Benefit-Cost Analysis to Develop The Lake Okeechobee Protection Plan

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This study was funded by the South Florida Water Management District to provide a benefit-cost analysis of 12 alternatives to reduce the amount of phosphorus entering Lake Okeechobee[1]. These alternatives are called phosphorus control alternatives, or PCAs. Benefits and costs of each alternative to the district, landowners, and the regional economy were described and quantified using the best available information.

A computerized Full Cost Accounting Evaluation Model was developed to measure the relative benefits and costs of the alternatives using evaluation criteria. The model provides a ranking of alternatives based on the magnitude of itemized benefits and costs. It can be updated as new data and information become available.

This study was the first attempt to estimate benefits and costs of the PCAs. In the process, some assumptions were used when sufficient information was lacking. Benefits and costs of each alternative to the district, to landowners, and to the regional economy were described and quantified using the best available information, not necessarily measured phosphorus reductions. The information from this study assisted in the development of the 2004 Lake Okeechobee Protection Plan, a state mandate implemented by multiple agencies.

Background

Lake Okeechobee supports valuable recreational and commercial fisheries, provides flood control, and acts as a reservoir for both potable and irrigation waters for much of South Florida. Land use (agricultural) and hydrological changes (more efficient delivery of stormwater) in the agricultural watershed surrounding Lake Okeechobee have contributed to a serious decline in lake and downstream water quality, affecting most all flora and fauna communities and causing substantial blue-green algae blooms during the mid-1980s.

Best Management Practices (BMPs) and regulatory programs have been implemented over the past 25 years to reduce phosphorus loads to the lake; however, these programs alone will not be sufficient to achieve an in-lake phosphorus concentration goal of 40 parts per billion (ppb) or the required total maximum daily load (TMDL) of 140 metric tons per year from all sources. Phosphorus loads delivered to the lake during the period 1995 through 2000 have been estimated at about 573 metric tons/year. Thus, the overall load reduction goal for the lake is 433 metric tons/year, based on the referenced five-year average load, or 75 percent. Current programs need to be supplemented by additional programs to meet this goal, and non-regulatory measures with willing landowners are needed.

The study area is north of Lake Okeechobee (**Figure 1**) and is primarily agricultural. The study period is 60 years in order to consider the time series of benefits and costs. General baseline conditions from which the benefits and costs of a PCA are measured include:

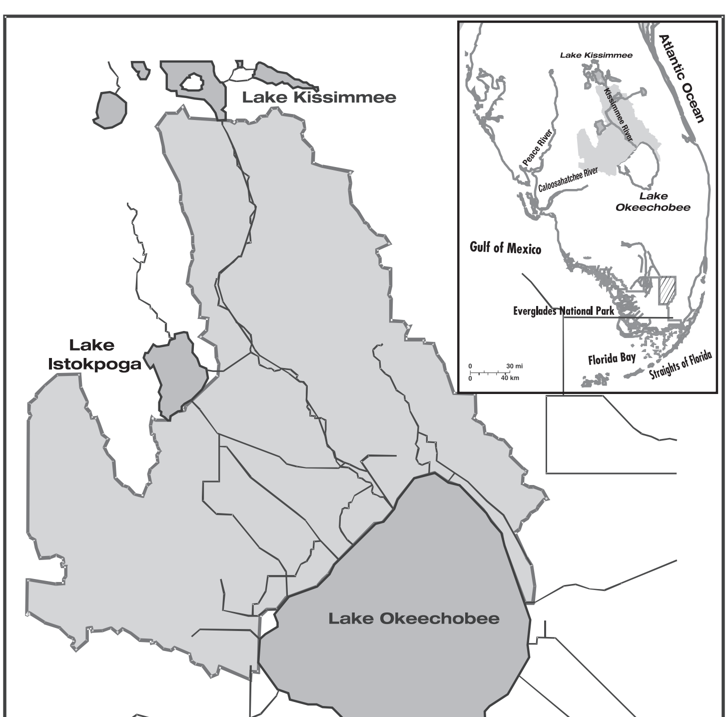

Figure 1 – Project Study Area

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1. The rules and programs that existed as of September 2000 are in effect throughout the study period. No new rules or programs affecting landowners in the study area are promulgated during the study period, including new or additional water-quality standards or new NPDES permitting requirements.
2. None of the projects described in the U.S. Army Corps of Engineer's and the South Florida Water Management District's Comprehensive Everglades Restoration Plan are built during the study period.
3. The land uses in the study area during the study period are those that were projected during this study.

Phosphorus Control Alternatives

The following PCAs were evaluated:

- *PCA 1—Chemical Treatment of Runoff at Edge of Properties.* Each landowner would be responsible for constructing, operating, and maintaining a chemical system that treats runoff and stormwater at the edge of the property before it enters local streams and tributaries.
- *PCA 2—Wetlands Treatment of Runoff at Edge of Properties.* Each landowner would be responsible for constructing, operating, and maintaining a wetland system that treats runoff and stormwater at the edge of the property before it enters local streams and tributaries.
- *PCA 3—Non-Structural Management at the Land Parcel Level.* Under this PCA, all landowners would use non-structural practices to reduce imports of phosphorus and to reduce the transportability of phosphorus from their land. Examples of new management methods include: (1) use of calibrated soil testing and leaf sampling to determine optimal fertilization using the services of the University of Florida

[1]*Hazen and Sawyer in association with Soil and Water Engineering Technology, Inc., "Natural Resource Analysis of Lake Okeechobee Phosphorus Management Strategies – Phase II", Summary Report and Documentation Report, Contract C-11677, prepared for South Florida Water Management District, December 2003.*

Cooperative Extension Service; (2) application of soil amendments to reduce the solubility and transportability of phosphorus, and (3) no applications of phosphorus to pasture land.

- ***PCA 4—Optimization of Dairy Rule Design.*** This PCA is an optimization of the existing Dairy Rule design to significantly increase the removal of phosphorus from stormwater. All lactating cows would be confined to the high-intensity area (HIA). The manure and the wastewater from the HIA would be treated in the same manner as the existing Dairy Rule modifications, and these modifications would be expanded to treat the larger volumes of water.

Table 1
Summary of Values for Criteria 1, 2, and 3 for Each Phosphorus Control Alternative (PCA)

PCA Description	1: Average Annual Reduction in P Load Entering Lake		2: P Concentration at Edge of Field/Site After PCA Implemented		3: PV Cost Per Pound of Phosphorus Removed From Lake (2000 $)	
	Pounds per Year	Confidence Level (a)	Parts per Billion	Confidence Level (a)	Dollars per Pound of P Removed	Confidence Level (a)
1. Chemical treatment of runoff at edge of property	226,000	High	125	High	$173	High
2. Wetlands treatment of runoff at edge of property	155,000	High	306	High	$119	High
3. Non-structural management at the land parcel level	261,000	Moderate	216	Moderate	$50	Moderate
4. Optimization of dairy rule design	35,000	High	750	High	$83	High
5. Enhanced cow-calf BMPs	198,000	Moderate	208	Moderate	$49	Moderate
6. Alternative land uses	73,000	High	501	High	$266	Moderate
7. Reservoir assisted stormwater treatment areas (RASTAs)	94,000	High	40	High	$104	High
8. Taylor Creek/Nubbin Slough RASTA with Lake Okeechobee supplemental water source	72,000	High	40	High	$90	High
9. Tributary sediment removal	29,000	Moderate	212	Moderate	$6	Moderate
10. Terminal large-scale water treatment facilities	119,000	High	10	High	$139	High
11. Isolated Wetlands Restoration on Pastureland (200,000 acres)	121,000	Moderate	193	Moderate	$109	Moderate
12. Dairy Farm Composting	38,000	Moderate	650	Moderate	$95	Moderate

(a) Confidence Level refers to the uncertainty associated with the data and information used to estimate the value in terms of obtaining "planning level" estimates. Moderate means that the studies used to obtain the estimates provided reservations about the accuracy of the results or that insufficient data and information exists to provide a High level of confidence. The High level implies that the data and information used to develop planning estimates are reasonable for a planning level analysis.

- ***PCA 5—Enhanced Cow-Calf BMPs.*** Under this PCA, a BMP program would be implemented by all cow-calf operations in the study area. The Enhanced Cow-Calf BMPs include the following elements: fencing; ponds, troughs, or tanks for cattle watering; and the setting of stocking rates for individual pastures based on phosphorus loading characteristics of the site. The average stocking rate used under this PCA is one cow per four acres from the estimated current average of one cow per three acres.
- ***PCA 6—Alternative Land Uses.*** Under this PCA, land uses that contribute relatively high phosphorus loads would be converted to land uses that contribute relatively low or no phosphorus loads to Lake Okeechobee. Land-use conversions include converting all dairy operations to cow-calf operations with improved management, converting all citrus and field-crop operations to natural areas, and converting all row-crop operations to cow-calf operations.
- ***PCA 7—Watershed Reservoir-Assisted Stormwater Treatment Areas (RASTAs).*** The U.S. Army Corps of Engineers and the South Florida Water Management District identified two RASTA projects as priority projects for Everglades restoration during their restudy. They include the Taylor Creek/Nubbin Slough Stormwater Treatment Area (STA); and two Lake Okeechobee Watershed water-quality treatment facilities. Each project includes an above-ground reservoir and stormwater treatment areas.
- ***PCA 8—Taylor Creek/Nubbin Slough RASTA with Lake Okeechobee Supplemental Water Source.*** This PCA is the Taylor Creek/Nubbin Slough Reservoir-Assisted Stormwater Treatment Area (TC/NS RASTA) as described under PCA 7. In addition, under PCA 8, half of this RASTA would have access to water from Lake Okeechobee. Overall, water would flow from the lake to the RASTA through the pipeline about 5 percent of the time.
- ***PCA 9—Tributary Sediment Removal.*** Under this PCA, sediment would be dredged from 10 miles of primary canals within eight sub-basins of the study area. This project is part of the Lake Okeechobee Watershed Project being evaluated by the U.S. Army Corps of Engineers and the South Florida Water Management District.
- ***PCA 10—Terminal Large-Scale Water Treatment Facility.*** Under this PCA, water would be diverted from the Kissimmee River prior to entering Lake Okeechobee and treated to reduce the total phosphorus content. The treated effluent would then be returned to the source water at a downstream location. This alternative considers the construction of a water treatment plant using chemical treatment, followed by solids separation advanced technology to achieve the necessary reduction in total phosphorus.
- ***PCA 11—Isolated Wetlands Restoration on Pastureland.*** Under this PCA, the owner of improved pastureland would restore a portion of his/her improved pastureland to isolated wetlands. The owner would implement certain best management practices on the remaining improved pastureland. For the purposes of this analysis, on average in the study area, a given improved pasture area would have 40 percent of the land restored to isolated wetlands with a cattle stocking rate of one cow per 16 acres (1/16 cows/acre), and 60 percent of the land would remain as improved pasture with a stocking rate of one cow per four acres (1/4 cows/acre). On the improved pasture, the owner would not apply any phosphorus. This program would be implemented on 200,000 acres of improved pastureland in the Lake Okeechobee watershed study area. As of 2002, there were about 433,000 acres of improved pastureland in the study area.
- ***PCA 12—Dairy Farm Composting.*** Under this PCA, owners of dairy farms in the Lake Okeechobee study area would collect, separate and compost animal solid waste. The compost would be sold in bulk to local farms for use as a soil amendment and a phosphorus source in lieu of inorganic fertilizer. PCA 12 is an expansion of PCA 4— Optimization of Dairy Rule Design, where the separated solids are composted and used in lieu of phosphorus fertilizer, either inside or outside the study area.

Evaluation Criteria

Each PCA was scored based on each of the following 10 criteria (numbers in parentheses are the weights assigned to each criterion, with 100 being the maximum weight):

A. **Phosphorus Reduction Benefits**

1. Average annual change in the amount of phosphorus entering Lake Okeechobee in pounds per year (100)
2. Expected phosphorus concentration at the edge of the field as measured in parts per billion (ppb) (75)

B. **Cost-Effectiveness**

3. Present-value cost per pound of phosphorus removed from the lake (100)

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Table 2
Summary of Values for Criteria 4 Through 10 for Each Phosphorus Control Alternative (PCA)

PCA Description	4. Surface Water Mgmt Objectives	5. Water Supply Increase	6. Acres of Wildlife Habitat	7. PV Change in Income (Millions of 2000 $)	8. Rec. Opport.	9. Engin. / Tech. Track Record	10. Env. Comp./ Permit Ease
1. Chemical treatment of runoff at edge of property	4	1	15,000	-$157.1	0	3	2
2. Wetlands treatment of runoff at edge of property	4	1	24,000	-$302.9	0	3	3
3. Non-structural management at the land parcel level	2	0	0	$22.1	0	3	4
4. Optimization of dairy rule design	3	0	0	$107.3	0	4	4
5. Enhanced cow-calf BMPs	4	1	0	$44.7	0	4	4
6. Alternative land uses	4	4	68,000	-$5,838.3	1	4	4
7. Reservoir assisted Stormwater Treatment Areas (RASTAs)	3	2	11,000	$51.8	1	4	4
8. Taylor Creek/Nubbin Slough RASTA with Lake Okeechobee supplemental water source	3	2	5,000	$27.2	1	4	4
9. Tributary sediment removal	2	0	0	$0.4	0	3	3
10. Terminal large-scale water treatment facilities	3	2	1,000	$65.9	1	3	2
11. Isolated Wetlands Restoration on Pastureland (200,000 acres)	4	3	80,000	-$37.5	0	3	4
12. Dairy Farm Composting	3	0	0	$113.7	0	2	4

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C. **External Benefits and Costs**
 4. Success in achieving surface-water management objectives (25)
 5. Water supply benefits (25)
 6. Acres of increased/improved wildlife habitat (25)
 7. Present-value change in regional income (100)
 8. Potential for increased recreation opportunities (10)

D. **Risk and Uncertainty Measures**
 9. Engineering/technological track record (50)
 10. Permitting uncertainty (50)

Evaluation of Phosphorus Control Alternatives

A summary of the values for each criterion and each PCA is presented in **Table 1** and **Table 2**. The Criterium Decision Plus (CDP) model was used for the evaluation. This model scales the quantitative and qualitative scores assigned to each criterion and each PCA (Tables 1 and 2) to a number between zero and one. For each PCA, the scaled value of each criterion was weighted based on the importance of each criterion and then summed among all 10 criteria to obtain the total score. The lowest possible total score is zero and the highest possible total score is one (0 < total score < 1).

Scoring and Ranking of PCAs

Table 3 shows the scoring and ranking results. PCA 5—Enhanced Cow-Calf Best Management Practices scored the highest of the 10 PCAs with a total score of 0.669, followed by PCA 7—RASTAs with a score of 0.630 and PCA 3—Non-Structural Management at the Land Parcel Level with a score of 0.614. The scores of PCA 8—Taylor Creek/Nubbin Slough RASTA with Lake Okeechobee Supplemental Water Source and PCA 11—Isolated Wetlands Restoration on Pastureland are very close to each other in value: 0.594 and 0.593 respectively.

Contributions of Criteria to Total PCA Scores

The contributions of the individual criteria to the total score for each PCA were evaluated. The highest-ranked PCA, Enhanced Cow-Calf BMPs (PCA 5), scores well overall because it scores relatively well under seven of the 10 criteria with respect to the other PCAs. RASTAs (PCA 7), the second-ranked PCA, is not one of the best in terms of overall phosphorus load reduction; however, it has positive scores for all 10 criteria.

The third-ranked PCA, Non-Structural Management at the Land Parcel Level (PCA 3), scores well with respect to Criterion 1, Total Phosphorus Reduction at the Lake; Criterion 3, Present-Value Cost per Pound of Phosphorus Removed from the Lake; and Criterion 10, Environmental Compliance and Permitting Ease.

The fourth-ranked PCA, Taylor Creek/Nubbin Slough RASTA with Lake Okeechobee Supplemental Water Source (PCA 8), scored well with respect to all 10 criteria. It ranks below PCA 7 because it does not reduce phosphorus loads to the lake as much as PCA 7, even though it is slightly less expensive per pound of phosphorus removed ($90 for PCA 8 versus $104 for PCA 7).

PCA 4—Optimization of Dairy Rule Design and PCA 12—Dairy Farm Composting scored the lowest of all PCAs because their total phosphorus load reduction to the lake is relatively low. This is because these PCAs apply only to dairy operations in the study area, which comprise only about 20,000 acres. In contrast, the land area that would be subject to some of the other PCAs, such as Enhanced Cow-Calf BMPs and Non-structural Management at the Land Parcel Level, cover from 400,000 to 500,000 acres.

PCAs 4 and 12 score well in terms of the present-value cost per pound of phosphorus removed and the present-value change in regional income, both important evaluation criteria. The evaluation model shows that phosphorus BMPs applied to pasture land uses in the study area, in addition to PCAs 4 and 12, have the potential to significantly reduce phosphorus loads to the lake at relatively low cost, in addition to other benefits.

Sensitivity of PCA Ranking to Criteria Weights

The sensitivities of the PCA ranking to the weights assigned to the criteria were evaluated to determine if alternative weighting of

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Table 3
Scoring and Ranking of the Phosphorus Control Alternatives

Rank	PCA #	Phosphorus Control Alternative	Score	Prob. PCA is Best
1	5	Enhanced cow-calf BMPs	0.669	95%
2	7	Reservoir assisted Stormwater Treatment Areas (RASTAs)	0.630	<5%
3	3	Non-structural management at the land parcel level	0.614	<5%
4	8	Taylor Creek/Nubbin Slough RASTA with Lake Okeechobee supplemental water source	0.594	<5%
5	11	Isolated Wetlands Restoration on Pastureland	0.593	<5%
6	1	Chemical treatment of runoff at edge of property	0.553	<5%
7	10	Terminal large-scale water treatment facilities	0.542	<5%
8	2	Wetlands treatment of runoff at edge of property	0.539	<5%
9	9	Tributary sediment removal	0.461	<5%
10	6	Alternative land uses	0.431	<5%
11	4	Optimization of dairy rule design	0.418	<5%
12	12	Dairy Farm Composting	0.388	<5%

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criteria would result in a significantly different ranking of PCAs. The results showed that the ranking of alternatives was sensitive only to the weight assigned to Criterion 1—Average Annual Reduction in Phosphorus Loads to Lake Okeechobee. Significant changes in the weight for Criterion 1 did not change the ranking of the first- through third-ranked PCAs; however, the rankings of PCAs 8 and 11 are very sensitive to the weight for Criterion 1. This is not surprising because the total scores of these PCAs are very close. The impacts of changing weights on the PCA ranking for the other criteria are not significant.

<u>Impact of Uncertainty in Criteria Values on Total Scores and Rankings</u>

The CDP model allows the user to examine the sensitivity of the total scoring and ranking results to uncertainty in the criteria values. For each PCA and each of the continuous, quantitative criteria (criteria 1, 2, 3, 6 and 7), a probability distribution of values was specified. The average (mean) of the distribution was the value that was used in the evaluation.

The model used these distributions to recalculate the total scores based on the probability distribution of the criterion values. From these scores, the probability of seeing the score based on the distribution functions was calculated. The distributions were based on the best available information regarding the criterion values for each PCA.

The percent of the time that each PCA has the highest total score is shown in Table 3. Enhanced Cow-Calf BMPs (PCA 5) has the highest total score of all 10 PCAs 95 percent of the time. The other 11 PCAs have the highest score less than 5 percent of the time.

Evaluation of PCA Combinations

Of the 12 PCAs, 10 were grouped into combinations and evaluated together. Based on the comments of a multi-agency oversight committee, 18 combinations of on-farm and regional PCAs were evaluated using the Full Cost Accounting Model. The goal was to evaluate the benefits and costs of the PCA combinations for use in developing the 2004 Lake Okeechobee Protection Plan to meet the phosphorus TMDL for the lake.

The ranking of the 18 combinations is shown in **Table 4**. By far, the highest-ranked combination is Combination 2: PCAs 7, 4, and 5—RASTAs with Dairy Rule Optimization and Enhanced Cow-Calf BMPs, with a score of 0.924 out of a maximum score of 1.00. The second-ranked combination is Combination 5: PCAs 7 and 3—RASTAs with Non-Structural Management at the Land Parcel Level, with a score of 0.787. The third-ranked combination is Combination 8: PCAs 10, 4 and 5—Terminal Large-Scale Water Treatment Facility with Dairy Farm Optimization and Enhanced Cow-Calf BMPs, with a score of 0.756.

Table 4
Summary of Evaluation Results – PCA Combinations

Rank	PCA Combination	Total Score	Criterion 1: P Removed per Year (pounds)	Criterion 2: Resulting P Concentration (ppb)	Criterion 3: Present Value Cost per Pound P removed ($)
1	Combination 2: PCAs 7, 4 and 5 - RASTAs with Dairy Farm Optimization and Enhanced Cow-Calf BMPs	0.924	301,242	40	$80
2	Combination 5: PCAs 7 and 3 - RASTAs with Non-Structural Management at the Land Parcel Level	0.787	327,788	40	$68
3	Combination 8: PCAs 10, 4 and 5 - Terminal Large-Scale Water Treatment Facility with Dairy Farm Optimization and Enhanced Cow-Calf BMPs	0.756	319,592	10	$103
4	Combination 14: PCAs 9, 4 and 5 - Tributary Sediment Removal with Dairy Farm Optimization and Enhanced Cow-Calf BMPs	0.722	261,258	233	$58
5	Combination 1: PCAs 7 and 11 - RASTAs w/ Isolated Wetlands Restoration on Pastureland	0.684	188,078	40	$121
6	Combination 11: PCAs 10 and 3 - Terminal Large-Scale Water Treatment Facility with Non-Structural Management at the Land Parcel Level	0.671	345,732	10	$83
7	Combination 4: PCAs 7 and 2 - RASTAs with Wetlands Treatment of Runoff at Edge of Property	0.653	232,516	40	$121
8	Combination 3: PCAs 7 and 1 - RASTAs with Chemical Treatment of Runoff at Edge of Property	0.624	295,426	40	$134
9	Combination 17: PCAs 9 and 3 - Tributary Sediment Removal with Non-Structural Management at the Land Parcel Level	0.614	289,473	216	$46
10	Combination 7: PCAs 10 and 11 - Terminal Large-Scale Water Treatment Facility with Isolated Wetlands Restoration on Pastureland	0.610	211,550	10	$139
11	Combination 6: PCAs 7 and 6 – RASTAs with Alternative Land Uses	0.604	159,312	40	$181
12	Combination 13: PCAs 9 and 11 - Tributary Sediment Removal with Isolated Wetlands Restoration on Pastureland	0.601	149,710	193	$72
13	Combination 10: PCAs 10 and 2 - Terminal Large-Scale Water Treatment Facility with Wetlands Treatment of Runoff at Edge of Property	0.580	253,053	10	$136
14	Combination 16: PCAs 9 and 2 - Tributary Sediment Removal with Wetlands Treatment of Runoff at Edge of Property	0.557	183,544	306	$103
15	Combination 15: PCAs 9 and 1 - Tributary Sediment Removal with Chemical Treatment of Runoff at Edge of Property	0.547	254,545	125	$157
16	Combination 9: PCAs 10 and 1 - Terminal Large-Scale Water Treatment Facility with Chemical Treatment of Runoff at Edge of Property	0.546	313,993	10	$177
17	Combination 12: PCAs 10 and 6 - Terminal Large-Scale Water Treatment Facility with Alternative Land Uses	0.512	182,186	10	$196
18	Combination 18: PCAs 9 and 6 - Tributary Sediment Removal w/ Alternative Land Uses	0.368	100,738	501	$194

These scores are significantly higher than those of the individual PCAs. Furthermore, the cost per pound of phosphorus removed is not significantly different between the combinations and the individual PCAs, suggesting that a combination of regional and on-farm PCAs provides higher net benefits than the individual PCAs alone. The cost-effectiveness of the individual PCAs ranges from $6 to $266 per pound of phosphorus removed, while the cost-effectiveness of the combinations ranges from $46 to $196 per pound removed.

Conclusions

This project compiled and summarized relevant existing research and studies to evaluate the benefits and costs of additional phosphorus management alternatives in the Lake Okeechobee watershed. During this study, several areas were identified where more data would improve the quality of the information used in this study. The Full Cost Accounting Evaluation Model allowed the South Florida Water Management District to organize all available information regarding methods to further reduce phosphorus loads to Lake Okeechobee. This model provided a structured approach to: (1) achieving an apples-to-apples comparison of phosphorus control methods, (2) identifying information gaps, (3) providing input to the development of the Lake Okeechobee Protection Plan, and (4) updating the conclusions as new data and information become available over time.