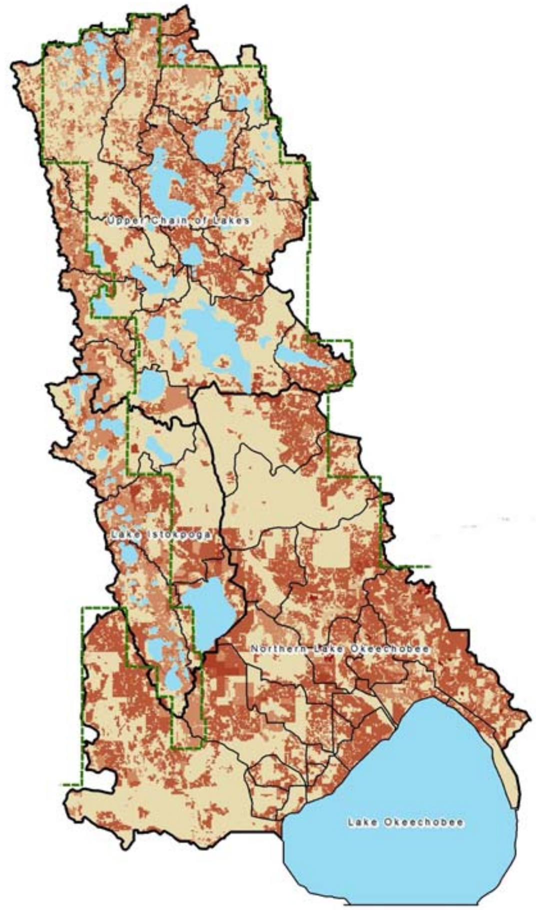
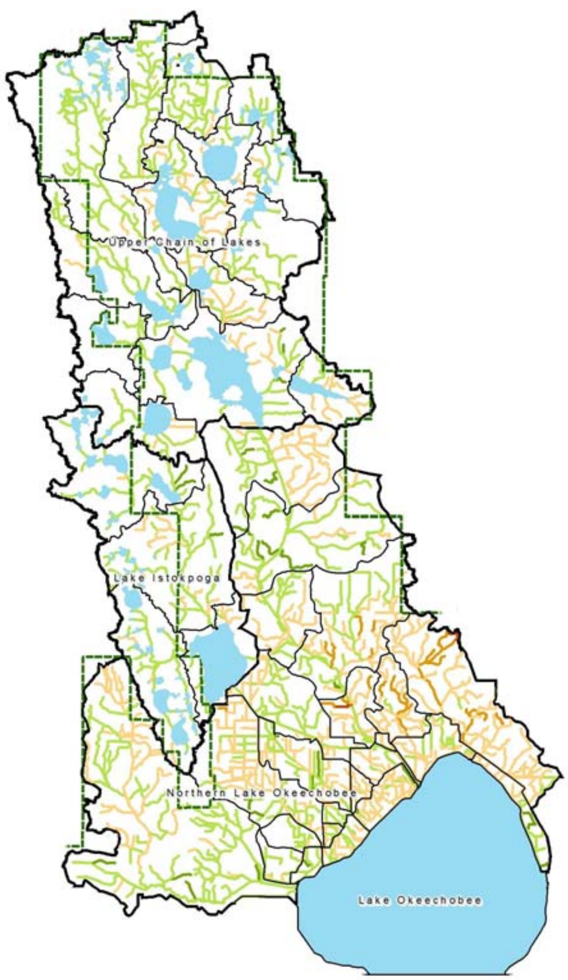
Task 3 Report

Legacy P Abatement Plan



For Project Entitled

Technical Assistance in Review and Analysis of Existing Data for Evaluation of Legacy Phosphorus in the Lake Okeechobee Watershed



Prepared for

South Florida Water Management District

by

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In association with

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Technical Assistance in Review and Analysis of Existing Data for Evaluation of Legacy Phosphorus in the Lake Okeechobee Watershed

Task 3: Legacy P Abatement Plan

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BAT	Best Available Technologies
BMAP	Basin Management Action Plan
BMP	Best Management Practice
CERP	Comprehensive Everglades Restoration Plan
cm	Centimeters
EPA	Environmental Protection Agency
EOF	Edge of Farm
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
Fe	Ferric
ha	Hectares
IFAS	Institute of Food and Agricultural Sciences
kg	Kilograms
mg	Milligrams
mt	Metric Tons
NRCS	Natural Resources Conservation Service
P	Phosphorus
ppm	Parts per million
RASTA	Reservoir Assisted Stormwater Treatment Area
SFWMD	South Florida Water Management District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
yr	Year

INTRODUCTION

The goal of this final task 3 report is to present a legacy phosphorus (P) abatement plan for the northern Lake Okeechobee watershed (Figure 1) based on the findings of the first two tasks of this project. Tasks 1 and 2 quantified, mapped, assessed mobility of, and identified abatement practices for the legacy P within the watershed based on the available field and literature data obtained during a comprehensive review process.

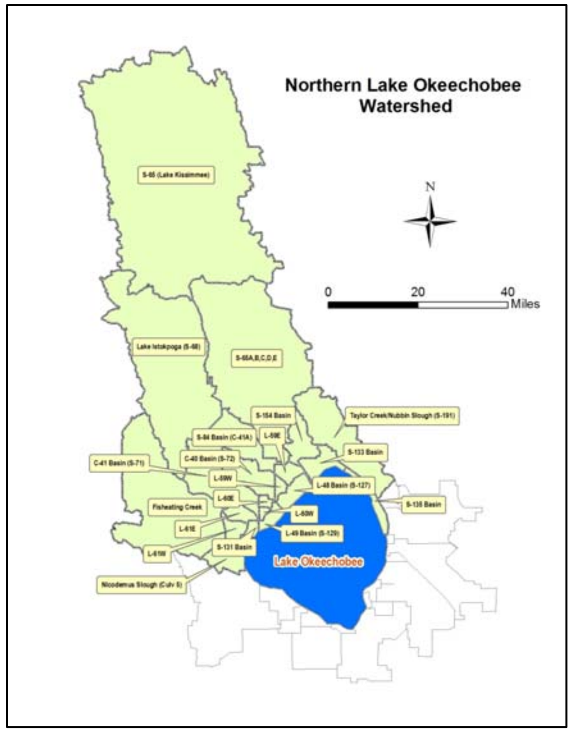

Figure 1. Northern Lake Okeechobee Watershed

The Statement of Work for this final task listed two options: 1) given sufficient information on legacy P in the Lake Okeechobee watershed develop an abatement plan, 2) if the current information on legacy P in the Lake Okeechobee watershed is deemed insufficient, develop a research and data acquisition plan to obtain the additional information needed to develop an abatement plan. Even though more information would obviously be useful, the current legacy P knowledge base is sufficient to proceed with option 1.

The specific objectives of this legacy P abatement plan were to outline specific P control practices and strategies at different spatial scales, anticipated P reduction performances, implementation costs, and a general implementation schedule. To accomplish these objectives the Task 2 findings, which provided estimates of the amount of legacy P by soil horizon and land use across the entire watershed (Figures 2 and 3) as well as estimates of its relative mobility, were first used to predict P discharges throughout the watershed. The accuracy of these predictions was then verified against observed data. Phosphorus reduction targets were then set based on existing and proposed TMDL targets for both Lake Okeechobee and its tributaries. Upland and regional abatement technologies were then applied at a level that would meet the TMDL targets. Costs for each of the technologies were then summed up across the watershed for various scenarios.

DEFINITION OF LEGACY P

Legacy phosphorus (P) is defined as phosphorus within the watershed that is present as the result of anthropogenic activities and has transport potential to Lake Okeechobee. Antecedent P is defined as the P that occurs naturally in soils based on the native properties of the soils and atmospheric (dry and wet) deposition. It is recognized that atmospheric deposition has risen due

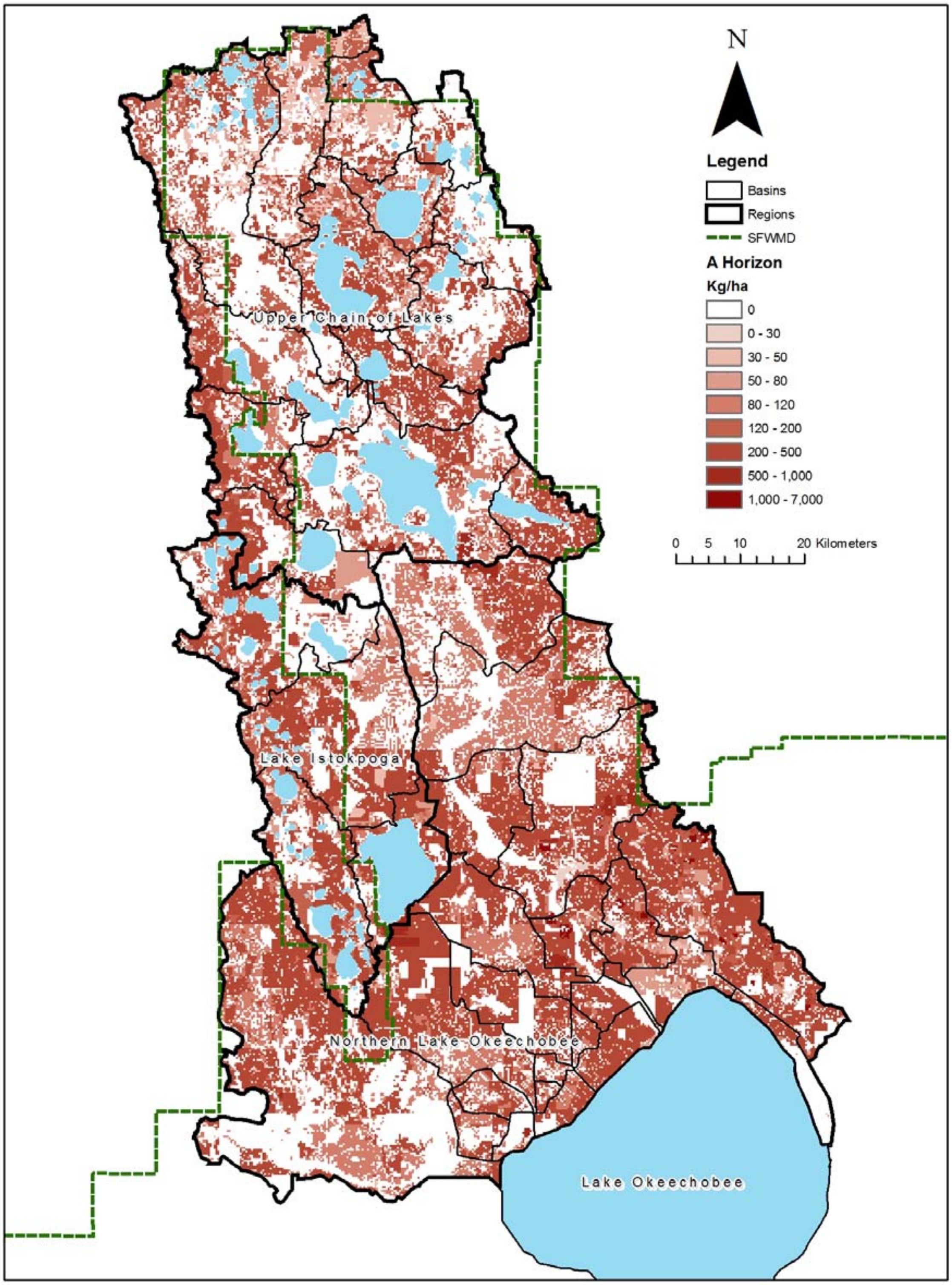

Figure 2. Legacy P Distribution for the "A" Horizon.

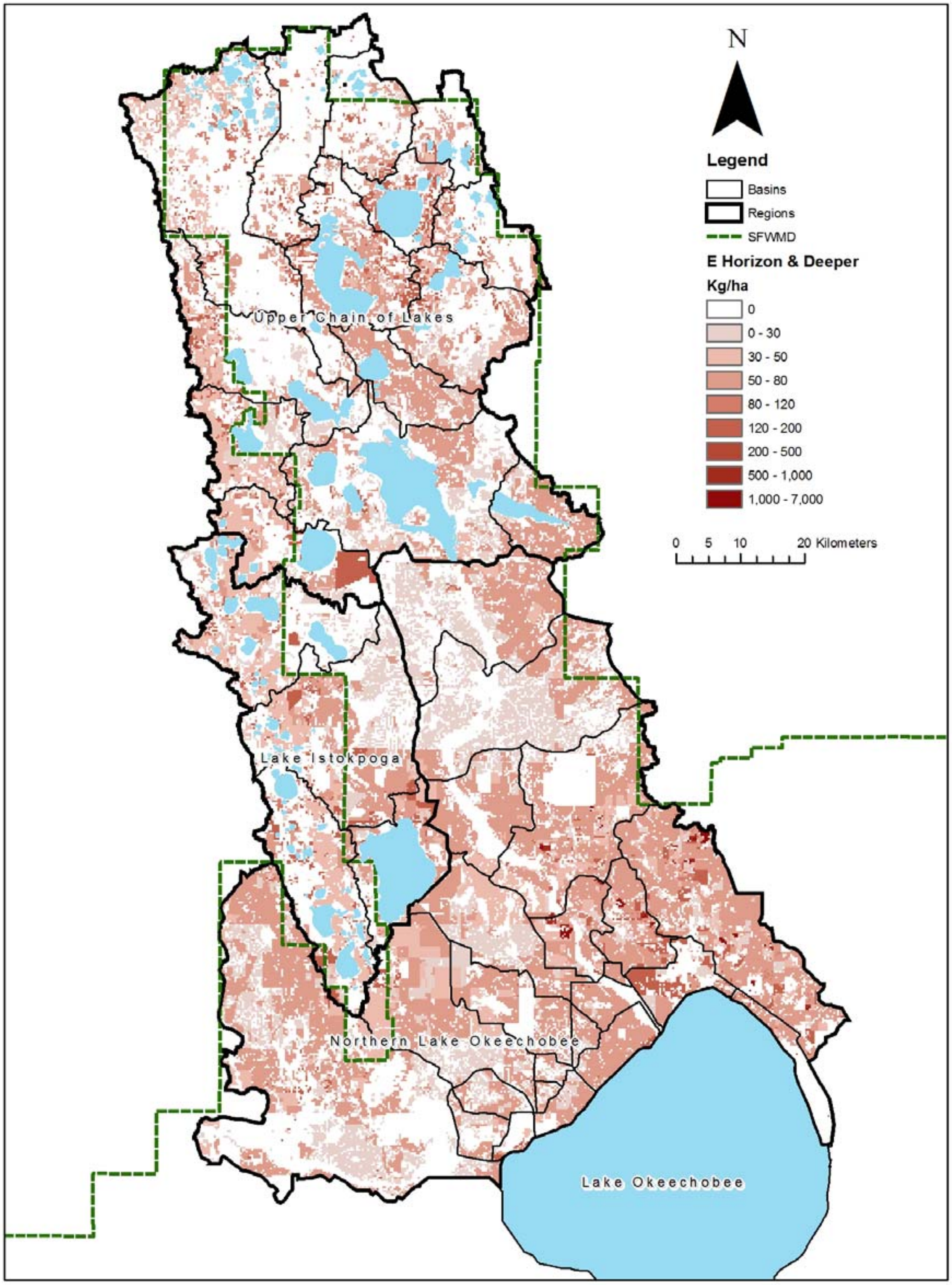

Figure 3. Legacy P Distribution Below the "A" Horizon (E, Bh, and Bw Horizons).

to anthropogenic activities, but it would not need to be considered separately because its impact would be reflected in the measured soil legacy P levels. Anthropogenic activities in the Lake Okeechobee watershed have resulted in more imported P into the watershed, as fertilizer, animal feed, and domestic goods, than has been exported resulting in the accumulation of P in soils, waste storage facilities, and landfills.

BACKGROUND OF LEGACY P

Over the last three decades, Lake Okeechobee has experienced accelerated eutrophication due to excessive phosphorus inputs from anthropogenic activities, particularly agricultural land uses that dominate in its watershed (Havens *et al.* 1996). Lake Okeechobee's northern watershed consists of 21 summary basins covering more than 2.65 million acres or 4,100 square miles (Figure 1). The established Total Maximum Daily Load (TMDL, Florida Department of Environmental Protection-FDEP-Rules Chapter 62-304) for total phosphorus to Lake Okeechobee is 140 metric tons per year (mt/yr) which includes 35 mt/yr of total P from atmospheric deposition. This TMDL was based on an in-lake phosphorus target concentration of 40 ppb. From 1991 to 2005 P loads to Lake Okeechobee from the northern drainage area were 457 mt/yr, which were about 83% of the total P load of 549 mt/yr to the lake including 35 mt/yr from atmospheric deposition (James & Zhang 2008). For the purposes of this analysis, it was assumed that in order to achieve the TMDL, the loading target for inflows from the northern Lake Okeechobee watershed would be equal to 40 ppb times the flow. Based on this assumption, the TMDL target for the northern Lake Okeechobee watershed would be 112 mt/yr. The northern Lake Okeechobee watershed (Figure 1) exceeds its TMDL target by 345 mt per year. The Environmental Protection Agency (EPA) has just set the Lake Okeechobee Tributary TMDL for in-stream P concentration at 113 ppb (EPA, 2008). This TMDL does not extend up into the Lake Istokpoga or Upper Kissimmee watersheds that will likely have lower TMDLs due to lower natural levels of P. Despite the long history of regulatory and voluntary incentive-based programs to control P inputs into Lake Okeechobee, current P loadings to the lake and P concentrations in the watershed north of the lake remain high. Intensive P management strategies will be needed to lower P loadings sufficiently to meet the TMDL targets by 2015.

Though the process of P accumulation has occurred since the late eighteen hundreds, the majority of the accumulation occurred over the past fifty years. The first major import of P was as fertilizer used for a developing vegetable crop industry around 1915 to 1920, but the vegetable farms disappeared after a brief time due to hard freezes resulting in little P accumulation (VanLandingham and Hetherington, 1978). From 1930 to 1940, there was a significant increase in the cattle business, with beef cattle going from 17,000 head in Okeechobee County in 1930 to 45,000 in 1940. Phosphorus fertilizer was used on beef pasture at this time, but was fairly limited due to costs and low animal densities. Beef cattle pastures were fertilized more aggressively starting in the 1940s and up through the 1980s, which is the period of the greater legacy P build up. Phosphorus fertilization on beef pastures was essentially stopped during the 1990s (Bottcher, 2008a).

The period starting in the late 1940s through the early 1960s saw dairy farms from the southeast coast of Florida move into the area. At their peak during the 1970s there were more than 45 dairies in the northern Okeechobee basins. More than half of these dairies have since closed as part of the Dairy Buyout Program in the mid to late 1980s and economic pressures. Most of these dairies operated without waste management systems until the 1960s when the US Soil Conservation Service constructed lagoons and seepage fields on most of the dairies. Other best management practices, such as stream fencing, were started on the dairies in 1979. By 1988, all of the dairies were operating under FDEP Dairy Rule permits that required Best Management Practices (BMPs) on all dairies. As these permits were transferred to NPDES (EPA) permits, starting about the year 2000, each dairy was required to show nutrient balancing across the dairy, which in some cases required additional BMPs (Bottcher, 2008b).

Residential and urban development also increased in the basin with its most rapid growth occurring during the last 20 years (US Census, 2008). The legacy P associated with residential and urban development is from landscape fertilization (IFAS, 2008), the accumulation of P in drain fields and septic tanks (Brown, undated), municipal sludge from wastewater treatment plants (Bottcher, 2008a), and landfills.

The findings of Tasks 1 and 2 provided a good picture of where the legacy P is located within the watershed and its relative mobility for eventually washing into the streams and ultimately to Lake Okeechobee. The P transport processes and associated practices that influence P transport were also identified. The purpose of this report is to use these data and information to formulate an abatement plan that will meet the TMDL target of 140 mt/y of P going to Lake Okeechobee by 2015 (FDEP, 2001) and tributary P TMDLs (EPA, 2008) for the watershed.

OVERALL ABATEMENT STRATEGY AND ASSUMPTIONS

The overall approach for controlling the legacy P within the northern Lake Okeechobee watershed from entering its tributaries and Lake Okeechobee is to identify where the legacy P is being stored and then identify practices that could most cost efficiently limit its mobility. Establishing where these practices should be located depends on where the TMDL P target levels are to be met. The Lake Okeechobee target has been set at 140 mt/yr (FDEP, 2001) and the tributary TMDL has been set at 113 ppb for the northern Lake Okeechobee watershed only (EPA 2008). The Upper Kissimmee and Lake Istokpoga watersheds do not have TMDLs set yet and therefore they were assumed to be 55 ppb for the purposes of this assessment based on the historic discharge P concentrations for Lake Kissimmee and Lake Istokpoga. The tributary TMDL targets and its associated Basin Management Action Plans (BMAPs) will be critical because they directly influence the legacy P control measures and ultimately the costs to meet the P reduction goals. It is also important to know how rigorously the BMAP would enforce this target within tributaries, i.e. would it extend to the limits of the Waters of the State designation or would some flexibility be provided within the secondary and tertiary reaches for more efficient practices? For this assessment, it was assumed that reason would prevail and that the BMAP would allow for the most efficient combination of treatment methods. In summary, the northern Lake Okeechobee watershed has a mandated tributary TMDL of 113 ppb TP while 55 ppb was assumed for a future P tributary TMDL for the Upper Kissimmee and Lake Istokpoga watersheds. For this assessment it was further assumed that P control measures could use Waters of the State for conveyance within predominately agricultural areas or individual property boundaries.

Meeting the northern Lake Okeechobee tributary TMDL targets will be impacted by the high land sourced P discharges within the basin, legacy P and buffering capacity of upstream lakes, existing P assimilation and future P releases from the extended sloughs, and current regional treatment systems and P control practices. For example, the lakes in the upper Kissimmee River watershed, particularly Lake Kissimmee, currently assimilate most of the P entering them from their watersheds, and therefore from the Lake Okeechobee TMDL perspective P control practices upstream of these lakes in this watershed would not be very effective. The same is true for the Lake Istokpoga watershed and the extensive slough system in Fisheating Creek, though to a lesser extent. Therefore tributary TMDLs within these upper basins would have limited benefits for the Lake Okeechobee and its northern tributary TMDLs and directly affect the P abatement strategies if the upper basins TMDLs do not come into play. An additional issue associated with the downstream systems, which have assimilated P for years, is that when their inflow P concentrations decrease due to upland P control practices they will likely become sources of P. This means that there can be significant delays between the P load reductions in upland tributaries and the P loads entering Lake Okeechobee, particularly for these upper basins.

Since the tributary TMDL targets are higher than the Lake Okeechobee TMDL targets and the in-stream accumulated legacy P could start washing out, there will be a need for additional P removal before discharging to the lake. It will be necessary to integrate upland P control practices with regional treatment systems on the lower tributaries in order to meet the lake TMDL. The approach taken for this abatement plan is to first meet the tributaries TMDL followed by regional treatment to obtain the additional P reductions needed to meet the Lake Okeechobee TMDL, but for comparison purposes the amount of regional treatment required to meet the Lake Okeechobee TMDL without tributary TMDLs being met is also presented.

LEGACY AND OTHER P SOURCES

In order to develop an abatement plan it was first necessary to understand and quantify where the P is coming from and how it is moving through the stream system. The 2008 South Florida Environmental Report provided the flow and P loads from 1991 through 2005 for all of the basins that drain to Lake Okeechobee (James & Zhang 2008). This information was reordered to separate out the northern Lake Okeechobee watershed data and to compare these data to the Lake Okeechobee TMDL and the tributary TMDL targets (Table 1). The measured data were used to verify the assessment tool developed as part of this project. This assessment tool predicts the P loads to streams by land use and P source category for the three primary basins within the northern Lake Okeechobee watershed based on assumed mobility factors (Table 2). The relative mobility factors were developed based on the author’s knowledge of numerous studies that had observed TP loads by land use that also had soil TP data by horizon and EAAMOD modeling experience. To roughly account for variable soil conditions within the three primary basins, mobility factors were developed separately for flatwood and ridge soils, where the northern Lake Okeechobee basins were categorized as being predominately flatwood soils while the other two

Table 1. Surface Water Inflows, TP Concentrations, Loading Rates, and TMDL Targets for Lake Okeechobee Tributary Basins (1991-2005).

Basins Draining to Lake Okeechobee	Discharge (ac-ft/yr)	Discharge (ha-m/yr)	Avg. TP (ppb)	TP Load From Basins (91-05) (mt/yr)	Lake TMDL[1] (mt/yr)	Trib-TMDL[2] (mt/yr)
Northern Lake Okeechobee Watershed						
Northern Lake Okeechobee Basins						
715 Farms (Culv 12A)	8,555	1,055	112	1.2	0.4	1.2
C-40 Basin (S-72) – S68	17,181	2,119	618	13.1	0.8	2.4
C-41 Basin (S-71) – S68	58,682	7,238	540	39.1	2.9	8.2
S-84 Basin (C-41A) – S68	60,456	7,457	77	5.7	3.0	8.4
Fisheating Creek	221,012	27,261	201	54.7	10.9	30.8
Nicodemus Slough (Culv 5)	634	78	51	0.04	0.03	0.1
L-48 Basin	20,047	2,473	231	5.7	1.0	2.8
L-49 Basin	13,964	1,722	105	1.8	0.7	1.9
L-59E	28,335	3,495	173	6.0	1.4	3.9
L-59W	8,981	1,108	394	4.4	0.4	1.3
L-60E	2,231	275	207	0.6	0.1	0.3
L-60W	502	62	237	0.2	0.0	0.1
L-61E	1,190	147	159	0.2	0.1	0.2
L-61W	1,810	223	95	0.2	0.1	0.3
Taylor Creek/Nubbin Slough (S-191)	108,625	13,399	644	86.4	5.4	15.1
S-131	10,996	1,356	119	1.6	0.5	1.5
S-133	26,404	3,257	253	8.3	1.3	3.7
S-135	24,982	3,081	123	3.8	1.2	3.5
S-154	27,579	3,402	760	25.9	1.4	3.8
Lower Kissimmee Regional Basin	373,435	46,063	167	76.8	18	52.1
Subtotal	**1,015,601**	**125,271**	**268**	**336**	**50**	**142**
Upper Kissimmee Regional Basin	**959,653**	**118,371**	**78**	**92**	**47**	**65**
Lake Istokpoga Regional Basin	**301,389**	**37,176**	**80**	**30**	**15**	**20**
Totals	***2,276,643***	***280,818***	***163***	***457***	***112***	***227***
Other Lake Okeechobee Drainage Sources						
S-2	37,149	4,582	167	7.6	1.8	5.2
S-3	15,936	1,966	135	2.7	0.8	2.2
S-4	28,994	3,576	213	7.6	1.4	4.0
Industrial Canal	21,981	2,711	119	3.2	1.1	3.1
S-308C (St. Lucie – C-44)	50,146	6,185	209	12.9	2.5	7.0
South FL Conservancy DD (S-236)	12,213	1,506	107	1.6	0.6	1.7
South Shore/South Bay DD (Culv 4A)	6,502	802	107	0.9	0.3	0.9
S-5A Basin (S-352 WPB Canal)	199	25	230	0.1	0.01	0.0
East Caloosahatchee (S-77)	5,835	720	139	1.0	0.3	0.8
L-8 Basin (Culv 10A)	58,992	7,277	102	7.4	2.9	8.2
Culvert 5A	1,487	183	104	0.2	0.1	0.2
East Beach DD (Culv 10)	8,608	1,062	589	6.3	0.4	1.2
East Shore DD (Culv 12)	10,890	1,343	169	2.3	0.5	1.5
Subtotal	**258,932**	**31,938**	**168**	**54**	**13**	**36**
All Areas Draining to Lake Okeechobee	***2,535,575***	***312,756***	***164***	***511***	***125***	***263***

[1] 40 ppb TP Target for Lake Okeechobee TMDL

[2] 113 ppb TP Target for Northern LO Basins and 55 ppb TP Target for Istokpoga and Upper Kissimmee basins

Table 2. Assumed Relative P Mobility Factors for Legacy P, Runoff Factors, and Estimated Native and Other Anthropogenic P Loads.

Land Use	Flatwood Basins Relative Mobility Factor		Ridge Basins Relative Mobility Factor		Relative Runoff Coeff.	Runoff (cm/yr)	Native P[1] (kg/ha/yr)	Non-Soil Based Anthropogenic[2] (kg/ha/yr)
	A-Horiz	E-Horiz	A-Horiz	E-Horiz				
Other, Non-relevant	0	0	0	0	1	28.2	0.099	0.000
Low Density Residential	1	0.1	0.75	0.075	1.1	31.0	0.108	0.065
Medium Density Residential, central	1	0.1	0.75	0.075	1.3	36.6	0.128	0.194
High Density Residential, central	1.5	0.1	1.5	0.1	1.7	47.9	0.168	0.454
Industrial, central	2	0.1	2	0.1	1.7	47.9	0.168	0.454
Commercial, central	2	0.1	2	0.1	2	56.4	0.197	0.648
Recreational	1	0.1	1	0.1	1.1	31.0	0.108	0.065
Native Areas	1	0.1	1	0.1	0.9	25.4	0.089	0.000
Isolated Wetlands in Pastures	0.25	0.1	0.25	0.1	0.5	14.1	0.049	0.000
Impacted Sloughs	0.05	0.05	0.05	0.05	0.5	14.1	0.049	0.000
Semi-Improved Beef Pasture	1	0.1	0.75	0.075	1	28.2	0.099	0.000
Improved Beef Pasture	1	0.3	0.75	0.075	1	28.2	0.099	0.000
Hayland	1	0.2	0.75	0.075	1	28.2	0.099	0.000
Dairy Dry Cow Pastures	1	0.2	1	0.2	1	28.2	0.099	0.000
Dairy Sprayfields	1.25	0.5	1.25	0.5	1.2	33.8	0.118	0.000
Dairy Intensive Lactating Pastures	1	0.2	1	0.2	1.2	33.8	0.118	0.000
Dairy High Intensive Holding Pastures	0.2	0.1	0.2	0.1	1.2	33.8	0.118	0.000
Abandoned Dairy Intensive	1	0.2	1	0.2	1	28.2	0.099	0.000
Vegetables	1.25	1	1.25	1	1.4	39.4	0.138	0.000
Citrus	0.3	0.2	0.1	0.05	1.2	33.8	0.118	0.000
Overall Dairy - Active	1	0.2	1	0.2	1.1	31.0	0.108	0.000
Overall Dairy - Abandoned	1	0.2	1	0.2	1	28.2	0.099	0.000
Sod	1	0.6	1	0.6	1.2	33.8	0.118	0.000
Ornamentals	1	0.6	1	0.6	1.2	33.8	0.118	0.000
Sugarcane	1	1	1	1	1.2	33.8	0.118	0.000
Poultry	1	0.1	1	0.1	1.2	33.8	0.118	0.000
Isolated Wetlands in Dairy Pastures	0.25	0.1	0.25	0.1	0.5	14.1	0.049	0.000
Lakes	0.01	0	0.01	0	0	0.0	0.889	0.000
Canals	0.01	0	0.01	0	0	0.0	0.889	0.000
Streams and Sloughs	0.01	0.01	0.01	0.01	0.23	6.5	0.023	0.000

[1] Assumed 35ppb P concentration (SWET, 2008a)

[2] Impervious surface runoff with assumed 230ppb P concentration (Harvey and Baker, 2007)

basins were categorized as ridge soil dominated. Native P and other anthropogenic sources, such as impervious surface runoff, that are not sourced from soil based legacy P are also provided in Table 2. Native P is calculated based on observed P concentrations (~35 ppb) from native soils provided in the Task 2 report (SWET, 2008a) and runoff volumes provided in Table 2. The P loads from impervious surface runoff due to urban and industrial anthropogenic activities are calculated by multiplying observed urban/industrial runoff P concentration (350 ppb, Harper and Baker, 2007) by the extra runoff generated by the impervious surfaces.

The relative mobility factors for the soil based legacy P in Table 2 were multiplied by the amount of soil legacy P (SWET, 2008a) to estimate the amount of annual P discharge being sourced from soil based legacy P (Table 3). The values in Table 3 were adjusted by a calibration coefficient to balance net P loads to observed-P discharges after native and other anthropogenic P sources (Table 4) and downstream assimilation were accounted for (Table 5). The streams, sloughs, and lakes assimilation rates were estimated based on a study done by the SWET (2001a). As seen in Table 5, observed annual average TP loads for the three primary basins matched the estimated P discharges well. These predicted net basin P loads were then compared to measured data and the Lake Okeechobee and tributary TMDL targets (Table 6). These comparisons provide an indication of the percentage reductions required to meet the TMDLs. These results also make it clear that meeting the tributary TMDL targets will not be sufficient to meet the lake TMDL target, and therefore either the land sourced P loads will have to be reduced significantly below tributary TMDL targets or additional in-stream treatment will be needed or a combination of both.

PHOSPHORUS CONTROL PRACTICES

The P control practices recommended for use in this plan can be categorized into one of the following spatial groupings that define the scale and type of P source to be addressed:

1. In-Field – Field practices that address the legacy P and its mobility within the soil/plant environment.
2. Edge-of-Field/Farm (EOF) – Practices that treat and/or retain runoff as it is leaving a field or farm.
3. Residential – Practices applied within residential areas.
4. Urban – Practices applied within transportation/urban/commercial/industrial areas
5. Facilities – Practices used in non soil-based areas that potentially discharge P into runoff, such as industrial sites, packing houses, old landfills, etc.
6. Regional – Practices that treat and/or retain stream flows within the tributary system where multiple upstream landowners drain to the system.

The following sections will describe the individual P control practices within each of these categories and provided estimated P removal efficiencies in terms of dollars per pound of P removed.

Table 3. Net P Loads from Soil Based Legacy P for Various Land Uses

Land Use	P Loads from Soil-Based Legacy P by Land Use[1]									
	Northern Lake Okeechobee			Lake Istokpoga			Upper Kissimmee			Total
	A Horizon (mt/yr)	E Horizon (mt/yr)	Subtotal (mt/yr)	A Horizon (mt/yr)	E Horizon (mt/yr)	Subtotal (mt/yr)	A Horizon (mt/yr)	E Horizon (mt/yr)	Subtotal (mt/yr)	(mt/yr)
Other, Non-relevant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low Density Residential	2.35	0.58	2.93	1.08	0.27	1.34	3.38	0.84	4.21	8.49
Medium Density Residential, central	1.50	0.00	1.50	4.52	0.00	4.52	8.50	0.00	8.50	14.52
High Density Residential, central	0.23	0.00	0.23	0.82	0.00	0.82	5.48	0.00	5.48	6.53
Industrial, central	0.07	0.00	0.07	0.07	0.00	0.07	1.01	0.00	1.01	1.15
Commercial, central	0.78	0.00	0.78	1.11	0.00	1.11	5.28	0.00	5.28	7.16
Recreational	0.28	0.01	0.30	0.40	0.02	0.42	2.37	0.11	2.49	3.20
Native Areas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated Wetlands in Pastures	0.37	0.23	0.60	0.02	0.01	0.03	0.15	0.09	0.25	0.88
Impacted Sloughs	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Semi-Improved Beef Pasture	29.47	0.13	29.61	4.51	0.02	4.53	8.67	0.04	8.71	42.84
Improved Beef Pasture	207.5	11.7	219.2	19.4	0.4	19.8	60.57	1.1	61.7	300.6
Hayland	2.24	0.11	2.35	0.73	0.02	0.75	1.92	0.05	1.96	5.06
Dairy Dry Cow Pastures	2.02	0.08	2.09	0.00	0.00	0.00	0.00	0.00	0.00	2.09
Dairy Sprayfields	0.86	0.05	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.91
Dairy Intensive Lactating Pastures	3.24	0.46	3.69	0.00	0.00	0.00	0.00	0.00	0.00	3.69
Dairy High Intensive Holding Pastures	2.40	0.41	2.81	0.00	0.00	0.00	0.00	0.00	0.00	2.81
Abandoned Dairy Intensive	6.19	0.66	6.85	0.00	0.00	0.00	0.00	0.00	0.00	6.85
Vegetables	13.10	0.81	13.91	2.05	0.13	2.17	3.78	0.23	4.02	20.10
Citrus	6.33	0.84	7.17	1.79	0.18	1.96	2.19	0.22	2.41	11.54
Overall Dairy - Active	0.43	0.03	0.46	3.08	0.25	3.33	0.00	0.00	0.00	3.79
Overall Dairy - Abandoned	1.15	0.09	1.24	0.00	0.00	0.00	0.00	0.00	0.00	1.24
Sod	0.00	0.23	0.23	0.00	0.05	0.05	0.00	0.11	0.11	0.39
Ornamentals	2.11	0.21	2.32	0.05	0.00	0.05	0.25	0.03	0.28	2.65
Sugarcane	2.70	0.00	2.70	0.00	0.00	0.00	0.00	0.00	0.00	2.70
Poultry	0.02	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.04
Isolated Wetlands in Dairy Pastures	0.34	0.02	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.36
Lakes	0.00	0.00	0.00	0.05	0.00	0.05	0.12	0.00	0.12	0.17
Canals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Streams and Sloughs	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Totals	**286**	**17**	**302**	**40**	**1.3**	**41**	**104**	**2.9**	**107**	**450**

1 The P loads presented in the table are the accumulative load for the entire acreage of the land use for basin indicated.

Table 4. P Loads from Native and Direct Impervious Surface Runoff (Urban/Industrial) for Various Land Uses.

Land Use	P Loads from Non-Soil Based Legacy P Sources by Land Use											
	Northern Lake Okeechobee			Lake Istokpoga			Upper Kissimmee			Entire Watershed		
	Native (mt/yr)	Imp.Surf. (mt/yr)	Subtotal (mt/yr)	Native (mt/yr)	Imp.Surf. (mt/yr)	Subtotal (mt/yr)	Native (mt/yr)	Imp.Surf. (mt/yr)	Subtotal (mt/yr)	Native (mt/yr)	Imp.Surf. (mt/yr)	Total (mt/yr)
Other, Non-relevant	2.61	0.00	2.61	1.23	0.00	1.23	1.73	0.00	1.73	5.57	0.00	5.57
Low Density Residential	0.93	0.55	1.48	0.57	0.34	0.91	1.78	1.06	2.84	3.27	1.95	5.23
Medium Density Residential, central	0.31	0.47	0.78	1.25	1.89	3.14	2.35	3.56	5.91	3.91	5.93	9.84
High Density Residential, central	0.06	0.16	0.22	0.22	0.58	0.80	1.45	3.92	5.38	1.73	4.67	6.40
Industrial, central	0.04	0.10	0.13	0.04	0.10	0.13	0.50	1.36	1.87	0.58	1.56	2.13
Commercial, central	0.45	1.47	1.92	0.63	2.09	2.72	3.03	9.96	12.99	4.11	13.51	17.62
Recreational	0.04	0.03	0.07	0.06	0.04	0.10	0.37	0.22	0.60	0.48	0.29	0.77
Native Areas	9.44	0.00	9.44	3.56	0.00	3.56	13.23	0.00	13.23	26.23	0.00	26.23
Isolated Wetlands in Pastures	0.50	0.00	0.50	0.03	0.00	0.03	0.21	0.00	0.21	0.73	0.00	0.73
Impacted Sloughs	0.13	0.00	0.13	0.01	0.00	0.01	0.00	0.00	0.00	0.14	0.00	0.14
Semi-Improved Beef Pasture	7.69	0.00	7.69	1.57	0.00	1.57	3.02	0.00	3.02	12.28	0.00	12.28
Improved Beef Pasture	16.45	0.00	16.45	2.05	0.00	2.05	6.40	0.00	6.40	24.91	0.00	24.91
Hayland	0.43	0.00	0.43	0.19	0.00	0.19	0.49	0.00	0.49	1.10	0.00	1.10
Dairy Dry Cow Pastures	0.16	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16
Dairy Sprayfields	0.13	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13
Dairy Intensive Lactating Pastures	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10
Dairy High Intensive Holding Pastures	0.07	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.07
Abandoned Dairy Intensive	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04
Vegetables	0.65	0.00	0.65	0.10	0.00	0.10	0.19	0.00	0.19	0.94	0.00	0.94
Citrus	2.91	0.00	2.91	2.46	0.00	2.46	3.01	0.00	3.01	8.38	0.00	8.38
Overall Dairy - Active	0.03	0.00	0.03	0.19	0.00	0.19	0.00	0.00	0.00	0.22	0.00	0.22
Overall Dairy - Abandoned	0.07	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.07
Sod	0.66	0.00	0.66	0.14	0.00	0.14	0.33	0.00	0.33	1.13	0.00	1.13
Ornamentals	0.24	0.00	0.24	0.01	0.00	0.01	0.03	0.00	0.03	0.28	0.00	0.28
Sugarcane	1.15	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	1.15
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Isolated Wetlands in Dairy Pastures	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02
Lakes (Atmospheric)	0.00	0.00	0.00	17.78	0.00	17.78	40.01	0.00	40.01	57.79	0.00	57.79
Canals (Atmospheric)	2.13	0.00	2.13	0.09	0.00	0.09	0.44	0.00	0.44	2.67	0.00	2.67
Streams and Sloughs	0.45	0.00	0.45	0.02	0.00	0.02	0.09	0.00	0.09	0.57	0.00	0.57
Totals	**47.9**	**2.8**	**50.7**	**32.2**	**5.0**	**37.2**	**78.7**	**20.1**	**99**	**159**	**27.9**	**187**

Table 5. Predicted P Source Loads to Streams, In-stream Assimilation, and Net Basin Export (1991 – 2005).

Basins	Sourced From Soil Legacy P[1] (mt/yr)	Native P Loads Assumed @ 35 ppb[1] (mt/yr)	Impervious Surf. Runoff[1] (mt/yr)	Total P to Streams[2] (mt/yr)	In-stream P Assimilated[3] (mt/yr)	Total P Leaving Basin[4] (mt/yr)
Northern Lake Okeechobee	302	48	3	353	17	336
Upper Kissimmee Regional	107	79	20	206	116	90
Lake Istokpoga Regional	41	32	5	78	48	30
Total	**450**	**159**	**28**	**637**	**181**	**456**

1 Columns 1-3 are the predicted P loads reaching the nearest stream from the three primary P sources on land surfaces.
2 Total P load reaching the nearest stream.
3 Amount of P assimilated within the stream network before reaching Lake Okeechobee.
4 Total P load reaching Lake Okeechobee

Table 6. Measured and Estimated P Source Loads to Stream and Net Basin Exports with TMDL Targets.

Basins	Source Loads To Tributaries (91-05)			Net P Export To Lake (91-05)			
	Predicted (mt/yr)	TMDL Target[1] (mt/yr)	Reduction Required	Measured (mt/yr)	Predicted (mt/yr)	TMDL Target[2] (mt/yr)	Reduction Required
Northern Lake Okeechobee	353	142	60%	336	336	50	85%
Upper Kissimmee Regional	206	65	68%	92	90	47	48%
Lake Istokpoga Regional	78	20	74%	30	30	15	50%
Total	**637**	**227**	**64%**	**456**	**456**	**112**	**75%**

1 Calcuated by multipling flow the tributary P TMDL of 113ppb, which is allowable limit reaching a stream. Note does not include atmospheric P in lakes and sloughs
2 Calcuated by multipling flow by the Lake Okeechbee P TMDL of 40ppb.

In-Field Agricultural BMPs

Previous studies and reports have estimated the effectiveness and cost of agricultural BMPs for the Okeechobee basin as described in the Task 2 report (SWETa, 2008). The Florida Department of Agriculture and Consumer Services (FDACS) has been instrumental in the development and implementation of agricultural BMPs around the Lake Okeechobee watershed and the rest of Florida. FDACS, IFAS, FDEP, and grower groups have developed BMP manuals for cow-calf production, forage grass, citrus, vegetables, silviculture, sod, and container nurseries (http://www.floridaagwaterpolicy.com/BestManagementPractices.html). These manuals, however, do not provide specific information on P reduction performances or costs. Therefore, the letter report entitled: "Phosphorus Reduction Performance and Implementation Costs under BMPs and Technologies in the Lake Okeechobee Protection Plan Area" (Bottcher, 2006) was used for providing the agricultural BMP response and cost data. This letter report summarizes the available BMPs and provides ranges and typical condition implementation costs and estimated P reductions. The typical condition was developed to account for existing BMPs on some farms and for variation in BMPs' effectiveness due to site-specific conditions, such as soils. Because of the complexity and diversity of the northern Lake Okeechobee basins two major assumptions were made to complete this assessment: 1) An integrated BMP program would be implemented based on the Bottcher 2006 letter report and 2) To roughly account for variable soil conditions between the three primary basins, the northern Lake Okeechobee basins were categorized as being predominately flatwood soils while the other two basins were categorized as ridge soil dominated. The second assumption was done because the well drained ridge soils have considerably less P transport potential than flatwood soils, thus reducing the legacy P influences on P losses as reflected by the mobility factors provided in Table 2. Table 7 summarizes the assumed BMP reduction performance and relative costs for the agricultural land uses used for this plan's development.

In-Field Soil Amendments

A few studies have looked at the benefits of applying soil amendments to reduce the mobility of the accumulated legacy P in the soils (Chinault and O'Connor, 2008, Wang *et al*. 1995, Ann *et al*. 2000, SWET, 2001b, Nair *et al* 2003, and Josan *et al* 2005). The soil amendments evaluated have been lime, gypsum, silica, aluminum and iron salts, and water treatment residuals. The intent of these compounds is to either raise pH to enhance P binding or to directly bind P to the applied compounds. Though these soil amendments can significantly reduce P they have three disadvantages that greatly limit their effectiveness for controlling P. First, soil amendments attempt to treat the entire legacy P pool within the soil, which is about 50 to 200 times larger than the P being discharged per year. This means large amounts of chemicals must be applied at high cost. Second, it is very difficult to get the amendments mixed into the soil adequately to maximize their effectiveness. Third, soil amendments do not reduce the amount of legacy P in the soil and over time many of the amendments can lose their binding properties and the legacy P can become mobile again.

Table 7. Phosphorus Control Practices - Assumed Effectiveness and Costs

Land Use		Site/Crop BMPs[1]		Retention/Detention		Edge-Of-Farm with Chemical[2]	
		P Reduction	Cost ($/lb-P/yr)	P Reduction	Cost ($/lb-P/yr)	P Reduction	Cost ($/lb-P/yr)
Urban							
	Low Density Residential	10%	$15	45%	$500	85%	$900
	Medium Density Residential, central	10%	$15	75%	$300	85%	$550
	High Density Residential, central	10%	$15	50%	$300	85%	$550
	Industrial, central	10%	$15	50%	$300	85%	$550
	Commercial, central	10%	$15	50%	$300	85%	$550
	Recreational	25%	$15	60%	$400	85%	$700
Agriculture							
	Semi-Improved Beef Pasture	10%	$43	10%	$150	85%	$200
	Improved Beef Pasture	30%	$73	20%	$116	85%	$155
	Hayland	40%	$20	25%	$113	85%	$150
	Dairy Dry Cow Pastures	30%	$73	35%	$75	85%	$100
	Dairy Sprayfields	20%	$15	45%	$75	85%	$100
	Dairy Intensive Lactating Pastures	40%	$73	65%	$23	85%	$30
	Dairy High Intensive Holding Pastures	30%	$73	65%	$23	85%	$30
	Abandoned Dairy Intensive	30%	$173	65%	$23	85%	$30
	Vegetables	60%	$25	45%	$45	85%	$60
	Citrus Ridge	10%	$15	-	-	-	-
	Citrus Flatwood - No Existing Retention	32%	$145	45%	$113	85%	$150
	Citrus Flatwood - Existing Retention	14%	$20	45%	$11	85%	$15
	Overall Dairy - Active	37%	$123	65%	$23	85%	$30
	Overall Dairy - Abandoned	30%	$173	65%	$38	85%	$50
	Sod	47%	$30	45%	$113	85%	$150
	Ornamentals	60%	$25	45%	$56	85%	$75
	Sugarcane	33%	$169	55%	$113	85%	$150
	Poultry	20%	$169	55%	$113	85%	$150
Impacted Wetlands							
	Isolated Wetlands in Dairy Pastures	50%	$900	75%	$45	85%	$60
	Isolated Wetlands in Pastures	50%	$1,100	45%	$60	85%	$80
	Impacted Sloughs[3]	-	-	-	-	-	-
Lakes							
	In Lake chemical treatmen	50%	$1,900	-	-	-	-

Land Uses associated with Regional Treatment		Wetland Based Systems		Retention/Detention with Chemical	
		P Reduction	Cost ($/lb-P/yr)	P Reduction	Cost ($/lb-P/yr)
Streams and Canals, Regional Treatment					
	High Inflow P Conc. (>0.2 mg/l)	80%	$1,300	80%	$355
	Low Inflow P Conc. (<0.2 mg/l	70%	$1,500	70%	$450

[1] These include fertility, water management, and chemical amendments and sediment consolidation within wetlands and lakes.

[2] Includes the cost of retention/detention system, except for citrus with existing retention.

[3] No treatment proposed within the systems, therefore must be handled by downstream regional treatment systems.

Lime and iron salts are particularly vulnerable to remobilization. Therefore, soil amendments were not considered a viable P control practice in this plan due to costs associated with availability and application logistical problems.

Edge-of-Field/Farm (EOF) Treatment Technologies

Edge-of-field/farm (EOF) P control practices are grouped together because they use identical technologies and only differ in the physical location of their implementation. The concept behind EOFs is that they treat the P leaving the field or farm and not the entire pool of legacy P in the field or farm. This means that all of the natural P assimilation processes upstream of the EOF are used before treatment. The Dairy Best Available Technologies (BATs) project discussed in the Task 2 report evaluated and ranked EOF technologies and then constructed and tested four systems in the northern Lake Okeechobee Basin. This project found that EOF systems for high P source areas are the most cost effective P control practice that can be implemented. However, the relative cost effectiveness of EOF systems decreases as the P concentration in the field or farm runoff decreases, where 2.0 ppm P runoff will cost about $20 /lb-P removed/yr as compared to about $120 /lb-P removed/yr for 0.35 ppm P runoff The assumed reduction performance and relative costs for EOF systems for various agricultural land uses used for this plan's development range from 10 to 85% and from $15 to over $150 per lb of P removed (Table 7).

Residential and Urban

Residential P control practices include site level and EOF systems. Site level practices are typically landscape management BMPs, such as fertility and water management practices. The EOF systems include standard stormwater retention/detention facilities and possible chemical treatment for pass-thru waters. The estimated responses and costs are based on work by Harvey Harper that was included in the 2006 letter report (Bottcher, 2006). The assumed P reduction performance and relative costs for EOF systems for various urban land uses were used for this plan's development and range from 45 to 85% and from $550 to over $900 per lb of P removed (Table 7).

Facilities or Point Sources

Direct discharges from point sources and other industrial and commercial operations were considered in the overall P balance for the watershed, but were not included as a control option within this plan because these sources typically do not include the mobility of accumulated legacy P and are assumed to be under existing FDEP permits, so additional modifications to these facilities were assumed unlikely. Therefore, no practices were applied to these sources; however it is strongly encouraged that these sources be periodically reviewed for their relative contributions and control practices.

Regional In-Stream Treatment Technologies

The final option for controlling P loads going into Lake Okeechobee is to treat the water flowing within the stream network at selected regional locations. The primary advantage of regional treatment, particularly nearest to the lake, is that only the P that is headed into the lake would be treated, thus taking full advantage of the other assimilative processes within the watershed. The two primary disadvantages are that tributary TMDLs upstream of the regional systems are not addressed and treatment of mixed or diluted flows will be less efficient than treating closer to the higher P source areas. Two regional treatment technologies were considered for this project, 1) reservoir assisted stormwater treatment areas (RASTAs) that use a reservoir to buffer flows and wetland treatment areas that provide P removal treatment and 2) a retention/detention reservoir system using chemical treatment for its pass-thru waters. Chemical treatment system was found to be more cost efficient (SWET, 2008b), so it has been included in this plan for comparative purposes.

The release and assimilation of legacy P within the stream network is an important issue to address when considering the placement of regional treatment systems. Wetland sloughs and lakes can assimilate and release P depending on the difference between current inflow P concentrations and long term historical inflow P concentrations. Over time these wetlands and lakes will trend toward an equilibrium with inflow P concentration, but in the case of large lakes and slough systems it is unlikely that they have reached such an equilibrium and therefore are still assimilating P. However, as inflow P concentrations are reduced these sloughs and lakes might begin to release either native or legacy accumulated P. Therefore placing regional treatment system upstream of such systems could greatly reduce its effectiveness especially in the short term. In time the accumulated P in these systems will wash out to establish a new equilibrium with the inflow P levels. Sloughs will likely respond within five to twenty years as compared to the larger lakes that could take much longer to establish a new equilibrium (Jeppesen *et al,* 2005). Therefore it is recommended the regional treatment systems not be placed upstream of sloughs and lakes. The assumed reduction performance and relative costs for the regional treatment systems are estimated between 70 to 80% and $355 to $1500 per lb P removed (Table 7)

ESTIMATED IMPLEMENTATION LEVELS AND COSTS TO ACHIEVE TMDL TARGETS

This section spatially assigns P control practices across the watershed to achieve both the Lake Okeechobee and assumed tributary TMDL targets based on the 2006 land use GIS coverage and assumed P control practices' performances and costs. The approach taken was to apply P control practices for meeting the tributary TMDLs first, and then to apply additional regional practices as needed to meet the Lake Okeechobee TMDL. The method of applying P control practices was to apply the most cost effective practice first, and then to add practices as needed to meet the TMDL targets for each land use.

The implementation of a modest "typical" BMP program was found to be the most cost effective initial P control practice for the watershed, and therefore was applied first across the watershed. To keep the logistics of BMP implementation to a manageable level, field level BMPs were applied as a suite of BMPs as previously identified as the most appropriate combination by Bottcher (2006). The next P control practice implemented was stormwater retention, which includes wetland restoration and water reuse, as well as standard urban R/D systems. Finally, chemical treatment was added to the retention based systems if the first two practices were not sufficient to meet TMDL targets. The P reduction percentages from Table 7 were applied stepwise to the P loads remaining after the previous set of BMPs that were applied.

The existing P loads to the tributaries, the tributary TMDL target, required P load reduction, P load reductions by P control practices, and annual costs (Table 7) for each land use category within the three primary basins were tabulated (Tables 8, 9 and 10) . The TMDL targets for the individual land uses were adjusted to account for the dilution effect of runoff from lower P concentration sources, such as native areas, groundwater contributions, and reduced P concentrations due to long term P assimilation in lakes and sloughs. These adjustment factors are provided as a footnote in the tables. They clearly show that the northern Lake Okeechobee basins have the least dilution effect thus requiring greater relative P reductions than for similar land uses for the other two primary basins, particularly compared to the Upper Kissimmee regional basin that had the greatest P dilution advantage.

The relative importance of the various land uses show that improved beef pastures are the dominant source of P in the watershed (Tables 8, 9, 10). Nearly 80% of the P load reduction needed in the northern Lake Okeechobee basin is associated with improved beef pasture while about 60% and 70% P reductions are needed for improved beef pasture for the Lake Istokpoga and Upper Kissimmee basins, respectively. BMPs and retention practices alone are not sufficient for improved beef pastures to meet tributary TMDL targets except within the Upper Kissimmee basin because of the lower P load reductions required in this basin. As anticipated only the more intensive dairy and vegetable land uses required EOF chemical treatment to meet tributary TMDL targets.

The cost for implementing the P control practices to meet the tributary TMDL include the amortized capital costs and annual operation and maintenance costs so that a direct comparison can be made as to the long term investment required to meet the TMDL targets (Tables 8, 9, 10). The annual costs are obviously closely related to the P load reductions, but the lower P load sources do have higher relative costs compared to high P load sources on a cost per pound of P removed basis. The estimated total annual cost for meeting the tributary TMDL throughout the northern Lake Okeechobee watershed is about $92 million with about 20% going to O&M costs and the remaining being the 15-year amortized initial outlay of capital expenses including land, equipment, and construction. This means about $830 million of initial capital expenditures are needed for all three primary basins to meet the tributary TMDL target.

Table 8. Northern Lake Okeechobee Basin P Control Practices Implementation Plan for Meeting the Tributary TMDL

Land Use	Area (ha)	P Load to Trib. (mt/yr)	TMDL[2] Target (mt/yr)	Reduction Target (mt/yr)	P Control Practices: BMPs (mt/yr)	Retention (mt/yr)	EOF (mt/yr)	Total (mt/yr)	Annual Cost ($/yr)
Other, Non-relevant	26466	2.61	2.61	0.00	-	-	-	-	-
Low Density Residential	8555	4.42	3.81	0.61	0.44	0.17	0.00	0.61	$ 199,863
Medium Density Residential, central	2427	2.28	1.28	1.01	0.23	0.78	0.00	1.01	$ 521,974
High Density Residential, central	358	0.45	0.25	0.20	0.04	0.16	0.00	0.20	$ 105,949
Industrial, central	212	0.20	0.15	0.06	0.02	0.04	0.00	0.06	$ 25,116
Commercial, central	2266	2.69	1.83	0.86	0.27	0.59	0.00	0.86	$ 399,520
Recreational	413	0.37	0.18	0.19	0.09	0.09	0.00	0.19	$ 84,871
Native Areas	106329	9.44	9.44	0.00	-	-	-	-	-
Isolated Wetlands in Pastures	10080	1.09	1.09	0.57	0.00	0.49	0.08	0.57	$ 78,653
Impacted Sloughs	2550	0.16	0.16	0.00	-	-	-	-	-
Semi-Improved Beef Pasture	78006	37.3	31.54	5.8	3.73	2.03	0.00	5.76	$ 1,022,267
Improved Beef Pasture	166843	235.6	67.47	168.1	70.7	33.0	64.5	168.1	$ 41,774,006
Hayland	4344	2.78	1.76	1.02	1.11	0.00	0.00	1.11	$ 48,929
Dairy Dry Cow Pastures	1622	2.25	0.66	1.60	0.68	0.55	0.37	1.60	$ 280,792
Dairy Sprayfields	1064	1.04	0.52	0.52	0.21	0.32	0.00	0.52	$ 59,031
Dairy Intensive Lactating Pastures	881	3.80	0.43	3.37	1.52	1.48	0.37	3.37	$ 341,797
Dairy High Intensive Holding Pastures	561	2.87	0.27	2.60	0.86	1.31	0.43	2.60	$ 231,628
Abandoned Dairy Intensive	362	6.88	0.15	6.74	2.06	3.13	1.54	6.74	$ 1,042,597
Vegetables	4694	14.6	2.66	11.9	8.73	2.62	0.54	11.90	$ 811,592
Citrus	24569	10.08	11.92	-1.84	0.97	0.00	0.00	0.97	$ 308,723
Overall Dairy - Active	250	0.49	0.11	0.38	0.18	0.20	0.00	0.38	$ 58,947
Overall Dairy - Abandoned	742	1.31	0.30	1.01	0.39	0.60	0.02	1.01	$ 201,386
Sod	5570	0.89	0.89	0.00	0.42	0.00	0.00	0.42	$ 27,569
Ornamentals	2047	2.56	0.99	1.57	1.54	0.03	0.00	1.57	$ 88,498
Sugarcane	9697	3.85	4.71	-0.86	0.51	0.00	0.00	0.51	$ 188,829
Poultry	34	0.03	0.02	0.01	0.01	0.01	0.00	0.01	$ 3,438
Isolated Wetlands in Dairy Pastures	474	0.38	0.10	0.29	0.00	0.29	0.00	0.29	$ 28,329
Lakes, Streams, Canal, Sloughs[1]	22,400	2.61	2.61	0.00	-	-	-	-	-
Totals	**483816**	**353**	**145**	**206**	**95**	**48**	**68**	**210**	**$ 47,934,302**

[1] Atmospheric Deposit, so is not included in the TMDL target sum.

[2] TMDL Target = 113ppb is assumed, but P load reduction needed is reduced by a wetland/Assimilation Dilution Factor = 1.27

Table 9. Upper Kissimmee Basin P Control Practices Implementation Plan for Meeting the Tributary TMDL

Land Use	Area (ha)	P Load to Trib. (mt/yr)	TMDL[2] Target (mt/yr)	Reduction Target (mt/yr)	P Control Practices BMPs (mt/yr)	Retention (mt/yr)	EOF (mt/yr)	Total (mt/yr)	Annual Cost ($/yr)
Other, Non-relevant	17521	1.73	1.73	0.00	-	-	-	-	-
Low Density Residential	16383	7.05	4.80	2.25	0.71	1.54	0.00	2.25	$ 1,719,980
Medium Density Residential, central	18330	14.41	6.35	8.06	1.44	6.62	0.00	8.06	$ 4,417,248
High Density Residential, central	8652	10.86	3.92	6.94	1.09	4.89	0.97	6.94	$ 4,429,589
Industrial, central	3008	2.88	1.36	1.52	0.29	1.23	0.00	1.52	$ 821,480
Commercial, central	15366	18.27	8.19	10.08	1.83	8.22	0.03	10.08	$ 5,520,146
Recreational	3454	3.09	1.01	2.07	0.77	1.30	0.00	2.07	$ 1,170,564
Native Areas	149089	13.23	13.23	0.00	-	-	-	-	-
Isolated Wetlands in Pastures	4161	0.45	0.55	0.00	0.00	0.00	0.00	0.00	$ -
Impacted Sloughs	-	-	-	-	-	-	-	-	-
Semi-Improved Beef Pasture	30591	11.73	8.15	3.57	1.17	1.06	1.34	3.57	$ 1,050,288
Improved Beef Pasture	64946	68.11	17.31	50.80	20.4	9.5	20.8	50.8	$ 12,823,697
Hayland	4958	2.45	1.32	1.13	0.98	0.15	0.00	1.13	$ 80,431
Dairy Dry Cow Pastures	-	-	-	-	-	-	-	-	-
Dairy Sprayfields	-	-	-	-	-	-	-	-	-
Dairy Intensive Lactating Pastures	-	-	-	-	-	-	-	-	-
Dairy High Intensive Holding Pastures	-	-	-	-	-	-	-	-	-
Abandoned Dairy Intensive	-	-	-	-	-	-	-	-	-
Vegetables	1356	4.20	0.51	3.70	2.52	0.76	0.42	3.70	$ 268,986
Citrus	25464	5.42	8.14	0.00	0.52	0.00	0.00	0.52	$ 165,947
Overall Dairy - Active	-	-	-	-	-	-	-	-	-
Overall Dairy - Abandoned	-	-	-	-	-	-	-	-	-
Sod	2764	0.44	0.44	0.00	0.21	0.00	0.00	0.21	$ 13,681
Ornamentals	243	0.30	0.08	0.23	0.18	0.04	0.00	0.23	$ 15,479
Sugarcane									$ -
Poultry	21	0.02	0.01	0.01	0.00	0.01	0.00	0.01	$ 2,983
Isolated Wetlands in Dairy Pastures	-	-	-	-	-	-	-	-	-
Lakes, Streams, Canal, Sloughs[1]	49667	40.7	40.67	0.00	-	-	-	-	-
Totals	**415974**	**205**	**77**	**90**	**32**	**35**	**24**	**91**	**$ 32,500,497**

[1] Atmospheric Deposition, so is not included in the TMDL target sum.

[2] TMDL Target = 55ppb is assumed, but P load reduction needed is reduced by a wetland/Assimilation Dilution Factor = 1.72

Table 10. Lake Istokpoga Basin P Control Practices Implementation Plan for Meeting the Tributary TMDL

Land Use	Area (ha)	P Load to Trib. (mt/yr)	TMDL[2] Target (mt/yr)	Reduction Target (mt/yr)	P Control Practices: BMPs (mt/yr)	Retention (mt/yr)	EOF (mt/yr)	Total (mt/yr)	Annual Cost ($/yr)
Other, Non-relevant	12479	1.23	1.23	0.00	-	-	-	-	-
Low Density Residential	5228	2.25	1.34	0.91	0.23	0.69	0.00	0.91	$ 764,538
Medium Density Residential, central	9741	7.66	2.94	4.72	0.77	3.95	0.00	4.72	$ 2,632,379
High Density Residential, central	1288	1.62	0.51	1.11	0.16	0.73	0.22	1.11	$ 749,750
Industrial, central	210	0.20	0.08	0.12	0.02	0.09	0.01	0.12	$ 69,529
Commercial, central	3218	3.83	1.50	2.33	0.38	1.72	0.23	2.33	$ 1,421,555
Recreational	577	0.52	0.15	0.37	0.13	0.23	0.01	0.37	$ 219,263
Native Areas	40079	3.56	3.56	0.00	-	-	-	-	-
Isolated Wetlands in Pastures	556	0.06	0.06	0.00	-	-	-	-	-
Impacted Sloughs	287	0.02	0.02	0.00	-	-	-	-	-
Semi-Improved Beef Pasture	15905	6.10	3.70	2.40	0.61	0.55	1.24	2.40	$ 784,665
Improved Beef Pasture	20808	21.82	4.84	16.99	6.5	3.1	7.4	17.0	$ 4,350,488
Hayland	1882	0.93	0.44	0.49	0.37	0.12	0.00	0.49	$ 46,411
Dairy Dry Cow Pastures	-	-	-	-	-	-	-	-	-
Dairy Sprayfields	-	-	-	-	-	-	-	-	-
Dairy Intensive Lactating Pastures	-	-	-	-	-	-	-	-	-
Dairy High Intensive Holding Pastures	-	-	-	-	-	-	-	-	-
Abandoned Dairy Intensive	-	-	-	-	-	-	-	-	-
Vegetables	734	2.28	0.24	2.04	1.37	0.41	0.26	2.04	$ 150,226
Citrus	20787	4.42	5.80	0.00	0.42	0.00	0.00	0.42	$ 135,467
Overall Dairy - Active	1793	3.52	0.46	3.06	1.30	1.44	0.32	3.06	$ 444,794
Overall Dairy - Abandoned	-	-	-	-	-	-	-	-	-
Sod	1176	0.19	0.19	0.00	0.09	0.00	0.00	0.09	$ 5,821
Ornamentals	44	0.06	0.01	0.04	0.03	0.01	0.00	0.04	$ 3,025
Sugarcane	-	-	-	-	-	-	-	-	-
Poultry	-	-	-	-	-	-	-	-	-
Isolated Wetlands in Dairy Pastures	-	-	-	-	-	-	-	-	-
Lakes, Streams, Canal, Sloughs[1]	20933	17.94	17.94	-	-	-	-	-	-
Totals	**157725**	**78**	**27**	**35**	**12**	**13**	**10**	**35**	**$ 11,777,911**

[1] Atmospheric Deposit, so is not included in the TMDL target sum.

[2] TMDL Target = 55ppb is assumed, but P load reduction needed is reduced by a wetland/Assimilation Dilution Factor = 1.5

Additional regional treatment required to meet the Lake Okeechobee TMDL was estimated for three conditions: 1) tributary TMDLs are not addressed, 2) tributary TMDL is met and existing wetlands and lakes equilibrate to the TMDL levels, and 3) tributary TMDLs are met and existing wetlands and lakes will maintain current P discharge levels (Table 11). The primary assumption is that wetland based RSTA regional treatment technologies with be used because they are the current systems being constructed and proposed. However, chemical based treatment (Table 12) is also provided for comparative purposes. As indicated, the first regional treatment scenario presented is for the condition where tributary TMDLs are not implemented so all existing P loads would have to be treated with regional systems to meet the Lake Okeechobee TMDL target. It is assumed that the regional treatment is implemented downstream of any significant P sinks or sources, such as lakes or wetland sloughs to maximize their benefits, i.e. as close to the Lake Okeechobee as possible. As seen in Table 11, this scenario is the most expensive with an annual cost of about $1.1 billion or about $10 billion initial capital cost. The next two scenarios consider the conditions where tributary TMDLs are met and existing wetlands and lakes have equilibrated to the tributary TMDL levels and tributary TMDLs are met and existing wetlands and lakes will maintain current P discharge levels for some period of time due to P release from previously assimilated legacy P.

The current P loads leaving the Lake Istokpoga and Upper Kissimmee basins are already in compliance with the Lake Okeechobee tributary TMDL due to their significant buffering effect. This means that achieving tributary TMDL targets within these basins will have minimum benefits for achieving the Lake Okeechobee TMDL. However, since the assumed tributary TMDL targets in these upper basins are lower than current P discharges, it is possible that over time these lakes will ultimately come into equilibrium with the assumed tributary TMDL of 55 ppb-P. This re-emphasizes the reason for presenting two tributary TMDL scenarios, which is to bracket potential future P loads between these two future conditions: 1) the lakes do come into equilibrium with TMDL, or 2) that the lakes will continue to buffer P concentrations to current levels (Table 11). The predicted results indicate that current upstream P assimilation/release or buffering by the large lakes and streams could maintain the P loads of about 53 mt per year to the Lake for an unknown number of years, which translates into an annual cost of about $175 million to treat this additional P load with regional treatment systems. This cost would only be needed until the lakes and streams come to equilibrium with the tributary TMDLs, which unfortunately could be many years.

In summary, meeting the Lake Okeechobee TMDL with just wetland based regional treatment would cost about $1.1 billion per year ($10 billion initial capital cost) while meeting both the tributary TMDLs with upland practices and using regional treatment to provide the additional P reduction needed to meet the Lake Okeechobee TMDL would be less expensive. How much less would depend on if the releases of stored legacy P within lakes and streams are included as previously mentioned. When P releases are included meeting both tributary and Lake TMDLs would cost about $554 million per year ($5 billion initial capital cost) while assuming equilibrium with tributary TMDLs would cost about $379 million ($3.4 billion initial capital cost). This assessment has assumed a wetland based regional treatment system at a cost of about $1300 per lb-P removed. For informational purposes, Table 12 shows how costs would change if regional chemical treatment systems were used instead of wetland systems. The cost

Table 11. Estimated Additional Wetland Based Regional Treatment Required to Meet Lake Okeechobee TMDL with and without Meeting Tributary TMDLs

Basins	Existing P Loads	Tributary TMDL P Loads	Lake Okee. TMDL P Loads	Addition Reduction by Regional Treatment to Meet Lake Okee TMDL						Cost to Meet Trib. TMDLs[2]
				Existing P Loads		Trib-TMDL Equilibrium		Trib-TMDL + sink/sources		
	(mt/yr)	(mt/yr)	(mt/yr)	(mt/yr)	Annual Cost[1]	(mt/yr)	Annual Cost[1]	(mt/yr)	Annual Cost[1]	Annual Cost[1]
Northern Lake Okeechobee	336	142	50	285	$ 941,792,280	91	$ 301,777,839	108	$ 357,877,839	$ 47,934,302
Upper Kissimmee Regional	92	65	47	45	$ 147,086,280	18	$ 58,593,645	45	$ 147,086,280	$ 32,500,497
Lake Istokpoga Regional	30	20	15	15	$ 48,739,680	6	$ 18,402,120	15	$ 48,739,680	$ 11,777,911
Total	**457**	**227**	**112**	345	**$ 1,137,618,240**	**115**	**$ 378,773,604**	**168**	**$ 553,703,799**	**$ 92,212,711**

[1] Annual cost include initial capital costs amortized over 15 years @ 8% and O&M costs. Note, initial capital cost approximately equals 9 x annual cost.

[2] Pulled from Tables 8 - 10 for comparison purposes.

Table 12. Estimated Additional Regional Chemical Treatment Required to Meet Lake Okeechobee TMDL with and without Meeting Tributary TMDLs

Basins	Addition Reduction by Regional Treatment to Meet Lake Okee TMDL						Cost to Meet Trib. TMDLs[2]
	Existing P Loads		Trib-TMDL Equilibrium		Trib-TMDL + sink/sources		
	(mt/yr)	Annual Cost[1]	(mt/yr)	Annual Cost[1]	(mt/yr)	Annual Cost[1]	Annual Cost[1]
Northern Lake Okeechobee	285	$ 282,537,684	91	$ 90,533,352	108	$ 107,363,352	$ 47,934,302
Upper Kissimmee Regional	45	$ 44,125,884	18	$ 17,578,094	45	$ 44,125,884	$ 32,500,497
Lake Istokpoga Regional	15	$ 14,621,904	6	$ 5,520,636	15	$ 14,621,904	$ 11,777,911
Total	**345**	**$ 341,285,472**	**115**	**$ 113,632,081**	**168**	**$ 166,111,140**	**$ 92,212,711**

[1] Annual cost include initial capital costs amortized over 15 years @ 8% and O&M costs. Note, initial capital cost approximately equals 9 x annual cost.

[2] Pulled from Tables 8 - 10 for comparison purposes.

reductions are due to the significantly lower land requirements for chemical treatment systems resulting in a cost of about $400 per lb-P removed.

UNCERTAINTIES

The data presented in the report have significant uncertainties that need to be considered before using these results. The three primary sources of uncertainty are associated with the estimated legacy P amounts, mobility factors for the legacy P, and the cost effectiveness of proposed P abatement control practices. Precise estimates of uncertainty are impossible to estimate because the uncertainty of the individual parameters involved in the development of the legacy P, mobility, and cost effectiveness are not available. However, using professional judgment based on past modeling experience and review of the available data resources, it is estimated that the legacy P amount are known to about ± 30% accuracy (SWET, 2008a) while the mobility factors are estimated to have about ± 25% accuracy. However, estimates for predicted P discharges using the legacy P and mobility values are estimated to be about ± 10% accuracy due to calibration to observed data, i.e. the errors for legacy P and mobility are partially self compensating. The cost effectiveness values for the P control practices are estimated to have uncertainties of about ± 25% and therefore net uncertainties of the levels and costs of the P control practices in this P abatement plan should be considered to be in the order of to ± 30%.

IMPLEMENTATION SCHEDULE

Previous sections presented the recommended P control practices required to meet the tributary and lake TMDL targets based on the 1991-2005 discharge data and average implementation conditions over that period. This means that the P control practices implemented since 2000 with many not fully coming on line until after the above base period means their costs must be included in any implementation plan based on these results. Hence, the following implementation schedule includes the period starting in 2000 and any monies spent on the P controls after this date would be included in the cost estimates presented in the previous section, thus reducing future expenditures.

The plan development requires set goals for when both the tributary and Lake Okeechobee TMDLs are to be met. The stated goal for meeting the Lake Okeechobee TMDL is 2015 where there is currently no set timeline for the tributary TMDL. The concern of different target compliance dates for the TMDLs is that the relative response times of various P controls practices will impact when and where TMDL targets can be met. The tributary or upland P controls, particularly BMPs, may take several years for their full benefits to be realized while EOF and regional treatment system will have much faster P reduction responses. This means that even if the described tributary and regional P controls practices are fully implemented by 2015, the Lake Okeechobee TMDL target likely will not be met fully for another five to ten years. Therefore, to achieve compliance with the Lake Okeechobee TMDL in 2015, the faster response P controls, such as EOF and regional treatment, should be implemented at levels that exceed what is needed for equilibrium conditions. If the compliance date for the tributary TMDLs is also set to 2015, then the retention and EOF upland P control practices would have to become the higher priority. The compelling argument for going with the more intensive upland EOF systems is that fast P reduction responses will be attained without overbuilding regional treatment systems and waiting for the slower response BMPs to take their full effect.

Making the assumption that meeting both tributary and Lake Okeechobee TMDLs by 2015 would be the preferred goal and that temporarily overbuilding regional treatment systems is not cost effective, the following generalized implementation schedule is recommended. The highest priority should be placed on EOF systems on the highest P source areas within the Northern Lake Okeechobee basin. BMPs should also remain as a very high priority because in the long run they provide the most cost effective P reduction response. Regional treatment must also continue to be implemented, but only to the level needed to address the equilibrium condition with the tributary TMDL.

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