluation Application

4.1 Evaluation Protocol

4.1.1 Frequency, Duration, and Percent Period of Record of Extreme Events.

A table of values will be generated showing the number, duration (in weeks) and percent period of record (PPOR) of extreme high and low water level events for NSM, base conditions, and

each alternative to be evaluated. The table is accompanied by box-and-whisker plots which represent the NSM v 4.62 (target) distributions for number, duration and PPOR for ridge and slough habitat. These box-and-whisker plots are created by calculating the response variable of interest for every cell within an indicator region, the scores from each cell are graphically displayed as a distribution of scores with a median, upper and lower quartile (which determines the size of the box), and extreme values (determining the length of the whiskers). The distribution of the same response variables in the same cells of the indicator regions are calculated and presented as companion box-and-whisker plots on the same graphic output sheet to allow direct comparisons of alternative model runs resulting value for evaluation. Calculations are made separately for the ridge and slough cells north (excluding Loxahatchee National Wildlife Refuge) and south of Tamiami Trail.

Values displayed on the whiskers represent the upper and lower 10 percent of the NSM distribution, while the remaining 80 percent of values make up the box. The box is divided into four categories, each encompassing a 20 percentile grouping of the cell values. The box-and-whiskers plots include labels or a legend off to the side indicating the percentage categories. A scale is included so that reviewers can see the percentage values that define the box-and-whisker areas. The mean and median values of the distribution are also calculated and shown (mean = x, median = y) at the top of the graph. The list of cells used to create the target boxplot is provided below each plot.

Scoring is accomplished by comparing the position of the IR value for each alternative on the box-and-whisker background to the position of the NSM (target) value for that IR. An “A” grade is assigned if the IR value for the alternative falls in the same 20 percentile category as predicted by NSM for the IR. A “B” grade is assigned if the IR value for the alternative falls in a 20 percentile category directly adjacent to the NSM target category. A “C” is assigned for performance two categories away, and a “D” for performance three categories away. IR performance within or beyond the whiskers generally receives a failing grade. In some cases where the target falls on the whiskers or the edge of the box, further discussion may be necessary to justify scoring. The final score for an IR is represented by the combination of scores for # and duration of events. It should be noted that using PPOR provides insight into the total change in performance but PPOR alone does not provide independent information on the number and duration of dry events or the distribution and timing of these events, both of which are ecologically meaningful. Any scoring method used, including the method suggested above, should be consistently applied across alternatives and should reflect best professional judgment about what differences in performance are ecologically significant.

For areas with NSM envelope targets, a failing grade indicates that the alternative would not be expected to support a sustainable natural Everglades landscape within the range of the landscape type. Any “passing” grade of A-D indicates that the alternative produces conditions within the IR that may be expected to support a sustainable natural Everglades landscape within the range of the landscape type. Higher grades indicate the alternative is expected to support a sustainable natural Everglades landscape closer to that found in the IR area historically.

Calculations of average depth and average and total duration of high and low water events are calculated as follows:

1) Period of record (POR) = 1965-2000 simulation period

a) Non-Leap Years -> last eight days of calendar year used for weekly average

b) Leap Years -> last nine days of calendar year used for weekly average

2) The average depth for a given week in a given year is calculated for each grid cell within an IR and these values are averaged over the cells within the IR to obtain an average depth for the IR for that week.

3) Average duration of high or low events (weeks per event) is the average number of weeks that water levels rise above or fall below the extreme high or low criteria for the period of record: average duration of high or low event = sum[duration of each extreme event in weeks] / (number of extreme events). Average values will continue to be used for information purposes, but comparing distributions of the response variables of interest is the best approach for evaluating differences.

4) Total duration of extreme events as a percent of POR = 100 x sum [duration of each extreme event in weeks] / (number of years in POR x 52)

4.1.2 Peat Exposure Due to Drought

Daily Drought Intensity Index:

For each day of the 36-year period of record every cell in the SFWMM 2X2 is queried for water depth. If water levels are below ground, the depth below ground is determined and scored in ft below ground units in an output spreadsheet. If water levels are at ground level or above ground, the cell is scored as a zero.

Monthly Drought Intensity Index:
The monthly drought index is calculated by summing all of the daily drought scores that are detected for each cell in an individual month.

Annual Drought Intensity Index:
The annual drought index is calculated by summing all of the daily drought scores that are calculated for each cell in an individual year.

Cumulative Drought Intensity Index:

The cumulative drought index is calculated by summing the annual drought scores calculated for each cell over the entire period of record of the model output.

4.2 Normalized Performance Output

4.2.1 Frequency, Duration, and Percent Period of Record of Extreme Events.

4.2.2 Peat Exposure Due to Drought

Normalization of output is currently being discussed by the Greater Everglades subteam and Module team.

4.3 Model Output

4.3.1 Frequency, Duration, and Percent Period of Record of Extreme Events.

Output tables are provided for each IR that summarizes the number, average duration, and percent period of record of both low and high events in each IR for each model run, as well as NSM.

4.3.2 Peat Exposure Due to Drought

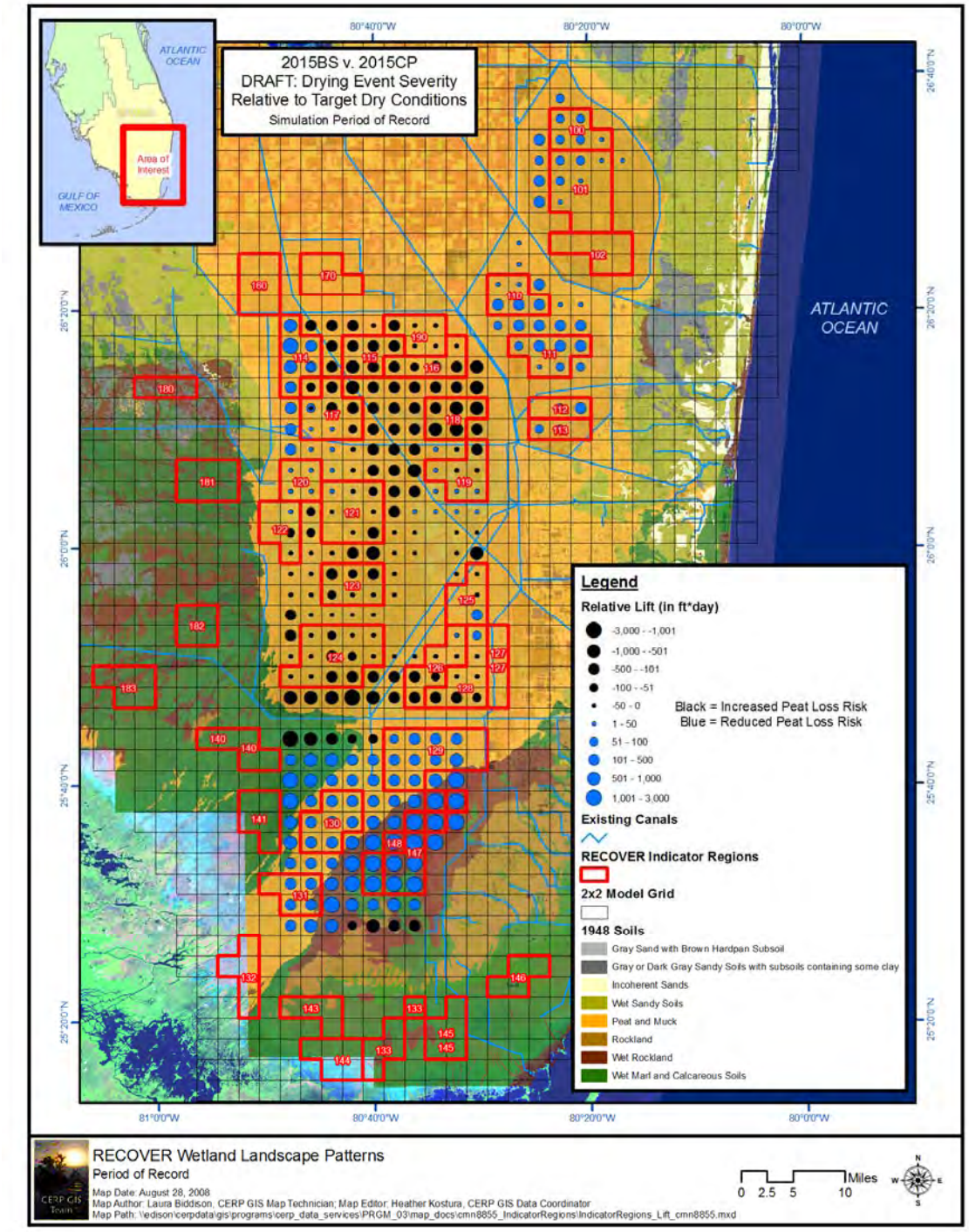
Each day's drought intensity index is output into a .csv file table and placed alongside other output from the model run.

Graphic maps that depict the annual cumulative drought index scores are developed that compare the cumulative dryness experienced by each cell for the 36 year period of record. All graphics are essentially plots where the cumulative ft*days of drought in each cell of the SFWMM 2x2 grid are indexed by the area of a circle that is superimposed over a map of the Greater Everglades areas that contained (prior to 1912) peat soils and are currently within the restoration area (Figure 2). The NSM v 4.6.2 provides the "target" condition for this component of the performance measure, and initially, the existing condition baseline (ECB) is overlaid atop the NSM plot to indicate what locations/regions are wetter or dryer than our best estimate of the historical natural condition. Since the ECB is generally drier than the historical condition, the NSM-ECB plot serves to orient the evaluators on where and to what degree the current system is drier than the natural system. Individual model runs are directly compared using a two-color graphical display where cells that are generally drier than the ECB are indicated by black dots (the degree of increased dryness is proportional to the area of the dot, see Figure 2), while cells that are wetter than the ECB are indicated by blue dots (also seen in Figure 2). Cells that are empty indicate no change in dryness from the ECB. It is important to note that this response variable graphic summary is intended to enhance the collective understanding of how projects, or operational strategies effects are experienced across the system. The size and current configuration of the system are such that effects are often felt regionally, or are contrasting in different regions of the system.

The graphical summary is used to develop hypotheses about how alternative model runs affect the system. It is expected that these hypotheses will be then tested as a part of the evaluation process using any one of a variety of appropriate statistical tools including: Analysis of Variance, linear regression, non-parametric tests for significant differences (such as sign tests, Mann-Whitney U tests or Kruskall-Wallace tests), spatial pattern analysis, temporal pattern analysis, and the interrelation of spatio-temporal patterns.

Cumulative drought intensity index roll-up scores are created for each IR in the Greater Everglades. The cumulative number of ft*days for the 36 year period of record for all cells within an IR is used to calculate an average and standard deviation of ft*days dry for the IR.

Figure 2. Cumulative drought intensity differences between project alternatives. Black circles indicate a condition that is drier than the alternative, blue circles indicate wetter conditions than the alternative, and no circle indicates that conditions in the cell are as wet as or wetter than the target condition. The size of the dot is proportional to the magnitude of difference between alternatives. The absence of a circle in a cell indicates that the cell is wetter than the NSM condition.



4.4 Uncertainty

Recognition of model uncertainty is needed when interpreting the ecological significance of model output. The Model Uncertainty Workshop Report provides guidance on the potential implications of uncertainty on model output interpretation (RECOVER 2002) (http://www.evergladesplan.org/pm/recover/recover_docs/et/052402_mrt_uncertainty_report.pdf).

The close link between the performance measure and the EDEN assessment tool provides an opportunity to systematically reduce the uncertainty associated with this performance measure through time. The network of water depth monitoring stations that exist across the Greater Everglades wetlands combined with EDEN's water surface interpolation and transect visualization tools can be compared to model output and will provide the opportunity for calibration/validation of model output with actual measurements. This type of validation of model results is a centrally important approach for system wide model results evaluation, as it provides the opportunity to ask the question of the validity/accuracy of the model (as well as providing an opportunity to help with operations and adaptive management of the restoration plan). The synthesis of evaluation and assessment tools that can be accomplished as a part of this performance measure will be an opportunity for RECOVER to perform a model validation process with observed information. This approach would allow RECOVER to achieve the NRC recommended goals of systematic uncertainty reduction (NRC 2003), and will help develop an understanding of the relationship between empirical conditions in the extant system to model based targets.

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research - South Florida Hydrology Monitoring Network Module sections 3.5.3.1 - 3.5.3.3 (RECOVER 2004)

5.2 Assessment Approach

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

Further work to increase the sensitivity of this performance measure is needed. Current methods count the number and duration of extreme events over the 36-year period of record, but lack information on the timing and distribution of these events. Continued discussion on how to best consolidate and present information on timing and distribution of extreme events is ongoing within the sub-team, and this effort is currently centered on the Slough Performance Measure. In addition, both Peat and Marl Soils and Fire Risk Performance Measures have been proposed and are the recommended path forward for gaining clarity in interpreting drought related risks to the Everglades ecosystem.

6.2 Assessment Tools Needed

7.0 Notes

The Greater Everglades subteam is currently reviewing the extreme high and low targets. Existing targets will be used until supporting science and relevant documentation indicate a change in targets is necessary. Further analysis linking extreme water depths to vegetation structure and distribution in ridge and slough and marl marsh habitats will provide a better understanding of the ecological implications of extreme highs and lows. Additionally, a better understanding of the physical requirements necessary for organic versus mineral soil accretion or production will help refine specific performance measure targets for the varying Greater Everglades habitat types. This would at a minimum provide the physical-hydrologic constraints to marl and peat formation.

The team is developing more refined guidance on scoring and weighting extreme high and low water level performance.

This performance measure supersedes and addresses GE-3 Extreme High and Low Water Levels in Greater Everglades Wetlands (Last Date Revised: November 22, 2005). This performance measure was previously referred to as GE-3.

8.0 Working Group Members

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9.0 References

Armentano, T.V., R.F. Doren, W.J. Platt, and T. Mullins. 1995. Effects of Hurricane Andrew on coastal and interior forests of southern Florida: overview and synthesis. Journal of Coastal Research Special Issue 2:111-114.

Browder, J.A., P.J. Gleason, and D.R. Swift. 1994. Periphyton in the Everglades: spatial variation, environmental correlates, and ecological implications. In: Davis, S.M., and J.C. Ogden (eds), Everglades, the Ecosystem and its Restoration. St. Lucie Press, Delray Beach, Florida, pp. 379-416.

Craighead, F.C., Sr. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 41:2-7, 69-74, 94.

Craighead, F.C., Sr. 1971. The Trees of South Florida, Volume 1: The Natural Environments and Their Succession. University of Miami Press, Coral Gables, Florida.

Dalrymple, G.H. 1987. The herpetofauna of Long Pine Key in relation to the vegetation and hydrology. In: C. Szaro et al., (eds), Management of Amphibians, Reptiles, and Small Mammals in North America, USDA Forest Service General Technical Report RM-166R, Fort Collins, Colorado.

Davis, J.J., Jr. 1943. The natural features of Southern Florida. Florida Geological Survey Bulletin 25, Tallahassee, Florida.

Davis, S.M., and J.C. Ogden. 1994. Towards ecosystem restoration. In: Davis, S.M., and J.C. Ogden (eds), Everglades, the Ecosystem and Its Restoration, St. Lucie Press, Delray Beach, Florida, pp 769- 796.

Davis, S.M., W.F. Loftus, E.E. Gaiser, and A.E. Huffman. 2005. Southern marl prairies conceptual ecological model. Wetlands 25(4):821-831.

Diffendorfer, J.E., P.M. Richards, G.H. Dalrymple, and D.L. DeAngelis. In preparation. Using ecosystem and food webs in conservation: an example from the herpetological assemblage.

Duever, M.J. 1984. Environmental factors controlling plant communities of the Big Cypress Swamp. In: Gleason, P.J. (ed.), Environments of South Florida: Past and Present II. Miami Geological Society, Miami, Florida, pp. 127-137.

Duever, M.J. 2005. Big Cypress regional ecosystem conceptual ecological model. Wetlands 25(4):843-853.

Hilsenbeck, C.E., R.H. Hofstetter, and T.R. Alexander. 1979. Preliminary Synopsis of Major Plant Communities in the East Everglades Area, Vegetational Maps Supplement. University of Miami, University of Miami Report, Coral Gables, Florida.

Hofstetter, R.H., and C.E. Hilsenbeck. 1980. Vegetational studies of the east Everglades. Final Report to Dade County Planning Department, East Everglades Resources Planning Project: 109pp.

Klein, H., W.J. Schneider, B.F. McPherson, and T.J. Buchanan. 1970. Some Hydrologic and Biologic Aspects of the Big Cypress Swamp Drainage Area. United States Geological Survey Open File Report 70003, Washington, DC.

Jacobsen, T., and J.A. Kushlan. 1984. Population Status of the American Alligator (Alligator mississippiensis) in Everglades National Park. South Florida Research Center, Everglades National Park, Homestead, Florida.

Kushlan, J.A., and T. Jacobsen. 1990. Environmental variability and the reproductive success of Everglades alligators. Journal of Herpetolology 24:176-184.

Loftus, W.F., R.A. Johnson and G. Anderson. 1992. Ecological impacts of the reduction of groundwater levels in the rocklands. In: Stafford, J.A., and J.J. Simon (eds.), Proceedings of the First

International Conference of Groundwater Ecology, American Water Resources Association, Bethesda, Maryland, pp. 199-208.

Loope, L.L., and N.H. Urban. 1980. A survey of fire history and impact in tropical hardwood hammocks in the east Everglades and adjacent portions of Everglades National Park. Report T-592, South Florida Research Center, Everglades National Park, Homestead, Florida.

Mazzotti, F.J. and L.A. Brandt. 1994. Ecology of the American Alligator in a seasonally fluctuating environment. In: Davis, S.M., and J.C. Ogden (eds), The Everglades, the Ecosystem and Its Restoration, St. Lucie Press, Delray Beach, Florida, pp. 485-505.

Ogden, J.C. 2005. Everglades ridge and slough conceptual ecological model. Wetlands 25(4):810-831.

RECOVER 2002. Model Uncertainty Workshop Report: Quantifying and Communicating Model Uncertainty for Decision Making in the Everglades, Restoration Coordination and Verification Program (RECOVER), United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

RECOVER. 2004. CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research. Restoration Coordination and Verification Program, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

RECOVER. 2004b. Draft Conceptual Ecological Models. In: RECOVER. CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research, Restoration Coordination and Verification Program (RECOVER), c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida, Appendix A.

RECOVER. 2006. Comprehensive Everglades Restoration Plan System-wide Performance Measures. Restoration Coordination and Verification Program, c/o South Florida Water Management District, West Palm Beach, FL, and United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. March 16, 2006.

RECOVER 2006b. CERP Monitoring and Assessment Plan: Part 2, 2006 Assessment Strategy for the MAP, Restoration Coordination and Verification. C/O U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, FL and South Florida Water Management District, West Palm Beach FL.

Ryan, J.G., J.A Ludwig, and C.A. Mcalpine. 2007. Complex adaptive landscapes (CAL): A conceptual framework of multi-functional, non-linear ecohydrological feedback systems. Ecological Complexity 4: 113-127.

Sklar, F., L. Brandt, D. DeAngelis, C. Fitz, D. Gawlik, S. Krupa, C. Madden, F. Mazzotti, C. McVoy, S. Miao, D. Rudnick, K. Rutchney, K. Tarboton, L. Vilchek, and Y. Wu. 2000. Hydrological needs – effects of hydrology on the Everglades. In: SFWMD. Everglades Consolidated Report, South Florida Water Management District, West Palm Beach, pp. 2-1 to 2-62.

Stober, J., D. Scheidt, R. Jones, K. Thornton, R. Ambrose, and D. France. 1996. South Florida Ecosystem Assessment Monitoring for Adaptive Management: Implications for Ecosystem Restoration. Interim report. EPA 904-R-96-008, Environmental Protection Agency, Athens, Georgia.

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

Van der Valk, A., F. Sklar, D. Mason, D. Gawlik, P. Wetzel, S. Newman, C. McVoy, Y. Wu, S. Miao, S. Krupa, and M. Korvela. 1998. Proposed Plan of Work for Tree Island Research. Everglades Systems Research Division, South Florida Water Management District, West Palm Beach, Florida.