Lake Okeechobee Performance Measure
Lake Stage

Last Date Revised: March 7, 2007

Acceptance Status: Accepted

1.0 Desired Restoration Condition

In most years, lake stage will vary within an "envelope" based on the annual hydrograph described above and shown in the response curve below. There will not be frequent or prolonged departures of lake stage outside of this prescribed envelope and the occurrence of extreme high and low lake stage events will be rare.

1.1 Predictive Metric and Target

Lake stage remains within the desired envelope – targets differ for deviations above vs. below the envelope, as described below. Also, extreme lake stages above 17 ft and below 10 ft NGVD (target = zero weeks for extremes).

1.2 Assessment Parameter and Target

Same as described in 1.1.

2.0 Justification

A wide body of published research (summarized in Havens 2002) documents the benefits of seasonally variable water levels within the range of 12.5 ft (National Geodetic Vertical Datum-NGVD, June-July low) and 15.5 ft (November-January high) on the plant and animal communities of Lake Okeechobee. Falling water levels in late winter to spring benefit wading birds by concentrating prey resources in the littoral zone where those birds forage (Smith et al. 1995), water levels near 12.5 ft benefit submerged plants and bulrush by providing optimal light levels for photosynthesis in the summer months (Havens et al. 2004), and variation in the prescribed range results in annual flooding and drying of upland areas of the littoral zone, which favors development of a diverse emergent plant community (Richardson et al. 1995, Keddy and Frazer 2000).

Conversely, there is also a wide body of published research on the adverse impacts of extreme high and low water levels on the littoral and near-shore areas of Lake Okeechobee (Havens 2002). Extreme high stage (above 17 ft NGVD) allows wind-driven waves to directly impact the littoral emergent plant and near-shore submerged plant communities, causing physical uprooting of plants. In addition, high stage permits suspended solids from the mid-lake region (where unconsolidated sediments are thickest) are transported to the shoreline regions, reducing water clarity and light penetration which in turn reduces the depth at which SAV growth can occur (James and Havens 2005). High stage conditions also allow deposition of unconsolidated mud which can cover the natural sand and peat sediment, reducing their suitability to sustain healthy and balanced vegetative communities. At extreme high stage, nutrient-rich water from the mid-lake region is transported into the littoral zone where it causes changes in periphyton biomass and taxonomic structure, as well as induce shifts in plant dominance including expansion of cattail. Overall, high lake stages result in extirpation or reduced growth of submerged plants, adverse impacts to germination of submerged plants, reductions in fish spawning and fish reproductive success, and undesirable shifts among species that comprise the macroinvertebrate community. Detailed research results regarding high stage impacts on the lake's plant and animal communities can be found in Maceina and Soballe (1990), Havens (1997), Havens et al. (1999), and Havens et al. (2001).

Conversely, extreme low stage (below 10 ft NGVD) can result in desiccation of the entire littoral zone, the shoreline fringing bulrush zone, and nearly all of the lake area that would otherwise support submerged plants. As a consequence, in-lake habitat for reptiles, amphibians, wading birds, apple snails, or fish that depend on aquatic plant-dominated regions for successful foraging and recruitment is severely compromised. Extreme low stage also encourages invasive exotic plants such as torpedograss and *Melaleuca* to establish in areas of the littoral zone where they did not formerly occur, displacing native vegetation. Recovery from the impacts of prolonged low stage events (below 10 ft MSL) is slow, requiring multiple years of appropriate stage regime to recover, as documented for submerged plants by Havens et al. (2004) and for sport fish such as largemouth bass by Havens et al. (2005).

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

The indicator for this performance measure is stressor in the following conceptual ecological models:

<u>Regional Models</u>
Lake Okeechobee

<u>Ecological Model for Hypothesis Clusters</u>
Ecological Communities and Effects of Water Stages Conceptual Ecological Model

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

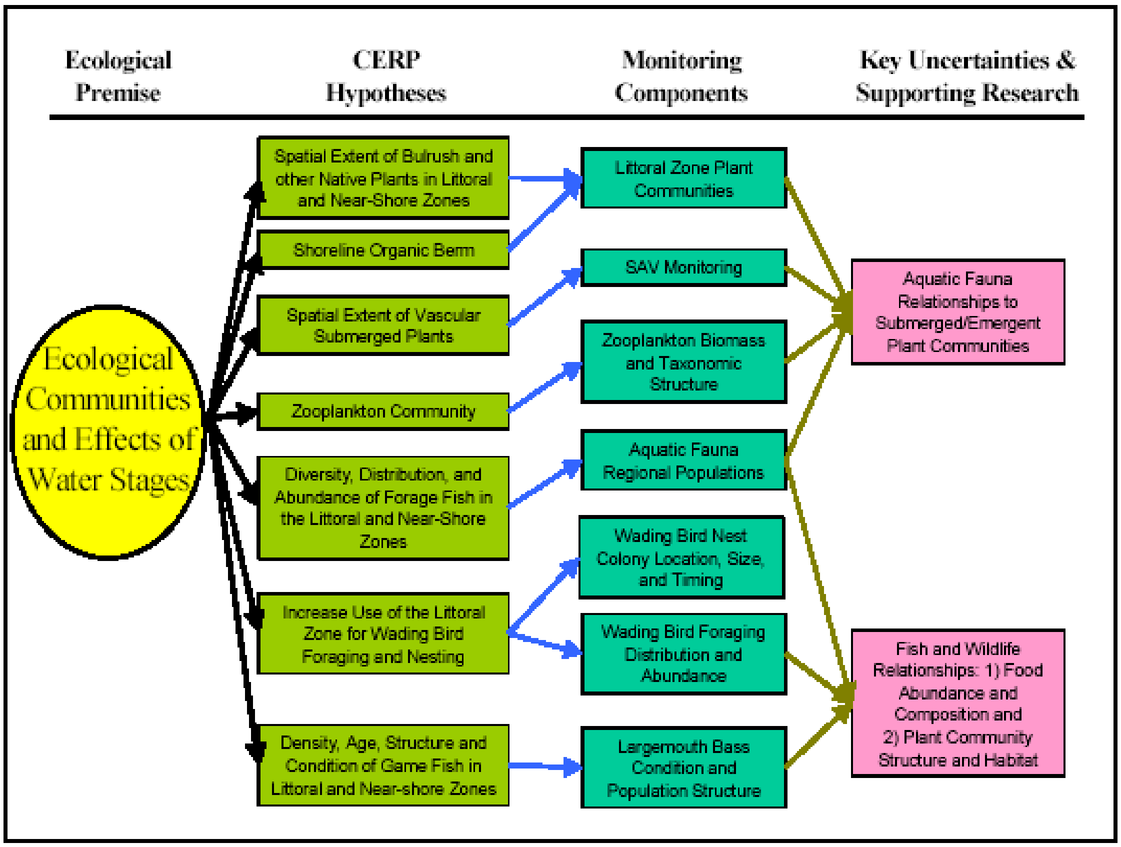
***Ecological Premise*:** Sustained lake levels and a reduction of spring recession conditions have resulted in the loss and degradation of predrainage floral and faunal communities in Lake Okeechobee.

***CERP Hypotheses*:** Providing a reduction in the frequency of extreme high water levels (stage >17 feet and stage >15 feet for more than 12 consecutive months) and low water levels (stage <11 feet and stage <12 feet for more than 12 consecutive months) and an increase in the frequency of spring recessions (yearly stage decline from near 15.5 feet in January to near 12.5 feet in June, with no reversal >0.5 feet) will result in the following changes (see Havens 2002).

- Increase in spatial extent of bulrush along the western lakeshore; increased spatial extent of spikerush, beakrush, willow, and other native plants in the littoral zone; and a reduction in the rate of expansion of exotic and nuisance plants

- Increase in spatial extent of vascular submerged plants, in particular eelgrass, peppergrass, and southern naiad

- Shift in taxonomic structure of zooplankton to better support fishery resources
- Increase in diversity, distribution, and abundance of forage fish in the littoral and near-shore zones.
- Increase in the use of the littoral zone for wading bird foraging and nesting
- Improvement in the density, age structure, and condition of black crappie, largemouth bass, and bream in the littoral and near-shore zones
- Reduction in the occurrence of harmful shoreline organic berms

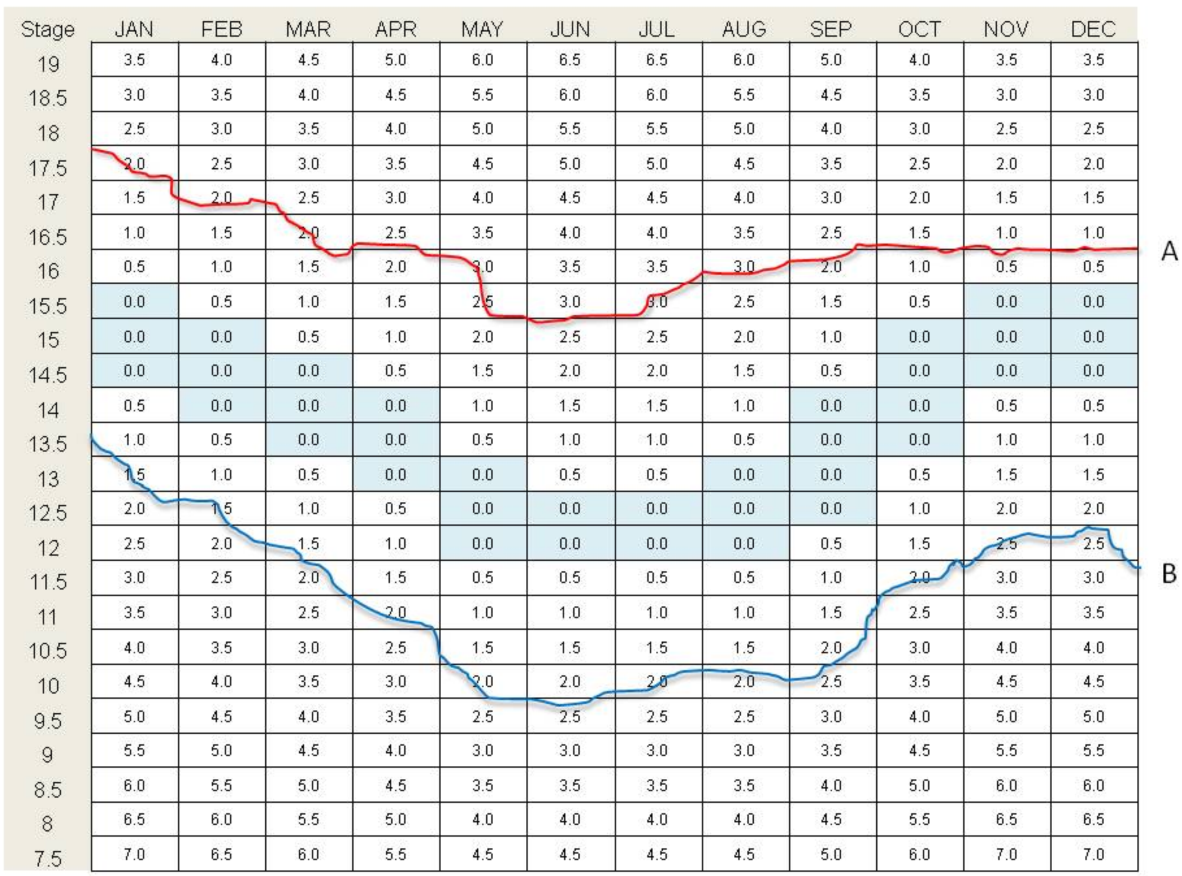


4.0 Evaluation Application

4.1 Evaluation Protocol

Evaluation is based on the 36-year (January 1, 1965 through December 31, 2000) hydrograph of Lake stages that is simulated by the SFWMM model. During each week of the model run, the absolute value of the deviation (in feet) of lake stage from the prescribed envelope is determined. This is done separately for stages above and stages below the envelope. A tally of the number of weeks is kept for each type of deviation. For extreme high and low lake stage events, a tally is made of the total number of weeks that the stage is above 17 ft or below 10 ft NGVD.

This graphic illustrates how the evaluation is performed for the lake stage envelope, where the vertical axis is stage in feet NGVD and the horizontal axis is in months of the year. The shaded central area is the desired stage envelope. In this example, hydrograph A has a score of 25.5 feet-months for stages above the envelope, and a score of 0 for stages below the envelope. Hydrograph B has a score of 0 feet-months for stages above the envelope and a score of 24.0 for stages below the envelope. The actual scoring based on a 36-year hydrographs will be performed with a smoothed upper and lower envelope boundary, in weekly time steps rather than months, and calculation of absolute deviations (ft) above or below the envelope rather than in discrete 0.5 ft units.



Stage	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
19	3.5	4.0	4.5	5.0	6.0	6.5	6.5	6.0	5.0	4.0	3.5	3.5
18.5	3.0	3.5	4.0	4.5	5.5	6.0	6.0	5.5	4.5	3.5	3.0	3.0
18	2.5	3.0	3.5	4.0	5.0	5.5	5.5	5.0	4.0	3.0	2.5	2.5
17.5	2.0	2.5	3.0	3.5	4.5	5.0	5.0	4.5	3.5	2.5	2.0	2.0
17	1.5	2.0	2.5	3.0	4.0	4.5	4.5	4.0	3.0	2.0	1.5	1.5
16.5	1.0	1.5	2.0	2.5	3.5	4.0	4.0	3.5	2.5	1.5	1.0	1.0
16	0.5	1.0	1.5	2.0	3.0	3.5	3.5	3.0	2.0	1.0	0.5	0.5
15.5	0.0	0.5	1.0	1.5	2.5	3.0	3.0	2.5	1.5	0.5	0.0	0.0
15	0.0	0.0	0.5	1.0	2.0	2.5	2.5	2.0	1.0	0.0	0.0	0.0
14.5	0.0	0.0	0.0	0.5	1.5	2.0	2.0	1.5	0.5	0.0	0.0	0.0
14	0.5	0.0	0.0	0.0	1.0	1.5	1.5	1.0	0.0	0.0	0.5	0.5
13.5	1.0	0.5	0.0	0.0	0.5	1.0	1.0	0.5	0.0	0.0	1.0	1.0
13	1.5	1.0	0.5	0.0	0.0	0.5	0.5	0.0	0.0	0.5	1.5	1.5
12.5	2.0	1.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0
12	2.5	2.0	1.5	1.0	0.0	0.0	0.0	0.0	0.5	1.5	2.5	2.5
11.5	3.0	2.5	2.0	1.5	0.5	0.5	0.5	0.5	1.0	2.0	3.0	3.0
11	3.5	3.0	2.5	2.0	1.0	1.0	1.0	1.0	1.5	2.5	3.5	3.5
10.5	4.0	3.5	3.0	2.5	1.5	1.5	1.5	1.5	2.0	3.0	4.0	4.0
10	4.5	4.0	3.5	3.0	2.0	2.0	2.0	2.0	2.5	3.5	4.5	4.5
9.5	5.0	4.5	4.0	3.5	2.5	2.5	2.5	2.5	3.0	4.0	5.0	5.0
9	5.5	5.0	4.5	4.0	3.0	3.0	3.0	3.0	3.5	4.5	5.5	5.5
8.5	6.0	5.5	5.0	4.5	3.5	3.5	3.5	3.5	4.0	5.0	6.0	6.0
8	6.5	6.0	5.5	5.0	4.0	4.0	4.0	4.0	4.5	5.5	6.5	6.5
7.5	7.0	6.5	6.0	5.5	4.5	4.5	4.5	4.5	5.0	6.0	7.0	7.0

4.2 Normalized Performance Output

LAKE STAGE ENVELOPE

For the lake stage envelope component, it is necessary to develop separate response curves for the stage above and below the envelope. For deviation of lake stage above the envelope, the target is 0 weeks. The response curve is developed from the performance measure graphic. Consider the stage envelope area with zero values to represent good conditions, the next bands of 0.5 ft stage above that envelope to represent fair conditions, and the subsequent (1.0 ft) band to represent poor conditions. The worst case scenario is considered to be one where the lake stage hydrograph always is in the poor zone. This equates to a total score of 1.0 ft x 52 weeks / year *

36 years 1,872 ft weeks. The response curve is a line between 0 (target) and 1,872 (worst case). Raw scores can be calculated from the following equation:

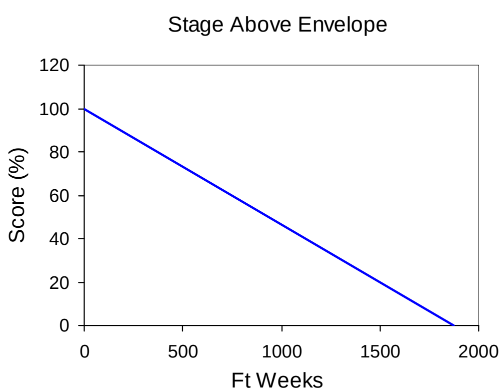
*Standardized score (%) = raw score * -0.0534 + 100*

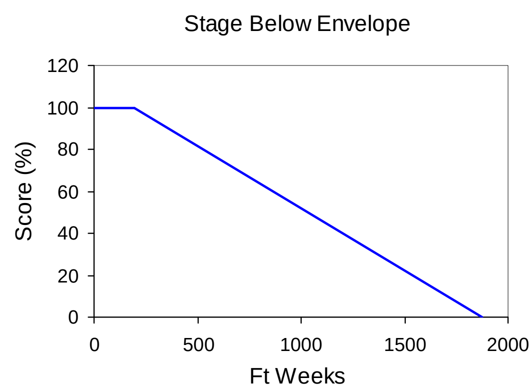
For deviation of lake stage below the envelope, the target is 192 ft weeks. This is the score that would be obtained if all years had hydrographs within the optimal zone, except for once per decade the stage falling to just below 11 ft for an average of 3 months. These periodic low stage events, which occurred at this approximate frequency and duration in the 1950s to 1970s (prior to implementation of high stage regulation schedules), are considered to be beneficial to the littoral zone because they allow for periodic exposure of seed banks, oxidation of accumulated organic material, and fires that are important to maintaining species diversity in the littoral zone.

In this case the response curve is a line between 192 (target) and 1,872 (worst case):

Standardized score (%) = raw score * -0.0595 +111.429

Except where the score is below 192, where the score remains at 100%. The following graphs show the response curves.





HIGH AND LOW LAKE STAGE

For extremes in high (>17 ft NGVD) and low (<10 ft NGVD) lake stages, the response curves (shown below) relate the raw scores for each component of the performance measure to a standardized scale of 0 to 100. Once a standardized score is calculated, it can be converted to other units of measure, such as habitat units, and/or combined with other scores to get a weighted or non-weighted average score for the alternative under consideration.

In the case of extreme high lake stage, the maximal value for the raw score is 52 weeks / year x 36 years = 1,872 weeks. However, based on our understanding of the impacts of high stage, it is quite certain that maximal impacts would occur at a lower frequency of these extreme events. For example, in 1998 and 1999, nearly 100% of the lake's submerged plant community was physically uprooted and piled up on the western shoreline and over 100 m of littoral emergent vegetation was also uprooted – when stage was over 17 ft for just 16 and 7 weeks, respectively. This was the most severe case of high water damage documented on the lake during the last 30 years. Thus, we take this duration for >17 ft stage (average 11 weeks / year = 396 weeks in a 36 year model run) and set it as the point equivalent to a score of 0 on the standardized scale. To convert from a raw score to a standardized score, the following simple regression equation is applied:

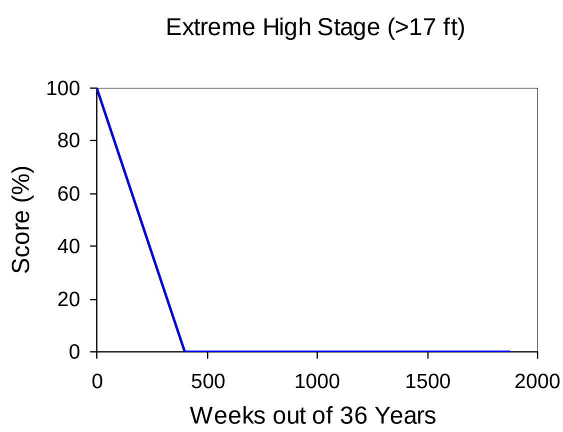
*Standardized score = raw score * -0.253 + 100*

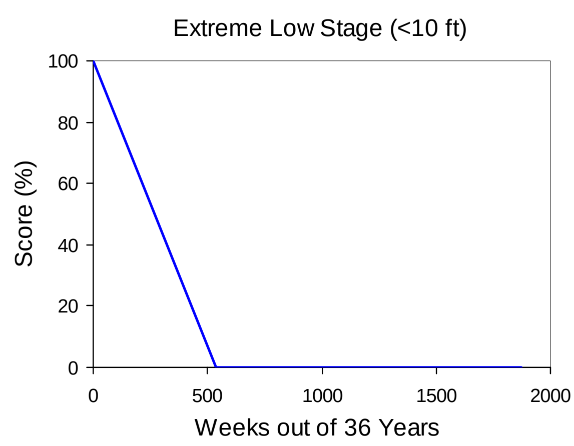
This assumes a linear increase in risk of ecological damage between the optimal conditions (zero weeks) and the most severe condition (396 weeks), which is the most conservative approach to take until there are data to support a more complex relationship. The equation will need to be re-calculated if in the future the model period is extended beyond 36 years.

In the case of extreme low lake stage, the maximal value for the raw score is 52 weeks / year x 36 years = 1,872 weeks. However, based on our observations of the impacts of just 15 weeks of lake stage below 10 ft during the 2001 drought, we can assign this value as the worst case situation, knowing that it produced impacts that took multiple years to recover (e.g., lost apple snail populations, extensive woody vegetation in shoreline areas). We take this duration for <10 ft stage (15 weeks / year = 540 weeks in a 36 year model run) and set it as the point equivalent to a score of 0 on the standardized scale. To convert from a raw score to a standardized score, the following simple regression equation is applied:

*Standardized score = raw score * -0.185 + 100*

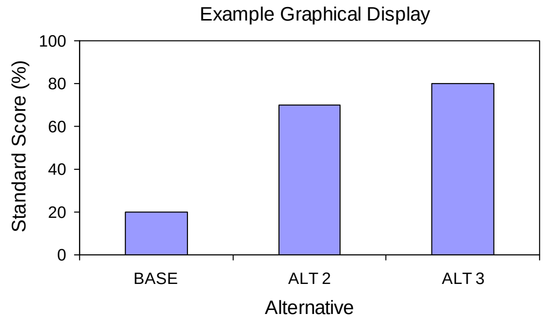
This assumes a linear increase in risk of ecological damage between the optimal conditions (zero weeks) and the most severe condition (540 weeks), which is the most conservative approach to take until there are data to support a more complex relationship. The equation will need to be re-calculated if in the future the model period is extended beyond 36 years.





4.3 Model Output

For each component of this performance measure, results for different planning alternatives can be displayed as simple bar graphs, where height of bars corresponds to standardized scores for this performance measure. The following is a generic example.



4.4 Uncertainty

There has not been a formal uncertainty analysis for this performance measure. There is a known amount of uncertainty associated with lake stages predicted by the SFWMM, and an unknown amount of uncertainty associated with how seasonal variation in lake stage affects various components of the lake's plant / animal community.

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

Hydrology Monitoring Network Module section 3.5.3.1 (RECOVER 2004a). Daily lake stages are recorded by the USACE at an array of stations in the lake. Assessment is performed by tracking changes in lake stage relative to the envelope described above. Additional assessment is performed by identifying the frequency of occurrence and duration of events where stage rises above 17 ft or falls below 10 ft NGVD. See *The RECOVER Teams' Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan –* Indicator 2.2 Water Levels in Lake Okeechobee (RECOVER 2005)

5.2 Assessment Approach

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

Lake Okeechobee Revised Stage Schedule model (LORSS).

6.2 Assessment Tools Needed

Daily lake stage information.

7.0 Notes

This Performance Measure supersedes and addresses LO-1 Lake Okeechobee Extreme Low Lake Stage (Last Date Revised: Nov 18, 2004), LO-2 Lake Okeechobee Extreme High Lake Stage (Last Date Revised: Nov 18, 2004), and LO-3 Lake Okeechobee Stage Envelope (Last Date Revised: Nov 18, 2004).

8.0 Working Group Members

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