Lake Okeechobee Performance Measure
Water Quality Mosaic

Last Date Revised: March 8, 2007

Acceptance Status: Accepted

1.0 Desired Restoration Condition

Reduce arithmetic average P concentrations in the lake to 40 ppb. Reduce arithmetic average total phosphorus loads from surface inflows to the lake to 105 metric tons/year. Elevate the pelagic zone TN:TP average mass ratio to a value higher than 22:1. Reduce frequency and intensity of algal blooms such that less than 5% of pelagic samples exhibit chlorophyll *a* concentrations greater than 40 ppb. When the Lake is within the desirable stage envelope (see Lake Okeechobee Stage Performance Measure for details) these lower water levels would increase the area of lake bottom that receives ample light for submerged plant growth. Increased amount of submerged plants can stabilize the local sediments, reducing re-suspension and enhancing water clarity and light penetration, which produces a feedback loop to improve the health of the lake.

1.1 Predictive Metric and Target

In-lake arithmetic average P values at or below 40 ppb. Pelagic TN:TP long-term average mass ratio higher than 22:1. Fewer than 5 percent of values collected during the routine monitoring program with greater than 40 ppb chlorophyll *a*.

1.2 Assessment Parameter and Target

Annual concentration at or below an arithmetic mean concentration of 40 ppb. Long-term average (five year) phosphorus loads into the Lake at or below 140 metric tons/year, including inputs from atmospheric deposition. Atmospheric deposition is considered to bring 35 metric tons/year of phosphorus to the Lake; therefore, the target is 105 metric tons/year from surface inflows (FDEP 2001). Pelagic TN:TP long-term average mass ratio higher than 22:1. Less than 5% of pelagic samples with >40 ppb chlorophyll *a* as determined on an annual and an inter-year month to same-month basis. Secchi disk visible on lake bottom in shoreline region from May to September to allow adequate light for submerged plant growth; trends shall be evaluated as increasing or decreasing per cent of observations inter-annually for the five month period combined, and inter-annually for each of individual month of the five month period.

2.0 Justification

Water quality encompasses very broad suites of many measurable attributes that result from substances either dissolved or suspended in water, a number of which are of environmental and/or public health concerns (see Surface Water Quality Standards, 62.302 FAC). Quality of water is a determinant factor as to the degree to which a water body may successfully sustain healthy, diverse plant and animal communities. Lakes, as a consequence of their typical hydrologic and morphologic characteristics, often act as sinks for substances and contaminants. Lakes present an area of relative quiescence allowing materials transported from faster flowing tributaries to settle and/or increase the time and exposure of introduced materials to biological processes. In cases where the assimilative capacity of a lake is exceeded, algal blooms, destabilized oxygen regime, and other symptomatic conditions may occur. Lakes are particularly vulnerable to watershed changes that result in decreased quality of basin runoff, changes in the timing and distribution of flows, and increased concentrations and loads entering the lake.

Key water quality characteristics of concern for Lake Okeechobee are the concentration of the nutrient phosphorus (P) and the ratio of nitrogen (N) to phosphorus, algal bloom frequency and composition, dissolved oxygen regime, ammonia, chloride and iron concentrations, turbidity, sedimentation rates, sediment resuspension, and cycling of nutrients sequestered in the bottom sediments. These characteristics are inter-related (see Figure 1) and must be evaluated within this context to determine acceptable and unacceptable water quality conditions. This Performance Measure considers water quality from the perspective of sustainable and desirable ecological response.

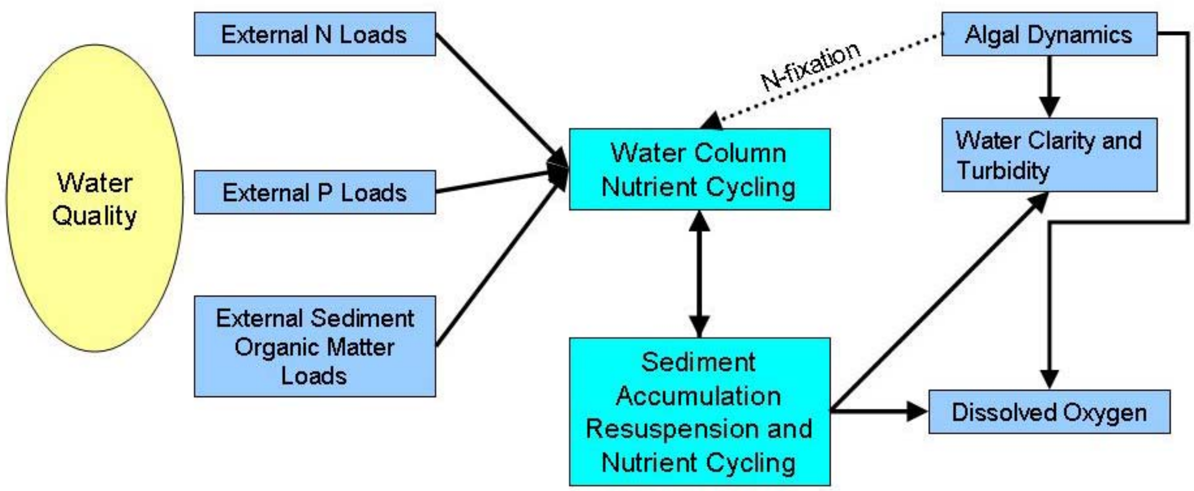


Figure 1. Inter-relationships of key water quality characteristics. Dotted lines denote key feedback loops: Undesirable algal species tend to float on the surface and can fix atmospheric nitrogen; Sediment cycling of phosphorus exacerbates basin P loads. Dissolved oxygen regime is result of aeration, temperature, etc., in addition to sediment oxygen demand and algal dynamics.

The purpose of this Performance Measure is to define expectations for water quality improvements that can be attributed to the implementation of CERP, and to provide a tool to evaluate and assess those improvements. Other state and local efforts, e.g. the State's Total Maximum Daily Load program (TMDL), are expected to compliment and supplement CERP-afforded improvements in water quality. The implementation of these other efforts, which include effective agricultural and urban Best Management Practices (BMPs), are outside the purview of CERP and are not addressed by this Performance Measure.

All conceivable variants of CERP implementation, e.g., water storage in reservoirs and passage through stormwater treatment areas (STAs), re-hydration of wetlands, mediation or re-direction of flows, are expected to beneficially impact multiple water quality attributes in Lake Okeechobee.

Under current conditions, the total phosphorus load to Lake Okeechobee has averaged more than 500 metric tons/year (Havens and James 2005). TP concentrations in Lake Okeechobee when first measured in the early 1970s were 40 to 50 ppb; however, as a result of the continued influx of elevated nutrient loads, concentrations have increased over the intervening decades and now average 158 ppb (Water Year 2002-2006, Zhang et al. 2006). This rapid rise in nutrient content has accelerated eutrophication of the lake (Havens et al. 1996), and has exacerbated a series of complex and interrelated adverse ecological responses.

A numeric goal of 40 ppb total phosphorus, as measured in the pelagic zone of the lake, was identified by Havens and Walker (2002) as that necessary to restore and sustain the health of the lake. This numeric goal is consistent with previous published research (Havens and James 1997). The purpose of Florida's Lake Okeechobee Protection Program is to achieve this goal (SFWMD et al. 2004). To achieve this goal, external P loads to the lake must be reduced to 140 metric tons per year (105 from surface inflows and 35 from atmospheric deposition, Havens and Walker 2002, FDEP 2001).

CERP will reduce phosphorus loads entering the lake through projects that provide treatment and storage within the watershed. Treatment facilities, aquifer storage and recovery (ASR) wells and sediment removal from tributaries also will reduce P loadings to Lake Okeechobee. Although meeting the TMDL is the responsibility of the state of Florida, CERP will make positive contributions toward attaining these goals. This performance measure will quantify those contributions.

Management of water levels can either beneficially or negatively impact phosphorus concentrations in Lake Okeechobee (Havens et al. 2001, Havens 1997, James and Havens 2005). Water levels either too high or too low can impair the function of the within-lake vegetative community that otherwise serves to mediate nutrient concentrations. Lake recovery, through reduced nutrient and sediment loadings, can be accelerated by prudent management of water depth.

Water quality data collected on the lake since the early 1980s indicate that the frequency of algal blooms (i.e., chlorophyll *a* concentrations >40 ppb) has significantly increased (Walker and Havens 1995, Havens et al. 1995) as a result of increasing nutrient availability. Of increasing concern are harmful algal blooms (e.g., cyanobacteria) in Lake Okeechobee, which become prevalent over more desirable algae when the TN: TP mass ratio within the water is below 22:1 (Smith et al. 1995). The present mass ratio is well below this threshold and is near 12:1 (Havens et al. 2003). Presently, cyanobacteria are extremely dominant and include those species known to produce toxins. The frequency and nature of these blooms threaten both the natural and societal (e.g., drinking water) values of the Lake's ecosystem (Paerl 1988).

Sedimentation rates in the Lake have increased about two-fold during the last century (Brezonik and Engstrom 1998) resulting in a layer of unconsolidated sediment covering approximately forty-four percent of the Lake bottom, especially in the pelagic areas. Water clarity in Lake Okeechobee is very low, primarily due to resuspended sediments. This is of particular concern in the shallow "near-shore" areas of the pelagic zone, which could otherwise support widespread beds of submerged plants provided water clarity remains sufficiently high (Havens et al. 2004). Submerged plants sequester nutrients, which may reduce algal bloom frequency. Increases in coverage of submerged plants would increase expanse of fish habitat thereby increasing reproductive success of fish populations. Poor clarity in the near-shore area is related to lake stage, because high lake stage facilitates horizontal mixing and transport of resuspended mud from mid-lake into this ecologically sensitive zone (James and Havens 2005).

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
Lake Okeechobee

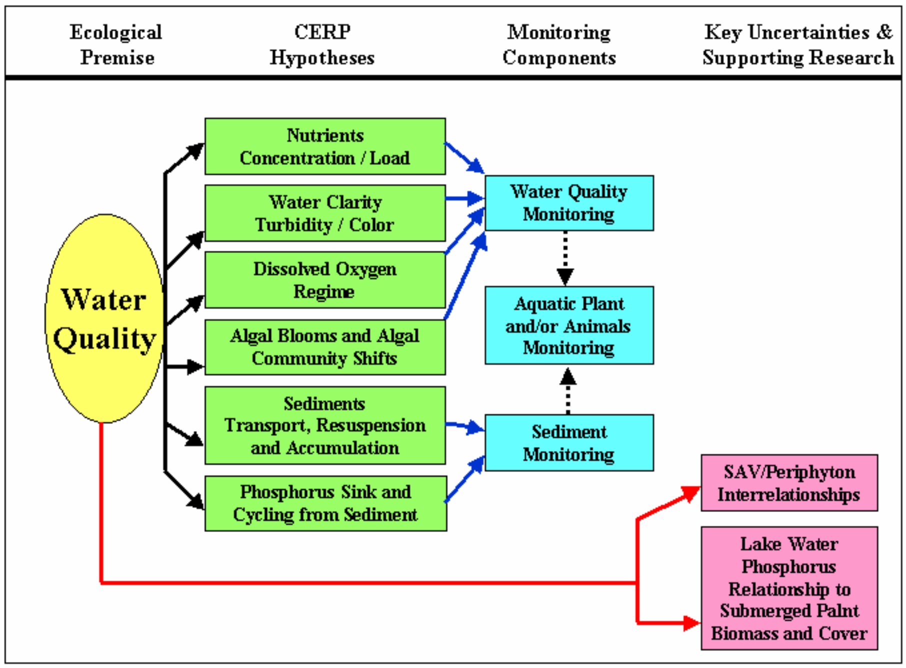
Ecological Model for Hypothesis Clusters
Water Quality Conceptual Ecological Model (See Figure Below)

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

Ecological Premise: The pre-drainage Lake Okeechobee was characterized by hydrologic inputs primarily from rainfall and inflow from tributaries draining wetlands, forest, and range lands. This resulted in relatively moderate phosphorus inputs to the lake and moderately eutrophic conditions in the ecosystem. This contrasts sharply with the present condition of high phosphorus inputs from agricultural lands and highly eutrophic lake conditions.

CERP Hypothesis: A decrease in phosphorus inputs to the lake will result in the following changes:

- Reduction in pelagic (open-water) total phosphorus concentrations to 40 ppb
- Increase in pelagic total nitrogen:total phosphorus mass ratios to >22:1
- Increase in the ratio of diatoms:cyanobacteria biovolume ratio to >1.5:1, resulting in a more desirable food web to support the lake's fishery
- Decrease noxious cyanobacteria bloom frequency
- Decrease in algal blooms with Chlorophyll a concentration > 40 ppb
- Increase in water clarity
- Decrease in the relative abundance of pollution-tolerant benthic macroinvertebrates in the lake sediments



4.0 Evaluation Application

4.1 Evaluation Protocol

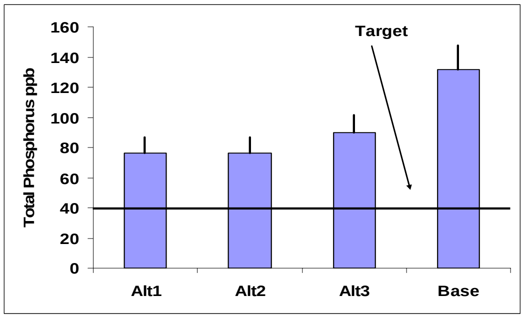
The Lake Okeechobee Water Quality Model (LOWQM) version 3.2 will be used to forecast TP and TN concentrations in the water column (James et al. 2005). Predicted annual arithmetic averages will be compared to the 40 ppb standard for each alternative. Alternatives that produce annual averages of TP closer to or below 40 ppb and mass ratio averages of TN:TP of 22:1 or higher will be preferred. The Lake Okeechobee Environment Model (LOEM) predicts nutrients, chlorophyll a, resuspended sediments, SAV.

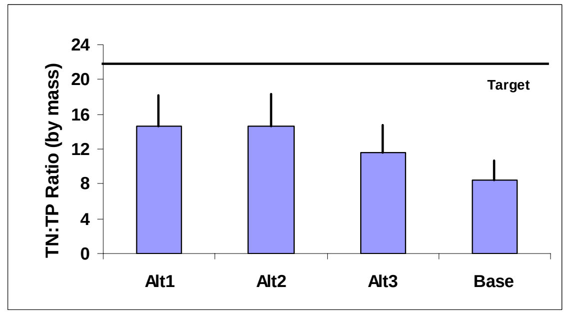
4.2 Normalized Performance Output

Scores have not been developed.

4.3 Model Output

For any particular comparison of planning alternatives, results can be displayed as simple bar graphs, where height of bars corresponds to the mean of total phosphorus in the last five years of each simulation. The error bars represent the uncertainty.





4.4 Uncertainty

Nutrients will be addressed through a limited uncertainty analysis (100 simulations) that will focus on parameters related to P and N cycles, and to N loadings (+/- 20% from predicted). Based on current information on STA performance (Indian River Lagoon Environmental Impact Statement), nitrogen loadings will not change from current values (with the exception of uncertainty).

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See *CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research* - Lake Okeechobee Module section 3.4.3.1 (RECOVER 2004a). Water samples are collected using standard methods at eight long-term pelagic monitoring stations (L001-L008) and other sites in the lake, depending on the variable. Samples are analyzed for total phosphorus, unionized ammonia, chlorophyll a, chloride, conductance, dissolved oxygen, iron, nitrate, pH transparency and turbidity by standard methods and following established SFWMD QA/QC guidelines. Performance is assessed on the basis of the most sensitive and appropriate statistical approach toward documenting long-term trends in concentration, which may include but may not be limited to utilization of geometric and/or arithmetic averages of the measured concentrations.

See *The RECOVER Team's Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan* – Indicator 2.1 Lake Okeechobee Phosphorus (RECOVER 2005)

5.2 Assessment Approach

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

SFWMM monthly budget output – Lake Okeechobee Water Quality Model – SAS Bayesian Uncertainty Program. Lake Okeechobee Environment Model

6.2 Assessment Tools Needed

7.0 Notes

8.0 Working Group Members

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9.0 References

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