

Chapter 10: Lake Okeechobee Protection Program – State of the Lake and Watershed

Joyce Zhang, R. Thomas James and Paul McCormick

Contributors: Pinar Balci, Rich Budell¹, Patricia Burke, Therese East, Don Fox², Steffany Gornak, Susan Gray, Herbert Grimshaw II, Charles Hanlon, Steven Hill, Nenad Iricanin, W. Chad Kennedy³, James Laing, Cheol Mo, Temperince Morgan, Kim O'Dell, Richard Pfeuffer, Rachael Pierce, Andrew Rodusky, Chad Rucks, Rebecca Shoemaker, Dave Unsell, Odi Villapando, Benita Whalen and Hongying Zhao

SUMMARY

Lake Okeechobee, the largest lake in the southeastern United States, is shallow, frequently turbid, eutrophic, and a central component of the hydrology and environment of South Florida. The lake supplies water and flood control for nearby towns and surrounding areas, including agricultural land and downstream estuarine ecosystems. Lake Okeechobee is home to migratory water fowl, wading birds, and the federally endangered Everglades snail kite (*Rostrhamus sociabilis*). It is also a multimillion-dollar recreational and commercial fishery. This chapter provides the Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008) status of Lake Okeechobee and its surrounding watershed regarding the major issues impacting the lake's flora and fauna, and ongoing projects to address those issues under the Northern Everglades and Estuaries Protection Program.

Lake Okeechobee has been subject to three long-term impacts: (1) excessive phosphorus loads, (2) unnaturally high and low water levels, and (3) rapid spread of exotic and nuisance plants in the littoral zone. The South Florida Water Management District (District or SFWMD), Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), U.S. Army Corps of Engineers (USACE), and Florida Fish and Wildlife Conservation Commission (FWC) are working cooperatively to address these interconnected issues in order to rehabilitate the lake and enhance the ecosystem services that it provides, while maintaining other project purposes such as water supply and flood control.

¹ Florida Department of Agriculture and Consumer Services, Tallahassee, FL

² Florida Fish and Wildlife Conservation Commission, Okeechobee Field Station, FL

³ Florida Department of Environmental Protection, Southeast District, West Palm Beach, FL

Despite a long history of regulatory and voluntary incentive-based programs to control phosphorus inputs into Lake Okeechobee, no substantial reduction in loading occurred during the 1990s. Consequently, the lake continues to become more eutrophic with blooms of noxious blue-green algae (cyanobacteria), loss of benthic invertebrate diversity, and spread of cattail (*Typha* spp.) in shoreline areas. In 2000, the Florida legislature passed the Lake Okeechobee Protection Act (LOPA), which requires state water quality standards to be achieved no later than January 1, 2015 (Section 373.4595, Florida Statutes). LOPA also requires the coordinating agencies to work together to address total phosphorus (TP) loading and exotic species control.

As specified by LOPA, the SFWMD, FDEP, and FDACS submitted the Lake Okeechobee Protection Plan (LOPP) to the Florida legislature in January 2004 (SFWMD et al., 2004). The LOPA requires that the protection plan be reevaluated every three years to determine if further TP load reductions are needed to achieve the TMDL. A three-year reevaluation report was submitted to the legislature in March 2007 (SFWMD et al., 2007). In April 2007, the Florida legislature substantially expanded the LOPA to include protection and restoration of the Lake Okeechobee Watershed and the Caloosahatchee and St. Lucie rivers watersheds and estuaries. At the same time, the legislature also extended the Save Our Everglades Trust Fund for 10 years, providing a dedicated state funding source for the restoration through 2020. The newly expanded program was named as the Northern Everglades and Estuaries Protection Program (NEEPP) (Section 373.4595, F.S., 2007). Consequently, the Lake Okeechobee and Estuary Recovery (LOER) Plan, announced in October 2005, was migrated into this program.

The NEEPP requires the SFWMD, in collaboration with coordinating agencies (FDEP and FDACS), to develop a Technical Plan for Phase II of the Lake Okeechobee Watershed Construction Project (LOWCP) by February 1, 2008, and to develop protection plans for the Caloosahatchee and St. Lucie River Watersheds by January 1, 2009. The Lake Okeechobee Watershed Construction Project Phase II Technical Plan (P2TP) (SFWMD et al., 2008) was submitted to the legislature in February 2008. The technical plan identifies construction projects, along with on-site measures that prevent or reduce pollution at its source such as agricultural and urban Best Management Practices (BMPs), needed to achieve the TMDL for TP established for Lake Okeechobee. In addition, the technical plan includes other projects for increasing water storage north of Lake Okeechobee to achieve healthier lake levels and reduce harmful discharges to the Caloosahatchee and St. Lucie rivers' estuaries. The plan is currently being implemented.

Conditions in Lake Okeechobee are reported as rolling five-year averages for consistency with the TP TMDL criteria and to reduce the variability that can be attributed to climate and hydrology. Of the 11 performance measures that can be compared to current five-year (2004–2008) averages, two reached their goal this water year: (1) the diatom-to-cyanobacteria ratio was greater than 1.5, and (2) algal blooms (chlorophyll *a* > 40 µg l⁻¹) occurred in less than five percent of the samples. In this water year, the lake stage never exceeded the extreme high lake levels because of the drought.

Excessive phosphorus loads to the lake are predominately associated with agricultural and urban activities that make up most of the land use in the watershed. The TP load averaged for the WY2004–WY2008 reporting period was 551 metric tons (mt), which is a decline from 630 mt during the previous five-year period, WY2003–WY2007. This decline can be attributed to the lower loadings to the lake in the past two water years (203 mt/yr in WY2007 and 246 mt/yr in WY2008). The current five-year average is nearly four times higher than the TMDL of 140 mt (as five-year average) considered necessary to achieve the in-lake TP target of 40 parts per billion (ppb). The TP load for WY2008 was 246 mt/yr due, at least in part, to the extremely dry conditions in the watershed. This is similar to the previous WY2007 load of 203 mt/yr that also

occurred during a dry year; and much less than the WY2006 load of 795 mt/yr that included a wet summer and the passage of Hurricane Wilma.

Water clarity in the nearshore region during the May to September (annual wet season) period for WY2004–WY2008 increased, with the Secchi disk being visible on the bottom of the water column in 15 percent of the observations. This increase in water clarity can be attributed to WY2008 conditions (a result of the shallower water depths due to drought). Nearshore TP also dropped in WY2008 to 47 ppb, reducing the nearshore five-year average from 120 ppb in WY2007 to 114 ppb in WY2008. This reduction in nearshore TP may be partially attributed to submerged aquatic vegetation (SAV), which increased by 10-fold between August 2006 and August 2007 mapping surveys.

The flow of water to Lake Okeechobee was 1,012,820 acre-feet (ac-ft) or 124,930 hectare meters (ha-m) in WY2008, approximately one-third of the 3,743,986 ac-ft or 461,814 ha-m recorded in WY2006, and approximately half the baseline average (calendar years 1991–2005, or CY1991–CY2005) of 2,535,572 ac-ft (312,758 ha-m). Lake stage at the beginning of WY2008 was at 9.51 feet (ft) or 2.9 meters (m) National Geodetic Vertical Datum (NGVD) and declined to a low of 8.82 ft (2.69 m) NGVD on July 2, 2007. Daily record lows were reached from July 2007 until March 2008 when water levels increased to 10.23 ft (3.12 m) NGVD. The low water levels resulted in establishment of water use restrictions throughout South Florida. These restrictions increased in severity from Phase I water use restrictions in November 2006, which reduced residential lawn watering to (typically) three days a week and agriculture watering by 15 percent, to Phase III restrictions implemented on May 16, 2007, which reduced lawn watering in most cases to one day a week and agriculture by 45 percent. To maintain water supply to the Everglades Agriculture Area (EAA), 14 temporary forward pumps were deployed in Lake Okeechobee. As water levels increased from January to April, the water use restrictions were eased back to Phase II, where lawn watering is now usually allowed twice a week.

The 2006–2008 drought exposed a number of littoral and nearshore areas that have been covered with mud sediments. The District, in cooperation with the state of Florida and FWC and Glades County, began a multi-million dollar effort to remove these muck materials and restore six locations in the lake. Over two million cubic yards of muck (1.6 million cubic meters) have been removed from an estimated 2,000 ac (809 ha) of exposed shoreline, potentially restoring SAV and emergent plant habitat. This project also removed an estimated 237 mt of phosphorus at an approximated cost of \$11 million (or \$46.5 per kg). Soil phosphorus-release tests are being conducted to determine the amount of internal phosphorus loading that could potentially be released into the water column following re-flooding. Greenhouse studies looking at the germination of wetlands and submerged aquatic plant seeds from different plowing/disking treatments is also ongoing.

In April 2008, the USACE approved a new regulation schedule (LORS2008) for Lake Okeechobee which replaced the WSE (Water Supply and Environment) regulation schedule. LORS2008 is intended to be a temporary schedule which focuses on public health and general welfare considerations associated with the Herbert Hoover Dike. A revised water shortage management plan was developed to mitigate the effects of extreme low lake levels, which are anticipated to be more severe and frequent under this new schedule. LORS2008 is anticipated to be in effect until either the risk of dike failure is reduced with improvements to Reaches 1, 2, and 3 of the dike, or the Comprehensive Everglades Restoration Plan (CERP) Band 1 projects are implemented, whichever comes first.

More than 40,000 ac of emergent vegetation, primarily in the Moore Haven region of the western marsh, burned as a result of arson and wildfires in early calendar year (CY) 2008. The fires burned mostly grasses and terrestrial vegetation that established following wildfires that burned the marsh in CY2007. Fire eliminated much of the invasive aboveground torpedograss

(*Panicum repens*). However, in many areas, the torpedograss reestablished from underground rhizomes that were insulated from the damaging effects of fire and has been actively growing in response to recent spring and summer rain events. As of WY2008, more than 5,000 ac (2,023 ha) of torpedograss have been treated chemically and effective control in these areas is anticipated.

A new initiative was begun to determine if apple snails (*Pomacea paludosa*), the primary food of the endangered Everglades snail kite (*Rostrhamus sociabilis*), could be grown in captivity using aquaculture techniques. Various stocking experiments showed promise, however the number of egg clutches produced per individual were much lower than observed in the wild. Further experiments with diet and temperature are planned to determine more optimal conditions to breed these animals.

Planting efforts for indigenous pond apple trees (*Annona glabra*) continued during WY2008. Due to ongoing construction at the EAA Reservoir in western Palm Beach County, several thousand pond apple trees were to be submerged and killed. The District transplanted 1,500 of these mature trees in April 2008, as part of ongoing habitat restoration work on Torrey Island in Lake Okeechobee. Pond apple trees provide desirable habitat for other native species, including the snail kite, endangered Okeechobee gourd (*Cucurbita okeechobeensis*, sometimes called Indian pumpkin), and wading birds. Future plantings of cypress trees (*Taxodium* spp.) are also planned.

INTRODUCTION

Lake Okeechobee (located at 27° N latitude and 81° W longitude) is an important resource for the interconnected South Florida aquatic ecosystem and the U.S. Army Corps of Engineers (USACE) regional flood control project. The lake has a surface area of 445,559 ac [1,803 square kilometers (km²)], and is extremely shallow, with a mean depth of 8.9 feet (ft) [2.7 meters (m)] and maximal depth of 18 ft (5.5 m) (James et al., 1995a). Lake Okeechobee receives water from a 5,400-square-mile (sq mi) (14,000 km²) watershed that includes the Upper Kissimmee Chain of Lakes, the Kissimmee River, Lake Istokpoga, Fisheating Creek, and other drainage basins (**Figure 10-1**). Lake waters flow south, east, and west to the Everglades Protection Area, the St. Lucie River (C-44 canal), and the Caloosahatchee River (C-43 canal), respectively.

Lake Okeechobee serves many roles: it provides water supply to urban areas, agriculture, and downstream estuarine ecosystems; supports a multimillion-dollar sport fishery (Furse and Fox, 1994), a commercial fishery, and various recreational activities; and provides habitat for migratory waterfowl, wading birds, alligators, and the Everglades snail kite (Aumen, 1995). The lake is also used for flood control during the wet season and water supply during the dry season. The lake faces three major environmental challenges: (1) excessive total phosphorus (TP) loads, (2) unnaturally high and low water levels, and (3) the rapid spread of exotic and nuisance plants.

This chapter updates the discussion of lake and watershed conditions presented in Chapter 10 of the *2008 South Florida Environmental Report (SFER) – Volume I* focusing on water quality, water levels, and aquatic vegetation. Results of recently completed research projects are presented, as well as status of ongoing watershed and in-lake management projects. Information regarding exotic plant control programs, and associated research projects to optimize those programs, are presented in Chapter 9 of this volume.

The extreme variability of weather in South Florida has been especially demonstrated in the past four years. WY2005 began very dry but ended very wet, primarily because of four hurricanes (Charley, Frances, Ivan, and Jeanne; see 2006 SFER – Volume I, Chapter 10). WY2006 began as a very wet year, and included one hurricane (Wilma) in October 2005 (see 2007 SFER – Volume I, Chapter 10), but within the calendar year (CY2006) bridging WY2006 and WY2007, conditions changed. Despite the passage of Tropical Storm Ernesto in September 2006, WY2007 was very dry to a point where water supply restrictions were enacted (see the *Water Shortage Management* section of this chapter). WY2008 was also very dry — and the lake experienced back-to-back water shortage years for the first time since the early 1980s. The lake had consistently set new record lows since early June, reaching an all-time record low of 8.82 feet above sea level on July 2, 2008. (For details on the South Florida hydrology of the recent drought, see Chapter 2 of this volume).

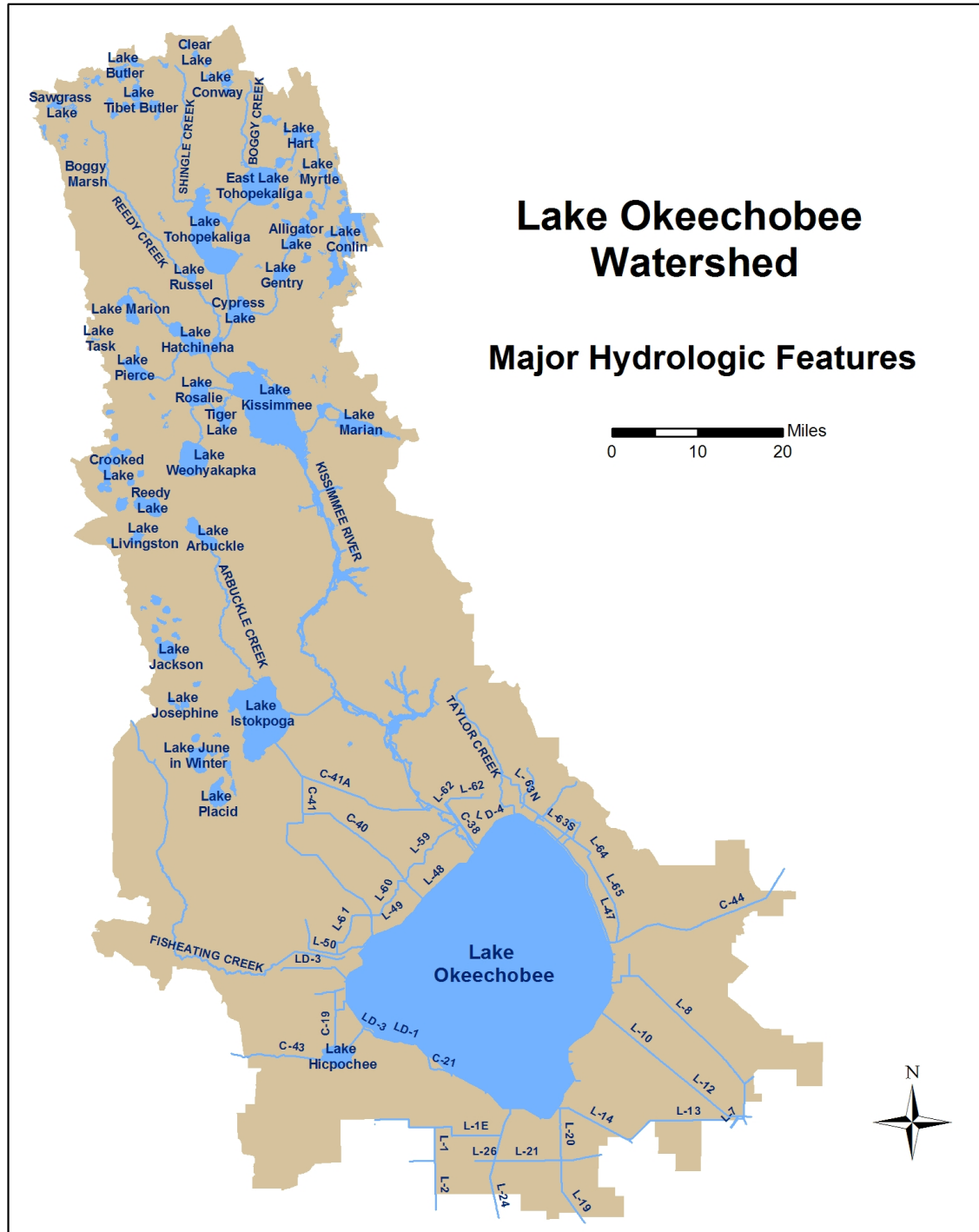


Figure 10-1. Major hydrologic features of the Lake Okeechobee Watershed (L = levee, C = canal).

OVERVIEW OF LAKE OKEECHOBEE PROGRAMS

The Lake Okeechobee Protection Act (LOPA) [Section 373.4595, Florida Statutes (F.S.)] was passed by the 2000 Florida legislature to establish a restoration and protection program for the lake. This program addresses the reduction of TP loading to the lake from both internal and external sources. Phosphorus load reductions will be achieved through a phased program of implementing long-term solutions based upon the Lake Okeechobee Total Maximum Daily Load (TMDL) for TP developed by the Florida Department of Environmental Protection (FDEP, 2001). This TMDL is a long-term (five-year) rolling average of 140 metric tons (mt) of TP to be attained by 2015. The TMDL consists of 105 metric tons per year (mt/yr) of TP from the watershed and 35 mt/yr from atmospheric deposition. LOPA also requires aggressive programs to control exotic plants and a long-term program of water quality and ecological assessment, research, and predictive-model development.

In 2007, the legislature amended LOPA to include the protection of the Caloosahatchee and St. Lucie River watersheds (**Figure 10-2**). Section 373.4595, F.S., is now known as the Northern Everglades and Estuaries Protection Program (NEEPP), which promotes a comprehensive, interconnected watershed approach to protecting these water bodies. The NEEPP contains the Lake Okeechobee Protection Program, now named the Lake Okeechobee Watershed Protection Program and the Caloosahatchee and St. Lucie River Watershed Protection Program. These programs address the reduction of pollutant loadings, restoration of natural hydrology, and compliance with applicable state water quality standards.

The NEEPP requires the South Florida Water Management District (SFWMD or District), in collaboration with the FDEP and the Florida Department of Agriculture and Consumer Services (FDACS) as coordinating agencies and in cooperation with local governments, to develop (1) the Lake Okeechobee Watershed Construction Project Phase II Technical Plan (P2TP), (2) the St. Lucie River Watershed Protection Plan (SLRWPP), and (3) the Caloosahatchee River Watershed Protection Plan (CRWPP). These plans will augment and enhance restoration currently under way in the Everglades south of the lake and build upon ongoing restoration efforts north of Lake Okeechobee and in the river watersheds. The P2TP, submitted to the legislature in February 2008, is currently being implemented. The P2TP identifies construction projects, along with on-site measures that prevent or reduce pollution at its source such as agricultural and urban Best Management Practices (BMPs), needed to achieve the Lake Okeechobee TMDL for phosphorus. In addition, the plan includes other projects for increasing water storage north of the lake to achieve healthier lake levels and reduce harmful discharges to the Caloosahatchee and St. Lucie river estuaries. The technical plan and its appendices are available on the District's web site at www.sfwmd.gov, under the *Lake Okeechobee* tab.

The Caloosahatchee and St. Lucie River Watershed protection plans were required to be submitted to the Florida legislature by January 1, 2009. Each river watershed protection plan includes three main components: (1) a construction project, (2) a pollutant control program, and (3) a research and water quality monitoring program. Details on the river watershed protection plans can be found in Chapter 12 of this volume.

As specified by the NEEPP, elements of the Lake Okeechobee Watershed Protection Program include: (1) Lake Okeechobee Watershed Protection Plan (LOWPP), (2) Lake Okeechobee Watershed Construction Project, (3) Lake Okeechobee Watershed Phosphorus Control Program, (4) Lake Okeechobee Watershed Research and Water Quality Monitoring Program, (5) Lake Okeechobee Exotic Species Control Program, (6) Lake Okeechobee Internal Phosphorus Management Program, and (7) Annual Progress Report. This chapter constitutes the ninth annual report to the legislature summarizing the water quality and habitat conditions of the lake and its watershed and BMP implementation activities. The internal phosphorus management program

can be found in the *In-lake Management* section of this chapter. The exotic species control program is documented in Chapter 9 of this volume. The remaining elements are documented in the watershed sections below.

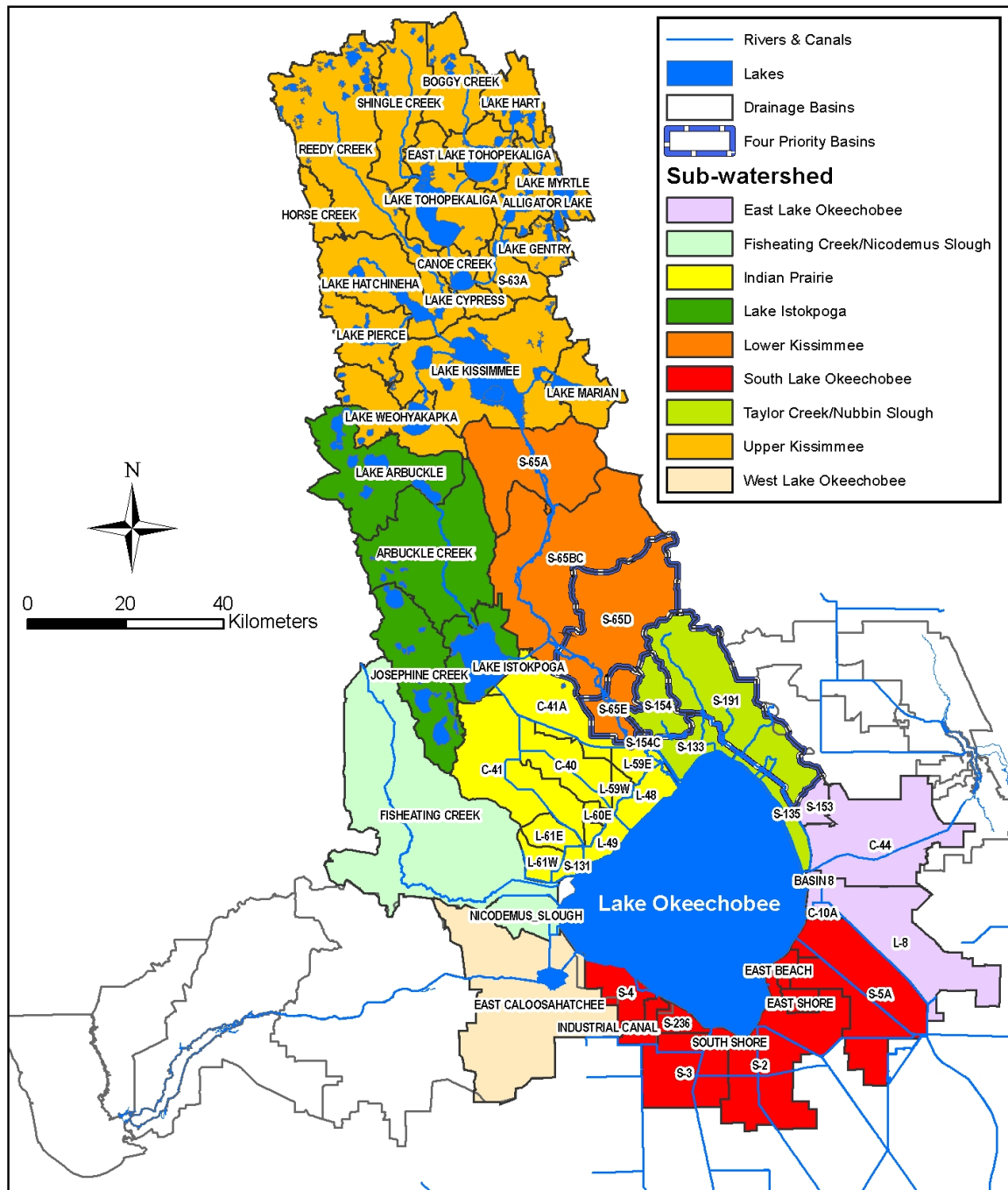


Figure 10-2. Northern Everglades and Estuaries Protection Plan area, including the Lake Okeechobee Watershed (color-coded by sub-watershed), the St. Lucie River Watershed (all east drainage basins), and the Caloosahatchee River Watershed (all west drainage basins).

WATERSHED STATUS AND MANAGEMENT

WATERSHED STATUS

The Lake Okeechobee Watershed comprises roughly 5,400 sq mi (13,859 km²) and contains nine sub-watersheds covering from just south of Orlando to areas bordering the lake on the south, east, and west (**Figure 10-2**). The most recent land use data were updated in May 2006 as part of the LOPP reevaluation effort (**Table 10-1**). Nutrient levels in surface runoff are directly related to local land use and land management practices (Hiscock et al., 2003; Zhang et al., 2002). Agriculture takes up about 46 percent (1.6 million acres) of the total area, where various agricultural BMPs are being implemented to reduce nutrient loads. Natural areas including upland forest, water, wetlands, rangeland, and barren land comprise about 42 percent of the total watershed area. The remaining 12 percent of areas are classified as urban (including residential and other urban), transportation, communication, and utilities, where various urban BMPs can be implemented. (Note: BMPs are practices determined by coordinating agencies, based on research, field-testing, and expert review, to be the most economic and technologically effective and practicable on-location means for improving water quality in agricultural and urban discharges.)

Surface water flow, TP loads, and total nitrogen (TN) loads to the lake for WY2008 were calculated for the major drainage basins (**Tables 10-2 and 10-3**). This includes discharges from lakes Istokpoga and Kissimmee. These lakes are the outfalls of sub-watersheds that collect water flow and nutrient loads from the smaller drainage basins that surround them (**Figure 10-2**). Data are based on continuous flow monitoring stations and TP and TN samples collected on a weekly basis (**Figure 10-3**). During WY2008, the largest surface water inflow came from the Upper Kissimmee sub-watershed (above structure S-65), followed by the L-8 basin, the C-44 basin (via structure S-308C), and the East Caloosahatchee Basin (S-77). Discharge from the S-308C structure contributed the largest TP loads to Lake Okeechobee, followed by the Upper Kissimmee sub-watershed, the L-8 basin, and the East Caloosahatchee Basin. By comparing with baseline data shown in **Table 10-4**, TP loads from structures S-308C, S-77, and C-10A (L-8 basin) for WY2008 (**Table 10-2**) would not be significant contributors if the lake stages were not extremely low for the year. The TP load to the lake in WY2008 from all drainage basins and atmospheric deposition was 246 mt. Discharge from the Upper Kissimmee sub-watershed contributed the largest TN loads to Lake Okeechobee, followed by the L-8 basin and the C-44 basin (S-308C) (**Table 10-3**). The TN load to the lake in WY2008 from all drainage basins (including an estimated 1,233 mt from atmospheric deposition) was 3,385 mt.

These current year discharges are much smaller than the baseline period of record, calendar years 1991–2005 (**Tables 10-4 and 10-5**). For the baseline period, the largest surface water inflow came from the Upper Kissimmee sub-watershed, followed by the Lower Kissimmee sub-watershed (between structures S-65 and S-65E), Lake Istokpoga sub-watershed, Fisheating Creek, and Taylor Creek/Nubbin Slough. The Upper Kissimmee sub-watershed contributed the largest TP loads to Lake Okeechobee, followed by Taylor Creek/Nubbin Slough, Lower Kissimmee sub-watershed, Fisheating Creek, and C-41. The average annual TP load to the lake for the baseline period from all drainage basins and atmospheric deposition was 546 mt. Discharge from the Upper Kissimmee sub-watershed contributed the largest TN loads to Lake Okeechobee, followed by the Lower Kissimmee sub-watershed, Lake Istokpoga sub-watershed, Fisheating Creek, and C-41. The average annual TN load to the lake in the baseline period from all drainage basins and atmospheric deposition was 6,364 mt.

Phosphorus loading rates into Lake Okeechobee have varied over time as a result of a combination of climatic conditions, land use changes and changes in water management conditions (**Table 10-6**). From 1981 to 2008, the highest loading rate was 1,189 mt in WY1983, followed by 960 mt in WY2005 and 795 mt in WY2006. The highest five-year average load was 715 mt from WY2002–WY2006. The most recent five-year average load from WY2004–WY2008 was 551 mt, which exceed the TMDL by 411 mt (**Table 10-6**). This five-year average included two of the consecutive wettest years on record (WY2005 and WY2006) that included the impacts of four hurricanes and the two subsequent dry years (WY2007 and WY2008). These extremes emphasize the reason that the TMDL is based on a five-year average — to account for variations in water flow and loads.

Table 10-1. Land use data grouped by basin and sub-watershed, as of May 2006.

Basin/Sub-watershed	Urban and Built Up	Agriculture	Rangeland	Upland Forest	Water	Wetlands	Barren Land	Transportation, Communication, and Utilities	Total (ac)
Basin 8	0	2,155		2		63	6	78	2,304
C-10A	25	4,224			122	11	156	32	4,570
C-44	3,343	57,089	2,416	15,069	11,850	22,324	1,803	2,601	116,496
L-8	19,622	13,126	106	22,469	903	42,213	872	2,218	101,529
S-153	669	6,011	232	4,315	30	1,666	10	1	12,934
Subtotal for East Lake Okeechobee Sub-watershed	23,659	82,604	2,754	41,855	12,905	66,277	2,846	4,931	237,832
Fisheating Creek	4,213	125,140	28,138	59,880	1,026	69,718	212	1,040	289,367
Nicodemus Slough	1	16,856	556	3,351	147	4,191	346	193	25,641
Subtotal for Fisheating Creek/Nicodemus Slough Sub-Watershed	4,214	141,996	28,693	63,231	1,173	73,910	558	1,233	315,008
C-40	154	33,167	717	3,585	191	5,528	617	6	43,965
C-41	3,519	67,601	3,773	8,342	568	9,293	1,181	377	94,655
C-41A	438	42,566	1,355	1,508	2,889	9,238	344	149	58,488
L-48	651	16,162	98	575	327	2,414	495	53	20,774
L-49	218	8,047	1,472	738	293	981	343		12,093
L-59E	1,179	7,766	405	875	271	1,816	1,461	635	14,409
L-59W	10	3,832	753	1,523	28	265	29		6,440
L-60E	97	1,444	1,018	2,097	0	362	20		5,038
L-60W	14	1,667	540	916	4	100	30		3,271
L-61E	19	8,271	1,145	2,519	17	2,154	161		14,286
L-61W		6,771	580	2,552	21	3,569	74		13,567
S-131	796	5,049	26	308	204	555	226		7,164
Subtotal for Indian Prairie Sub-watershed	7,096	202,342	11,882	25,540	4,813	36,276	4,980	1,220	294,148
Arbuckle Creek	17,068	65,837	5,299	25,613	4,218	20,750	97	2,131	141,013
Josephine Creek	24,369	26,278	1,539	11,789	15,971	9,322	396	760	90,424
Lake Arbuckle	11,958	34,502	7,048	17,885	15,398	18,090	187	424	105,491
Lake Istokpoga	6,603	13,739	785	3,466	24,205	6,202	19	200	55,221
Subtotal for Lake Istokpoga Sub-watershed	59,998	140,356	14,672	58,754	59,791	54,364	699	3,514	392,148
S-65A	3,493	49,072	11,196	15,896	287	22,253	752	402	103,351
S-65BC	1,050	61,190	45,460	17,168	928	51,117	2,296	916	180,125
S-65D	14,531	59,101	6,987	4,657	2,753	26,835	672	1,114	116,651
S-65E	2,999	19,272	440	1,684	530	3,266	588	379	29,157

Table 10-1. Continued.

Basin/Sub-watershed	Urban and Built Up	Agriculture	Rangeland	Upland Forest	Water	Wetlands	Barren Land	Transportation, Communication, and Utilities	Total (ac)
Subtotal for Lower Kissimmee Sub-watershed	22,073	188,635	64,082	39,406	4,497	103,472	4,308	2,810	429,284
715 Farms	44	2,980			8		17	252	3,302
East Beach	998	5,408	3	14	84		37	80	6,624
East Shore		8,196			24		64	131	8,416
Industrial Canal	1,441	9,915		46	978	129	282	234	13,024
S-2	4,676	98,205	19	44	1,215	43	1,030	1,140	106,372
S-236	373	9,792	16	131	84	172	206	255	11,028
S-3	34	61,312	0		578	160	394	469	62,946
S-4	1,809	22,481	27	305	393	731	327	316	26,389
S-5A	2,200	113,006		1	1,252	156	1,458	1,370	119,443
South Shore	190	3,644		26	73	7	69	125	4,134
Subtotal for South Lake Okeechobee Sub-watershed	11,764	334,938	65	566	4,686	1,399	3,886	4,372	361,676
S-133	13,933	6,626	276	1,558	1,003	1,420	192	653	25,660
S-135	951	13,259	87	936	631	856	668	701	18,089
S-154	3,583	20,937	1,250	1,001	148	4,373		327	31,619
S-154C		1,729		110	40	175	124		2,179
S-191	21,715	73,976	1,727	10,238	1,294	11,403	4	396	120,754
Subtotal for Taylor Creek/Nubbin Slough Sub-watershed	40,183	116,527	3,341	13,844	3,116	18,227	987	2,076	198,301
West Lake Okeechobee Sub-watershed	5,844	127,172	8,317	23,903	2,199	29,738	1,774	2,047	200,993
Upper Kissimmee Sub-watershed	211,453	245,508	36,337	127,215	131,466	241,965	5,791	21,938	1,021,674
Grand Total (acre)	386,285	1,580,079	170,144	394,314	224,647	625,626	25,828	44,142	3,451,065
Percentage	11%	46%	5%	11%	7%	18%	1%	1%	100%

Table 10-2. WY2008 surface water inflows, total phosphorus (TP) concentrations, and loading rates for the major drainage basins or sub-watersheds in the Lake Okeechobee Watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Area (acre)	Average TP Concentration (ppb)	TP Load (mt)
715 Farms (Culv 12A)	0	0	3,302	0	0.0
C-40 basin (S-72) – S68	5,122	632	43,965	389	2.5
C-41 basin (S-71) – S68	24,225	2,988	94,655	358	10.7
S-84 basin (C-41A) – S68	12,220	1,507	58,488	376	5.7
S-308C (St. Lucie – C-44)	180,040	22,208	129,430	324	72.0
East Beach DD (Culv 10)	6	1	6,624	114	0.0
East Shore DD (Culv 12)	847	104	8,416	171	0.2
Fisheating Creek	34,700	4,280	289,367	252	10.8
Industrial Canal	15,175	1,872	13,024	234	4.4
L-48 basin	0	0	20,774	0	0
L-49 basin	0	0	12,093	0	0
L-59E	0	0	14,409	0	0
L-59W	1,082	133	6,440	104	-0.1
L-60E	2,112	261	5,038	341	0.6
L-60W	332	41	3,271	205	0.0
L-61E	N/A	N/A	14,286	N/A	N/A
L-61W	N/A	N/A	13,567	N/A	N/A
Taylor Creek/Nubbin Slough (S-191)	23,959	2,955	120,754	531	10.4
S-131	166	20	7,164	125	0.0
S-133	0	0	25,660	0	0.0
S-135	0	0	18,088	0	0.0
S-154	91	11	33,798	227	0.0
S-2	3,850	475	106,372	121	0.6
S-3	258	32	62,946	295	0.1
S-4	720	89	26,389	180	0.2
Lower Kissimmee Sub-watershed	15,089	1,861	429,284	617	11.5
South FL Conservancy DD (S-236)	39	5	11,028	101	0.0
South Shore/South Bay DD (Culv 4A)	0	0	4,134	0	0.0
Nicodemus Slough (Culv 5)	N/A	N/A	25,641	N/A	N/A
Upper Kissimmee Sub-watershed	301,970	37,247	1,021,674	87	32.6
Lake Istokpoga Sub-watershed	30,931	3,815	392,147	52	2.0
S-5A Basin (S-352 WPB Canal)	0	0	119,443	0	0.0
East Caloosahatchee (S-77)	103,248	12,735	200,993	135	17.2
L-8 basin (Culv 10A)	244,930	30,212	108,402	67	20.2
Culvert 5A	11,675	1,440	N/A		3.7
Atmospheric Deposition					35
Totals	1,012,785	124,925	3,451,065	197*	246

*Surface inflow concentration only

N/A – Not Available

Table 10-3. WY2008 surface water inflows, total nitrogen (TN) concentrations, and loading rates for the major drainage basins or sub-watershed in the Lake Okeechobee Watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Average TN Concentration (ppm)	TN Load (mt)
715 Farms (Culv 12A)	0	0	0	0
C-40 basin (S-72) – S68	5,122	632	2.08	13.2
C-41 basin (S-71) – S68	24,225	2,988	2.26	67.5
S-84 basin (C-41A) – S68	12,220	1,507	1.93	29.1
S-308C (St. Lucie – C-44)	180,040	22,208	1.97	436.5
East Beach DD (Culv 10)	6	1	1.75	0
East Shore DD (Culv 12)	847	104	8.67	9.1
Fisheating Creek	34,700	4,280	2.16	92.5
Industrial Canal	15,175	1,872	2.62	49.0
L-48 basin	0	0	0	0
L-49 basin	0	0	0	0
L-59E	0	0	0	0
L-59W	1,082	133	1.18	1.6
L-60E	2,112	261	2.15	5.6
L-60W	332	41	1.51	0.6
L-61E	N/A	N/A	N/A	N/A
L-61W	N/A	N/A	N/A	N/A
Taylor Creek/Nubbin Slough (S-191)	23,959	2,955	1.82	53.7
S-131	166	20	1.52	0.3
S-133	0	0	0	0
S-135	0	0	0	0
S-154	91	11	1.74	0.2
S-2	3,850	475	4.47	21.2
S-3	258	32	3.44	1.1
S-4	720	89	2.68	2.4
Lower Kissimmee Sub-watershed	15,089	1,861	0.68	12.7
South FL Conservancy DD (S-236)	39	5	2.42	0.1
South Shore/South Bay DD (Culv 4A)	0	0	0	0
Nicodemus Slough (Culv 5)	N/A	N/A	N/A	N/A
Upper Kissimmee Sub-watershed	301,970	37,247	1.49	554.3
Lake Istokpoga Sub-watershed	30,931	3,815	1.45	55.2
S-5A Basin (S-352 WPB Canal)	0	0	0	0
East Caloosahatchee (S-77)	103,248	12,735	1.55	197.2
L-8 basin (Culv 10A)	244,930	30,212	1.73	523.6
Culvert 5A	11,675	1,440	1.70	24.5
Atmospheric Deposition*				1233.4
Totals	1,012,785	124,925	1.75	3,385

*Surface inflow concentration only from James et al. (2005)

N/A - Not Available

Table 10-4. Baseline (CY1991–CY2005) surface water inflows, TP concentrations, and loading rates for the major drainage basins or sub-watershed in the Lake Okeechobee Watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Average TP Concentration (ppb)	TP Load (mt)
715 Farms (Culv 12A)	8,555	1,055	112	1.18
C-40 basin (S-72) – S68	17,181	2,119	618	13.10
C-41 basin (S-71) – S68	58,682	7,238	540	39.08
S-84 basin (C-41A) – S68	60,456	7,457	77	5.72
S-308C (St. Lucie – C-44)	50,146	6,185	209	12.92
East Beach DD (Culv 10)	8,608	1,062	589	6.26
East Shore DD (Culv 12)	10,890	1,343	169	2.27
Fisheating Creek	221,012	27,261	201	54.70
Industrial Canal	21,981	2,711	119	3.23
L-48 basin	20,047	2,473	231	5.70
L-49 basin	13,964	1,722	105	1.80
L-59E	28,335	3,495	173	6.03
L-59W	8,981	1,108	394	4.36
L-60E	2,231	275	207	0.57
L-60W	502	62	237	0.15
L-61E	1,190	147	159	0.23
L-61W	1,810	223	95	0.21
Taylor Creek/Nubbin Slough (S-191)	108,625	13,399	644	86.35
S-131	10,996	1,356	119	1.62
S-133	26,404	3,257	253	8.25
S-135	24,982	3,081	123	3.78
S-154	27,579	3,402	760	25.86
S-2	37,149	4,582	167	7.63
S-3	15,936	1,966	135	2.65
S-4	28,994	3,576	213	7.63
Lower Kissimmee Sub-watershed	373,435	46,063	167	76.77
South FL Conservancy DD (S-236)	12,213	1,506	107	1.62
South Shore/South Bay DD (Culv 4A)	6,502	802	107	0.86
Nicodemus Slough (Culv 5)	634	78	51	0.04
Upper Kissimmee Sub-watershed	959,653	118,371	78	91.92
Lake Istokpoga Sub-watershed	301,389	37,176	80	29.64
S-5A Basin (S-352 WPB Canal)	199	25	230	0.06
East Caloosahatchee (S-77)	5,835	720	139	1.00
L-8 basin (Culv 10A)	58,992	7,277	102	7.40
Culvert 5A	1,487	183	104	0.19
Atmospheric Deposition				35.0
Totals	2,535,572	312,758	163*	546

*Surface inflow concentration only

N/A – Not Available

Table 10-5. Baseline (CY1991–CY2005) surface water inflows, TN concentrations, and loading rates for the major drainage basins or sub-watershed in the Lake Okeechobee Watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Average TN Concentration (ppm)	TN Load (mt)
715 Farms (Culv 12A)	8,555	1,055	4.73	49.9
C-40 basin (S-72) – S68	17,181	2,119	4.65	98.6
C-41 basin (S-71) – S68	58,682	7,238	4.82	348.6
S-84 basin (C-41A) – S68	60,456	7,457	1.45	108.5
S-308C (St. Lucie – C-44)	50,146	6,185	1.68	103.9
East Beach DD (Culv 10)	8,608	1,062	7.88	83.7
East Shore DD (Culv 12)	10,890	1,343	6.85	92.0
Fisheating Creek	221,012	27,261	1.52	414.5
Industrial Canal	21,981	2,711	2.89	78.5
L-48 basin	20,047	2,473	2.08	51.4
L-49 basin	13,964	1,722	1.60	27.6
L-59E	28,335	3,495	2.39	83.6
L-59W	8,981	1,108	2.24	24.8
L-60E	2,231	275	1.89	5.2
L-60W	502	62	1.98	1.2
L-61E	1,190	147	2.19	3.2
L-61W	1,810	223	1.48	3.3
Taylor Creek/Nubbin Slough (S-191)	108,625	13,399	2.00	267.9
S-131	10,996	1,356	1.49	20.2
S-133	26,404	3,257	1.73	56.2
S-135	24,982	3,081	1.62	49.9
S-154	27,579	3,402	2.03	69.2
S-2	37,149	4,582	5.28	242.2
S-3	15,936	1,966	4.61	90.6
S-4	28,994	3,576	3.18	113.6
Lower Kissimmee Sub-watershed	373,435	46,063	0.99	454.6
South FL Conservancy DD (S-236)	12,213	1,506	4.46	67.2
South Shore/South Bay DD (Culv 4A)	6,502	802	4.65	37.3
Nicodemus Slough (Culv 5)	634	78	1.74	1.4
Upper Kissimmee Sub-watershed	959,653	118,371	1.21	1436.4
Lake Istokpoga Sub-watershed	301,389	37,176	1.21	449.7
S-5A Basin (S-352 WPB Canal)	199	25	6.76	1.7
East Caloosahatchee (S-77)	5,835	720	1.91	13.7
L-8 basin (Culv 10A)	58,992	7,277	2.45	178.0
Culvert 5A	1,487	183	1.36	2.5
Atmospheric Deposition*				1233.4
Totals	2,535,572	312,758	1.64	6,364

**Surface inflow concentration only

*from James et al. (2005)

N/A – Not Available

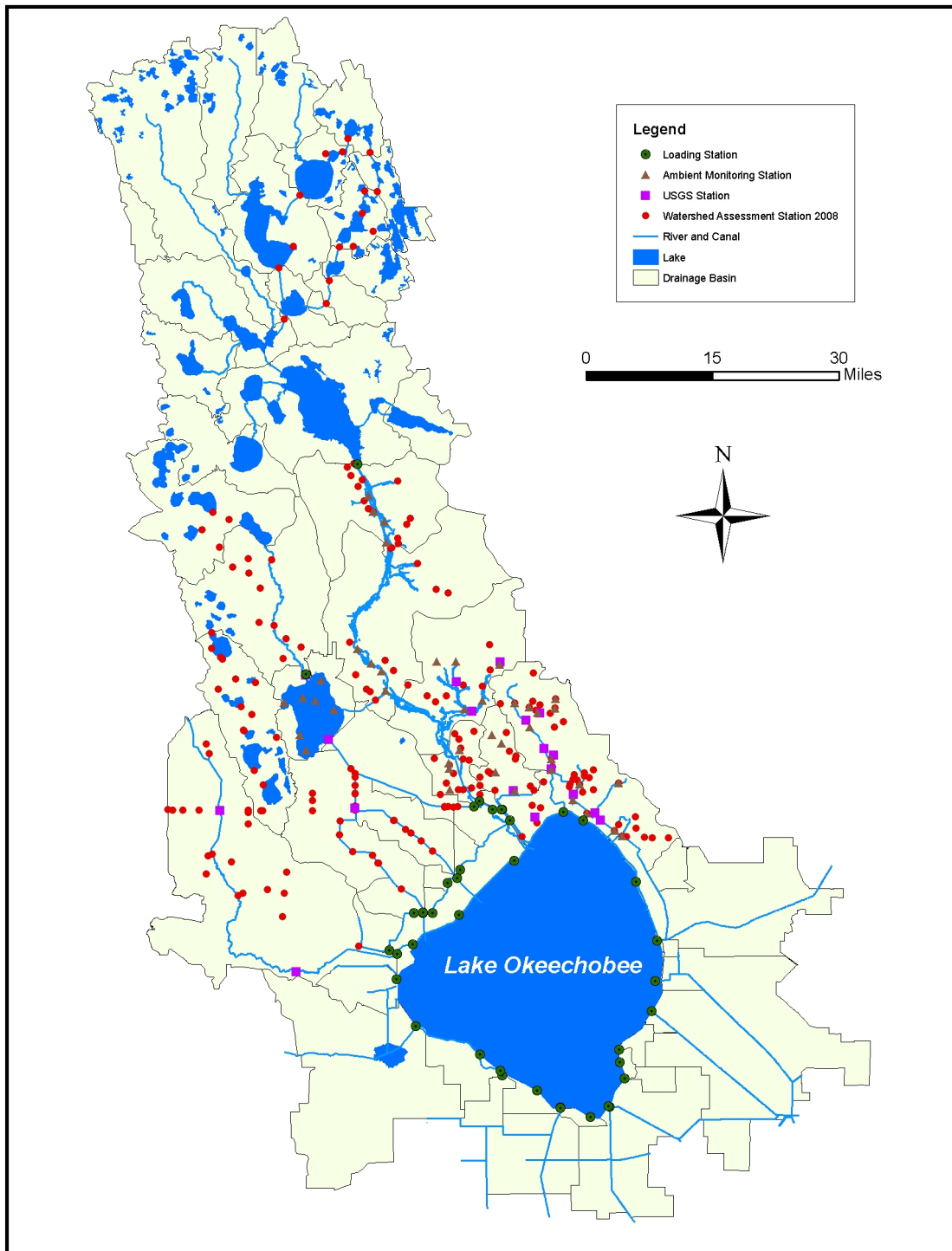


Figure 10-3. Locations of Water Year 2008 (WY2008) sampling stations where TP loads were determined from tributary basins that drain into Lake Okeechobee (green dots and purple squares). Other watershed water quality sampling stations also are shown.

Table 10-6. Annual TP loads to Lake Okeechobee (WY1981 through WY2008).

Water Year May–April	Measured Load ^a (mt)	Long-term Load (five-year moving average) ^a (mt)	Long-term over-target Load (five-year moving average) ^{a/b} (mt)
1981	151	N/A	N/A
1982	440	N/A	N/A
1983	1189	N/A	N/A
1984	369	N/A	N/A
1985	500	530	390
1986	421	584	444
1987	562	608	468
1988	488	468	328
1989	229	440	300
1990	365	413	273
1991	401	409	269
1992	408	378	238
1993	519	385	245
1994	180	375	235
1995	617	425	285
1996	644	474	334
1997	167	425	285
1998	913	504	364
1999	312	531	391
2000	685	544	404
2001	134	442	302
2002	624	533	393
2003	639	479	339
2004	553	527	387
2005	960	582	442
2006	795	715	575
2007	203	630	490
2008	246	551	411

^a Includes an atmospheric load of 35 mt/yr based on the Lake Okeechobee TMDL (FDEP, 2001).

^b Target is the Lake Okeechobee TMDL of 140 mt compared to a five-year moving average.

WATERSHED PHOSPHORUS CONTROL PROGRAMS

The Lake Okeechobee Watershed Phosphorus Control Program in LOPA includes (1) continued implementation of existing regulations and voluntary agricultural and non-agricultural BMPs, (2) development and implementation of improved BMPs, (3) improvement and restoration of hydrologic function of natural and managed systems, and (4) use of alternative technologies for nutrient reduction. In February 2001, the SFWMD, FDEP, and FDACS entered into an interagency agreement to address how to implement this program and coordinate with existing regulatory programs, including the Lake Okeechobee Works of the District (LOWOD) Permitting Program [Chapter 40E-61 Florida Administrative Code (F.A.C.)], Dairy Rule, and Everglades Forever Act (EFA). Under LOPA, the FDACS is charged with implementing a voluntary BMP program (Chapter 5M-3, F.A.C) on all agricultural lands within the Lake Okeechobee Watershed. In general, farmers are eligible to receive between 75 and 87.5 percent cost share, either through the FDACS or a combination of FDACS and U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) funds. The FDEP is responsible for developing non-agricultural, non-point source BMPs. The District is responsible for the implementation of TP-reduction projects and large-scale regional projects, research and monitoring, existing regulations, and exotic plant control.

FDACS Agricultural Programs

LOPA required the FDACS, in consultation with the FDEP, SFWMD, and affected parties, to initiate rule development for interim measures, BMPs, conservation plans, nutrient management plans, or other measures necessary for Lake Okeechobee phosphorus reduction. In response to this directive, the FDACS adopted Chapter 5M-3, F.A.C. The purpose of this code is to effect pollutant reduction through the implementation of non-regulatory and incentive based programs, which may be determined to have minimal individual or cumulative adverse impacts to the water resources of the state. The rule defines the phosphorus management requirements of agricultural producers necessary to receive a presumption of compliance with state water quality standards, including those established by the TMDL program, pursuant to Section 403.067, F.S., and the LOWOD contained in Chapter 40E-61, F.A.C. (see Rule 5M-3.001, F.A.C). Pursuant to LOPA, an owner or operator of an agricultural non-point source shall either implement interim measures or BMPs, or shall demonstrate compliance with the LOWOD by conducting monitoring prescribed by the FDEP or SFWMD. Where water quality problems are detected for agricultural non-point sources despite the appropriate implementation of adopted BMPs, the FDACS, in consultation with the other coordinating agencies and affected parties, shall institute a reevaluation of the BMPs and make appropriate changes to the rule adopting BMPs. In addition to the presumption of compliance with state water quality standards, participants in the FDACS BMP program are eligible to participate in cost-share programs that provide monetary assistance with the implementation of BMPs. These provisions are meant to provide an incentive for owners or operators of agricultural non-point sources to increase the likelihood that they will participate in the implementation of BMPs to improve water quality in the long term.

Chapter 5M-3, F.A.C., requires landowners participating in the FDACS BMP program to develop and implement site-specific conservation plans. These plans must be consistent with NRCS planning guidelines. Rule 5M-3.004, F.A.C., that requires the participant to submit a Notice of Intent to implement any of the non-regulatory and incentive based programs set forth in the rule, and requires that all landowners who receive cost-share assistance to complete implementation of applicable BMPs within 24 months of cost-share assistance becoming available.

Because the FDACS rule relies heavily on conservation planning, FDACS and NRCS have executed an interagency Memorandum of Agreement that commits available federal resources to

expedite conservation planning. In support of this agreement, the FDACS contracted with the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), in conjunction with NRCS, to provide training for private-sector third-party vendors that wish to assist in plan development. This cooperative arrangement has been used to identify, train, and contract with private-sector technical service providers to develop whole-farm plans for cow/calf, citrus, row crop, and other agricultural operations. This effort has significantly increased plan development and implementation, including the engineering and design of planned water-control structures.

A critical component in the success of the agricultural BMP program is the collection and analysis of data to determine whether the BMPs are working as anticipated. The interagency team plans to continue funding on-farm BMP demonstration projects at representative sites that, over time, will provide both effectiveness data and insight into what new or modified practices may be necessary to reach the phosphorus reduction goals required to achieve lake and tributary restoration. These BMP demonstration and evaluation projects are ongoing at representative sites for all agricultural land uses in the watershed, including dairies, beef cattle, citrus, and vegetable production. This effort incorporates regional and sub-regional water quality monitoring in collaboration with the SFWMD and the U.S. Geological Survey (USGS), which can help identify where to focus on plan development and implementation and BMP-effectiveness studies.

The agricultural area in the Lake Okeechobee Watershed covers about 1.58 million ac (639,000 ha), 46 percent of the total watershed area (**Table 10-1**). Completed nutrient management plans now cover approximately 550,000 ac (222,577 ha) in the watershed, and BMPs are in various stages of implementation. The majority of this acreage lies within the four priority basins (S-191, S-154, S-65D, and S-65E) (**Figure 10-2**). Plans are being developed for an additional approximately 600,000 ac (242,811 ha) of agricultural operations. Thus, more than half of the agricultural acreage in the entire watershed is participating in FDACS programs to plan and implement practices to control off-site movement of phosphorus. Funding shortfalls for FY2008–FY2009 and anticipated additional shortfalls in FY2009–FY2010 and FY2010–FY2011 will delay BMP planning and implementation efforts. If funding shortfalls continue as predicted, BMP plans for the remaining acreage will not be completed until 2012 and full implementation of those plans by the end of 2017. The TP load reduction to Lake Okeechobee from typical BMPs implemented/planned through June 2008 is 15 mt (**Table 10-7**). This total reduction amount reflects special BMP projects in the FDACS' typical cost-share BMP program and does not include the TP load reduction from either owner-implemented or typical cost-share BMPs implemented on cow/calf operations throughout the watershed. It is noteworthy that the potential load reductions by the stormwater management system for the Larson dairies were not included due to the delay and uncertainty of the schedule.

Table 10-7. TP load reduction projects implemented or planned by the Florida Department of Agriculture and Consumer Services (FDACS) under typical cost-share Best Management Practice (BMP) programs.

Project Category	Project Site	Estimated Annual Phosphorus Reduction to the Lake (mt)	Construction Status
Dairy Hurricane Upgrade	Milking R	0.63	Complete
	Larson 5	0.93	Complete
	McArthur 1 and 3	0.4	Complete
	Butler Oaks	0.28	Complete
	Wabasso Dairy	To be determined	Complete
Dairy Stormwater Management System	Larson 5 and 6	1.58*	On hold
	Larson 7 and 8	1.84*	On hold
	B-4	3.08	Complete
	Butler Oaks	4.45	Complete
Tailwater Recovery Project	Joe Hall	0.36	Complete
Dairy Composting Project	McArthur 1 and 3	2.74	Complete
	Butler Oaks	1.91	Complete
Citrus Variable Rate Fertilizer Technology	Lykes Brothers	0.2	Complete
Alternative Water Supply Project**	Haynes Williams	0.16	Complete
	David Williams	0.16	Complete
Florida Ranchlands Environmental Services Project	Williamson Cattle Company	0.09	Complete
Total Estimated Phosphorus Reduction		15.39	

* not included in the total reduction estimate

** cost share with SFWMD

FDEP Non-Agricultural Programs

Over the past year, Lake Okeechobee has experienced record low water levels. As a result of the drought the urban stormwater runoff from Okeechobee City and other urban areas around the lake has been nearly non-existent. The reduction in water flowing into the lake has resulted in fewer nutrients entering the lake during WY2008 (**Tables 10-2 and 10-3**).

A phased approach is being used to reduce TP loads to Lake Okeechobee from non-agricultural areas in the Lake Okeechobee Watershed. The largest contributors of TP loading from non-agricultural areas to Lake Okeechobee are non-point and point sources within existing residential developments (fertilization, pet wastes, and septic tanks) without stormwater treatment.

The FDEP has various regulatory programs that address urban point source stormwater and non-point source inflows to Lake Okeechobee tributaries. The two primary regulatory programs are administered through Environmental Resource Permits (ERP) and the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program.

The Environmental Resource Permit (ERP) program regulates activities on or over wetlands or other surface waters and the management and storage of all surface waters. This includes activities in uplands that alter stormwater runoff as well as dredging and filling in wetlands and other surface waters. Generally, the program's purpose is to ensure that activities do not degrade water quality, compromise flood protection, or adversely affect the function of wetland systems. The program applies to new activities only, or to modifications of existing activities, and requires an applicant to provide reasonable assurances that an activity will not cause adverse impacts to existing surface water storage and conveyance capabilities, and will not adversely affect the quality of receiving waters such that any applicable water quality standards will be violated. ERP applications within the District's jurisdiction are processed by either the FDEP or the District, in accordance with the division of responsibilities identified in the operating agreement between the agencies. Additionally, the FDEP and the District are working with stakeholders to promulgate a statewide stormwater quality rule, which is being proposed to increase the level of nutrient (TP and TN) removal required of stormwater treatment systems serving new development.

The U.S. Environmental Protection Agency (USEPA) developed the federal NPDES stormwater permitting program. In October 2000, the USEPA authorized the FDEP to implement the NPDES in Florida. The NPDES stormwater program regulates point source discharges of stormwater into surface waters of the Lake Okeechobee Watershed and the state of Florida from certain municipal, industrial, and construction activities. As the NPDES stormwater permitting authority, the FDEP is responsible for promulgating rules and issuing permits, managing and reviewing permit applications, and performing compliance and enforcement activities.

Although the FDEP is a regulatory agency, one of the agency's most productive and cost-effective methods to protect surface water is the use of educational outreach and partnering with local agencies to encourage behavior change. Public education offers a means to promote common sense, low-cost measures for reducing phosphorus from entering stormwater in urbanized areas.

The FDEP funding grants provide funding support for the Okeechobee County Extension Service and UF/IFAS to provide information to the residents in the Lake Okeechobee Watershed. UF/IFAS provides weekly articles in Okeechobee area newspapers that address proper lawn maintenance practices. Additionally, a brochure has been developed in conjunction with the fertilizer industry to promote the use of low-phosphorus fertilizers and the use of appropriate non-structural BMPs when applying such chemicals. This brochure is available at retail stores in the City of Okeechobee where fertilizers are sold. UF/IFAS works with the Okeechobee County

Extension Service to do educational mailings and public outreach seminars regarding the selection of appropriate fertilizer rates and the planting of drought-tolerant native plants to reduce the need for irrigation.

The nonstructural BMPs primarily target homeowners and businesses and rely on behavior changes rather than the construction of treatment tools or facilities. UF/IFAS extension agents work with homeowners on better lawn management through the Florida Yards and Neighborhoods program. UF/IFAS staff has educated employees of landscape management companies about environmentally sound landscaping through the Green Industry BMP Program. Additionally, the FDEP and UF/IFAS have continued their multi-year research partnership to determine minimum fertilizer and irrigation requirements for establishing and maintaining turf grasses. Other turf grass studies will quantify the amount of nutrient runoff to surface waters.

The acres of urban land which drain to Lake Okeechobee are dwarfed by the vast acres of agricultural land draining to the lake. Thus, the percentage of the total tons of nutrients flowing into Lake Okeechobee from urban areas is relatively small when compared to the contribution from agricultural lands. Yet, the high per-acre nutrient contribution from urban areas prompts the FDEP and other stakeholders to continue to take a comprehensive approach to reducing the nutrient loads flowing into Lake Okeechobee.

SFWMD Phosphorus Control Programs

The SFWMD, in coordination with the FDACS and FDEP, has developed and implemented more than 30 TP reduction projects (**Table 10-8**). These BMP implementation projects in the LOPP area continue as an effort to reduce TP loads to the lake during WY2008. Total phosphorus load reduction, from the projects that have been implemented, is estimated at 28 mt of load reductions necessary to meet the lake's TMDL for phosphorus. All these projects have some level of performance monitoring to facilitate the evaluation and potential future use of these types of technologies.

Phosphorus Source Control Grants

The intent of the Lake Okeechobee Phosphorus Source Control Grant Program was to fund the early implementation of projects that have the potential for reducing phosphorus exports to Lake Okeechobee from the watershed. The program originally consisted of 13 projects with a total cost of \$7.5 million. The funded projects ranged in size and complexity, and grant recipients consisted of landowners, public facilities, and private corporations. Currently, the program includes nine projects that are operational with varying degrees of success (**Table 10-8**).

Isolated Wetland Restoration

The Lake Okeechobee Isolated Wetland Restoration Program (LOIWRP) is designed to enhance and restore wetlands, reduce TP loads, and retain stormwater flows by increasing regional water storage in the Lake Okeechobee Watershed. Historically, isolated wetlands covered a considerable percentage of land area in the four priority basins, capturing stormwater runoff and helping to retain phosphorus in the watershed. However, many of these wetlands have been drained to increase the amount of land in agricultural production, allowing more phosphorus to reach Lake Okeechobee.

As a cost-share program, the LOIWRP pays for all wetland restoration costs — including land survey, design, permits, construction, initial exotic and nuisance plant removal, fencing and monitoring, as well as the value of the easement. The landowner is responsible for paying property taxes and for the operation and maintenance of the restored area. Landowners have the choice of entering into a 30-year or perpetual easement agreement for the portion of their property that is enrolled in the program. The District is administering the LOIWRP with the

cooperation of a multi-agency team that includes the FDACS, FDEP, NRCS, U.S. Fish and Wildlife Service (USFWS), and UF/IFAS. The four projects under the program are: (1) Kirton Ranch, which was completed in March 2004 and continues to operate; (2) Lemkin Creek, a state-owned property completed in February 2006; (3) Eckerd Youth Center, a state-owned property completed in July 2008; and (4) Nubbin Slough Area A Isolated Wetland Restoration Project completed in July 2008 (**Table 10-8**).

Former Dairy Remediation

Five of the six former dairy remediation projects have been implemented for the privately owned former dairies that are now cow/calf operations. Remediation practices included retaining runoff from old high-intensity areas, rehydrating on-site wetlands, amending high-phosphorus soils, and reducing the flow of stormwater off-site. Construction of the remaining former dairy was still under discussion at the time of this report. Water quality monitoring for TP concentration reductions during flow events was conducted for a year and a half following construction completion, but because of the ongoing drought, very few data exist. The updated TP reductions are summarized in **Table 10-8**.

Table 10-8. TP load reduction projects implemented or planned under the District's watershed phosphorus source control programs.

Project Category	Project Site	Estimated Annual Phosphorus Reduction to Lake (mt)	Construction Status
Phosphorus Source Control Grant Program	Tampa Farms – Indiantown	7.67	Complete
	QED – McArthur Farms 3	6.02	Complete
	Davie-Dairy Cooling Pond	0.39	Complete
	Evans Properties – Bassett Grove	0.13	Complete
	OUA-Ousley	0.22	Complete
	Smith Okeechobee Farms	0.59	Complete
	Lofton Ranch	0.04	Complete
	Solid Waste Authority	2.32	Under construction
	Lazy S Ranch Iron Humate	0.11	Complete
Isolated Wetland Restoration Project	Kirton Ranch	0.81	Complete
	Nubbin Slough Area A Restoration	0.39	Complete
	Eckerd Youth Center	0.40	Complete
	Lemkin Creek	0.12	Complete
Former Dairy Remediation	Mattson	0.54	Complete
	McArthur 5	0.30	Complete
	Candler	0.03	Complete
	Larson Dairy 7	0.29	On hold
	Lamb Island Dairy – East	1.85	Complete
	Lamb Island Dairy – West	0.11	Complete
Dairy Best Available Technology	Dry Lake 1 (now Hudson Lakes Ranchettes)	1.27	Complete
	Milking R	1.60	Complete
	Butler Oaks	1.62	Complete
	Davie Dairy 1 and 2	0.10	Complete
Public-Private Partnership	Davie Dairy 1 and 2 offsite stormwater treatment	0.09	Complete
Florida Ranchlands Environmental Services Project (FRESP)	Lykes Brothers	0.20	Complete
	Buck Island Ranch*	0.37	Complete
	Williamson Cattle Company**	0.09***	Complete
	Alderman-Deloney Ranch (not in the Lake Okeechobee watershed)	0.08***	Complete
Aquatic Based Treatment System	Taylor Creek Algal Turf Scrubber® Nutrient Recovery Facility	0.05	Complete
Total for Watershed Phosphorus Control Programs		27.63	

* cost share with FDACS

** also included in Table 10-5

*** not included in the total reduction estimate

Dairy Best Available Technologies

In October 2000, the District initiated the dairy Best Available Technology (BAT) projects to identify, select, and implement various technologies to significantly reduce TP discharge from dairy operations in the Lake Okeechobee Watershed. After a thorough evaluation of alternatives by an interagency project team, edge-of-farm stormwater treatment was selected for implementation on three dairy properties in the Lake Okeechobee Watershed (**Table 10-9**). These projects consist of (1) capturing stormwater runoff (especially from all of the high-nutrient pasture areas), (2) reusing the runoff on-site in current operations if possible, and (3) if off-site discharge is necessary, chemically treating the stormwater prior to its release.

Three dairy BAT projects are fully constructed, and performance monitoring was initiated in May 2004. The FDEP provided funds for the design and implementation of a fourth BAT site, the Milking “R” Dairy. This fourth site was completed in December 2005. The performance monitoring and evaluation phase was completed in June 2008. Based on data summarized from Task 4.1 Final Report (SWET, 2008), the annual TP load reductions ranged from 0.19 to 1.62 mt (**Table 10-9**).

Butler Oaks, Dry Lake, and the Davie Dairy use retention and reuse followed by chemical treatment to achieve reduction rates ranging from 66–100 percent. Drought conditions in the last two years contributed to the high phosphorus load reduction rates via sole retention/reuse. For example, for Milking “R” Dairy, no off-site outflow occurred. The phosphorus load reduction rate via retention was 100 percent. During the design phase, a 15 percent phosphorus reduction rate was assumed for this method. Of note, the Dry Lake Dairy is being redeveloped as Hudson Lakes Ranchettes, a project that is expected to include an urban stormwater treatment system to provide additional load reductions due to the termination of the on-site chemical treatment system. The land-use conversion is partially completed.

Table 10-9. A summary of TP load reduction and removal efficiency from the edge-of-field treatment system at four dairy Best Available Technologies sites.

Edge of Field Treatment Site	Annual P Load from Surface Runoff (lb)	Total Load Reduction Since Operation (lb)	Years of Operation	Average Annual Reduction (lb)	Annual Reduction Due to Retention (lb)	Annual Reduction Due to Treatment (lb)	Average Annual Reduction (mt)	Overall Efficiency (%)
Butler Oaks	4,449	13,439	3.8	3,555	2,965	586	1.62	80%
Dry Lake	4,212	10,536	3.8	2,787	2,511	275	1.27	66%
Davie Dairy	4,594	1,713	4.2	412	3	409	0.19	9%
Milking R	3,527	3,527	1.0	3,527	3,527	-	1.60	100%

Public-Private Partnership Program

Davie Dairy is the participant of both the dairy BAT and the Public-Private Partnership programs. The TP load reduction from the dairy averaged 0.19 mt per year during the past four years (**Table 10-9**). Based on the drainage area, the load reduction from Davie Dairy BAT is estimated to be 0.10 mt per year and the remaining 0.09 mt is attributed to the Public-Private Partnership Program. The Davie Dairy flow-through system with a reduction of nine percent proved far more technically challenging with frequent equipment failures and inefficient chemical flocculation. This system has been retrofitted with the Hybrid Wetland Chemical Treatment

Technology and increased phosphorus load-reduction efficiencies are expected (based on the preliminary result from this flow-through system).

Alternate Water Storage and Treatment

The 2005 Lake Okeechobee Estuary and Recovery (LOER) Action Plan was developed to help restore the ecological health of Lake Okeechobee and adjoining estuaries, through a series of fast-track water quality improvement projects and several other far-reaching and innovative components. Among these additional components is an initiative to identify options for storage and/or disposal of excess surface water to aid in reducing lake levels and high discharge volumes to the estuaries. Assessments of available public and tribal lands for storage of excess surface water have been completed for the watershed, with assessments continuously on going for private lands. Eight water storage/disposal projects have been completed including Lykes Basinger Grove and Phase II Indiantown Citrus Growers Association. Additional water storage projects are under way with investigations and designs continuing for additional water storage projects with a goal of a total 450,000 ac-ft.

A related effort was also launched in October 2005. The Florida Ranchlands Environmental Services Project (FRESP) is intended to design a program in which ranchers in the Northern Everglades sell environmental services of water retention, TP load reduction, and wetland habitat expansion to agencies of the state and other willing buyers. These ranches can bring services on-line quickly as compared to other options and are planned to complement public investment in regional water storage and water treatment facilities. The sale of the services is expected to provide additional income for ranchers that face low profit margins and to provide an incentive against selling land for land uses that could further aggravate water flow, pollution, and habitat problems.

FRESP is being implemented through collaboration among World Wildlife Fund, eight participating ranchers, NRCS, and the FDACS, the District, and the FDEP. Technical support is being provided by scientists from the MacArthur Agro-Ecology Research Center and UF. Funding from federal, state, and private sources exceeds \$6 million for Phase One (pilot project implementation and program design).

One key accomplishment of FRESP is the development of procedures to compare protocols for documenting environmental services from ranchlands. FRESP is expected to field test different methods of monitoring and modeling of hydrology, water and soil chemistry, and vegetation change to document the level of environmental services provided by ranch water management projects.

Four FRESP water management projects have been designed, constructed, and are being monitored to capture hydrological and chemical data (**Table 10-8**). Alderman-Deloney Ranch is located in the C-25 basin which is not part of the Lake Okeechobee Watershed. Data collection started in 2007 and is planned to continue through the end of the pilot project in 2011. Additional water management projects are to be implemented by four additional ranchers. Projects include rehydrating drained wetlands, water table management, and pumping water from a nearby off-site canal through the existing ranch and then back into the canal. The eight ranchland water management projects occupy approximately 8,500 acres, not including drainage acres. A planning level estimate of the static water-retention capacity of the eight projects is 8,260 ac-ft (1,019 ha-m) of water for a single storm event with the average storage depth of 0.98 ft (0.3 m).

Regulatory

Other ongoing regulatory activities include proposed revisions to SFWMD's LOWOD program (see the *Watershed Phosphorus Source Control Programs* section of this chapter.) Chapter 40E-61, F.A.C., is being revised to implement the statutory amendments in NEEPP. Rule workshops were held in July and August 2008, and there will be additional workshops scheduled once the proposed rule language is released. The proposed revisions are as follows:

1. Implement a phosphorus source control program utilizing BMPs for all lands within the Lake Okeechobee Watershed
2. Provide an option for agricultural land uses of greater than 100 acres to participate in the FDACS BMP rule under Chapter 5M-3, F.A.C., to meet the intent of the LOWOD rule
3. Establish a timeline for implementation of all BMP source control programs within the watershed by 2010
4. Establish load-based performance measures for the combined BMP source control programs implemented in the watershed
5. Define the monitoring network necessary to monitor compliance with the established performance measures, to identify priority areas of water quality concern and BMP optimization, and to provide data to evaluate and enhance performance of downstream treatment facilities
6. Establish a plan for optimizing the combined BMP source control programs should the expected water quality criteria not be met
7. Ensure that the rule is consistent with data presented in LOPP
8. Include incentives for permittees to participate in TP reduction demonstration projects that will provide valuable data for expanding, accelerating, and optimizing the implemented BMPs to meet water quality objectives and for further refinement of the program as necessary

In March 2008, the SFWMD initiated rule development for a proposed basin rule for the Lake Okeechobee and the St. Lucie and Caloosahatchee estuary watershed basins with specific supplemental criteria designed to result in zero increase in total runoff volume from new development. The basin rule will be supplemental to existing criteria and the proposed statewide stormwater quality rule. Average annual discharge volumes and specific storm event discharge volumes are proposed to be addressed in the basin rule.

LAKE OKEECHOBEE CONSTRUCTION PROJECT

Phase I

The Lake Okeechobee Construction Project is being implemented in two phases. Phase I projects in the four priority basins include two pilot Stormwater Treatment Areas (STAs) and a sediment removal pilot project. This phase is intended to bring immediate TP load reductions to Lake Okeechobee. The design of the two pilot STAs, Taylor Creek and Nubbin Slough, was started in 2002 and completed in 2006. The sediment removal pilot project was completed in 2004, but no significant removal of particulate phosphorus was observed.

The Taylor Creek STA has passed all of the water quality permit requirements of the start-up phase and work is under way to verify the operational controls and plans developed for the flow-through phase (flow through the STA was initiated in June 2008). Once all flow-through phase requirements are satisfied, the District is expected to begin the long-term operational phase by taking over control of the project from the USACE. Water quality reporting and assessments, including load calculations for the inflow versus discharge structures, are planned for presentation

in future SFERs once the project is operated under the District's Operations Authorization Permit #0194485-002-GL.

Operation of the Nubbin Slough STA by the USACE remains non-operational due to an electrical issue with the pumps discovered during the pump tests conducted in October 2007. At the time this report was written, the USACE expected repairs to be completed by the end of 2008.

Phase II

Phase II projects, fully specified in the P2TP (SFWMD et al., 2008), aim to provide the TP load reduction necessary to meet the lake's long-term TMDL target of 140 mt per year. The preferred P2TP was developed by the District, in coordination with the FDEP and FDACS, and with extensive input from stakeholders. The coordinating agencies evaluated various alternatives using best available scientific information to achieve restoration goals for the lake. The development and comparisons of the alternatives – along with extensive public input and review – ultimately identified what are expected to be the best science-based and technologically feasible options for improving lake and estuary health.

The P2TP submitted to the legislature on February 1, 2008, identifies construction projects, along with on-site measures such as agricultural and urban BMPs, needed to achieve water quality targets for the lake. In addition, it includes other projects for increasing water storage north of Lake Okeechobee to achieve healthier lake levels and reduce harmful discharges to the Caloosahatchee and St Lucie estuaries. Major components of the plan include:

- implementing BMPs on more than 1.7 million acres of farm and urban lands
- adopting new regulations that will reduce the impacts of development on water quality and flow
- building treatment wetlands to clean water flowing into the lake
- using other nutrient control technologies to reduce phosphorus loads from the watershed
- creating between 900,000 and 1.3 million ac-ft of water storage north of the lake through a combination of aboveground reservoirs, underground storage, and alternative water storage projects on public and private lands

Completion of the P2TP is a critical step in the state's Northern Everglades initiative to protect and improve Lake Okeechobee and downstream receiving estuaries. The preferred plan outlines the steps expected to reduce pollution and improve storage in the watershed north of the lake as necessary to clean water flowing into Lake Okeechobee. The Lake Okeechobee Watershed Protection Plan is expected to be updated every three years as required by the NEEPP. The plan update will include the results of several studies as described below and will be submitted to the legislature in 2010.

Since the delivery of the P2TP to the Florida legislature in February 2008, numerous efforts identified in the process development and engineering component have begun including the Chemical Treatment Study and the Fisheating Creek (FEC) Feasibility Report. The Chemical Treatment Study is designed to identify technologies expected to be appropriate for use in the Lake Okeechobee Watershed. Phase I is currently under way and includes a literature review of existing chemical treatment technologies, laboratory water quality testing, and technical recommendations for the selection of feasible options. This phase scheduled for completion by July 2009.

The objective of the Fisheating Creek (FEC) Feasibility Report is to identify alternative sites that meet storage and water quality goals for the FEC sub-watershed. Of the nine sub-watersheds in the P2TP study area, the FEC sub-watershed is one of the major sources of phosphorus loading

to Lake Okeechobee at a rate of almost 39 mt per year. Fisheating Creek drains into Lake Okeechobee from the west and is the only sub-watershed with an uncontrolled, native discharge to Lake Okeechobee. The feasibility report is scheduled for completion by the end of calendar year 2009. The report is intended to evaluate alternative sites that either alone, or in combination with other sites in the FEC sub-watershed, potentially achieves the storage goal and the average annual TP load reduction goal. The feasibility report will also provide an initial cost estimate for land acquisition, design, and construction of each alternative site (and each combination of sites) that is expected to achieve the FEC storage and water quality goals.

Other efforts include development of new assessment tools to evaluate the effectiveness of various phosphorus control programs at the watershed level on load reductions to the lake. The Lake Okeechobee Watershed Assessment Model is being developed to meet this purpose. The model is expected to be fully recalibrated and verified for the northern Lake Okeechobee basins using available monitoring data. The effectiveness of the field level BMPs and the basin/regional level phosphorus control projects on phosphorus load reductions to the lake will be evaluated. The project is expected to be completed in May 2009.

WATERSHED RESEARCH, ASSESSMENT AND MONITORING

RESEARCH AND STUDIES

A comprehensive research and assessment program for water quality in the Lake Okeechobee Watershed has been conducted by the SFWMD, in cooperation with the FDEP and FDACS, to provide the predictive understanding necessary to evaluate the effectiveness of water management alternatives on TP load reductions. A brief summary of research and demonstration projects completed, started, or continued in WY2008, is shown in **Table 10-10**. Among the five projects completed by August 2008 (**Table 10-10**), legacy phosphorus and Upper Kissimmee efforts are highlighted in more detail following the table.

Table 10-10. Status of Lake Okeechobee Watershed research, demonstration, and assessment projects during WY2008.

PROJECT NAME (INVESTIGATOR)	MAJOR OBJECTIVES/CONCLUSIONS	STATUS
Dairy Lagoon Seepage Characterization and Remediation Processes (UF/IFAS)	An extensive monitoring-well network has been established to determine the movement of nutrients in groundwater resulting from lagoon leakage. Modeling and monitoring were completed in June 2008. Preliminary results indicate very little movement of phosphorus away from the bottom of the lagoon.	Complete
Development of Cost-effective and Sustainable Forage Production and Fertilization Strategies for Remediation of Phosphorus-Loaded Soils (UF/IFAS)	Pastures are an integral part of the landscape in the Lake Okeechobee Watershed. Previous work showed that improved forage production systems can facilitate TP exports from phosphorus-impacted soils. This project extended existing on-farm demonstration studies monitoring the effects of soil phosphorus values on forage productivity, diagnostic tissue values, and phosphorus mining capacity. Results were used to revise UF/IFAS recommendations for nutritional needs of pasture grasses statewide.	Complete
Rapid Soil and Tissue Analysis Techniques Using Near Infrared Reflectance Spectroscopy (UF/IFAS)	This project was to evaluate remote-sensing techniques as a substitute for elaborate wet chemistry methods for soil, plant tissue, and water analysis to provide improved, accurate, precise, and rapid in-field diagnostics. The project was completed in June 2008.	Complete
Evaluation of Legacy Phosphorus in the Lake Okeechobee Watershed (Soil & Water Engineering Technology, Inc.)	The objective of this project was to conduct a comprehensive search, review, and analysis of available relevant data and literature related to the quantification and mobility of legacy phosphorus in the Lake Okeechobee Watershed. Given sufficient information on legacy phosphorus in the watershed, the consultant was also to develop a phosphorus abatement plan that outlines specific phosphorus control practices and strategies at different spatial scales and anticipated phosphorus reduction performances. The project was completed in August 2008.	Complete
Chemicals, Runoff, and Erosion from Agricultural Systems – Water Table (CREAMS-WT) Calibration for the Upper Kissimmee region (Lake Okeechobee Division, SFWMD)	The first objective of this study was to calibrate the CREAMS-WT input parameter files and further verify the model with measured data to justify the model's applicability for the entire Upper Kissimmee region. These files were initially based on those data developed for the Lake Okeechobee Watershed CREAMS-WT application. The calibrated input parameter files can be applied to simulate the long-term annual flow and load series for basins within the region when combining with local rainfall data. The second objective was to develop unit flow, unit load, and TP concentration datasets that can be applied to predict the long-term annual average flow and load for basins or a land parcel within the Upper Kissimmee region that has not been monitored. The project was completed in August 2008.	Complete
Long-term Water Quality Trends and BMPs in the Lake Okeechobee Watershed (SFWMD)	The project objectives were to (1) obtain the baseline conditions characterizing phosphorus and nitrogen concentrations in the monitored tributaries of the Lake Okeechobee Watershed; (2) conduct the Seasonal Kendall Tau test to verify the statistical significance of the trends in the time series of monthly average total phosphorus concentrations by station, land use, and basin; and (3) evaluate the effectiveness of various BMPs implemented through the Lake Okeechobee Watershed Protection program and other reduction programs implemented during past two decades. The first two tasks were completed and the final task was expected to be completed in December 2008.	Ongoing

Table 10-10. Continued.

PROJECT NAME (INVESTIGATOR)	MAJOR OBJECTIVES/CONCLUSIONS	STATUS
Optimization of BMPs for Beef Cattle Ranching in the Lake Okeechobee Watershed (Archbold Expeditions)	The project objectives are to (1) develop an understanding of the relationship between beef cattle operational practices and water quality; and (2) provide recommendations for the development of environmentally and economically sustainable cow/calf practices in the Lake Okeechobee Watershed. Earlier research results indicate that changes in cattle stocking density are unlikely to produce measurable effect on nutrient loads in the short term, and that phosphorus loads may be related to phosphorus accumulation in soils due to past fertilization practices in improved pastures. Given these results, another BMP study was initiated in 2004 to evaluate the feasibility of on-farm retention/detention of water in controlling phosphorus losses from beef cattle ranches. Water-control structures were installed in the ditches to allow management of water in the pastures during high- and low-flow periods. The hypothesis is that more phosphorus is retained when water flows more slowly or is held back relative to when it drains off quickly. The project is in its fourth year of monitoring and was scheduled for completion in December 2008.	Ongoing
Taylor Creek Algal Turf Scrubber® Nutrient Recovery Facility (HydroMentia, Inc.)	This is a scaled-up demonstration of HydroMentia's proprietary water-treatment technology that employs algae to remove pollutants from impaired waters. The process design for this 15-MGD facility in Taylor Creek was based upon the results obtained from a pilot investigation of the single ATS™ treatment system in the S-154 basin. The new facility contains 3.6 acres of effective treatment area and is located on a 70-acre parcel owned by the District in the S-191 basin. The facility was expected to remove 1.81 mt of TP per year, but water quality data demonstrated only minimal phosphorus removal of 0.05 mt/yr to date. Investigations into inconsistencies in phosphorus removal measurements and phosphorus removal underperformance are currently under way. Operation of the Taylor Creek ATS™ facility commenced in late January 2007 and was planned to continue through January 2009.	Ongoing
Hybrid Wetland Treatment Technology (HWTT) (Watershed Technologies, LLC)	This project involves the design, deployment, and monitoring of Hybrid Wetland Treatment Technology (HWTT) facilities in the St. Lucie and Lake Okeechobee watersheds. The HWTT technology combines attributes of treatment wetlands and chemical treatment systems. Overall, the project consists of four full-scale HWTT facilities and one mesocosm-scale HWTT facility. The three full-scale HWTT facilities are on two Lake Okeechobee tributaries (Nubbin Slough and Mosquito Creek), and at a citrus grove that drains to the St. Lucie River. The fourth HWTT system is located within a dairy lagoon. Also, a mesocosm-scale facility at Mosquito Creek has been operational since mid-January 2008; three of the full-scale systems since early March 2008; and the fourth full-scale facility since August 2008. All systems are being operated initially in a "test and adjust" mode to optimize treatment performance and operating costs. Initial performance is promising: the mesocosm and full-scale systems are attaining around 80-90 percent reduction in TP. It is anticipated that upon completion of this project, HWTT systems can be deployed throughout these watersheds to treat flows from farms, parcels, and small sub-basins that contribute a significant phosphorus load to the lake and its tributaries. The construction of the project was completed in July 2008, however, additional monitoring is planned to continue through 2009.	Ongoing
Lake Istokpoga Environmental Evaluation and Restoration (SFWMD)	In conjunction with an approved USACE deviation from the regulation schedule for water supply deliveries from Lake Istokpoga, a Biological Opinion from the U.S. Fish and Wildlife Service recommended the initiation of drought-related restoration efforts in the lake, such as vegetation mapping and apple snail monitoring. A stand of native pond apple trees was recently found in Lake Istokpoga near Big Island. An additional 800 pond apple trees will be planted in the same area; other native tree plantings are planned for when lake levels are favorable. An in-house apple snail egg monitoring study is being conducted to evaluate the density and distribution of adult snails and eggs. Torpedograss (<i>Panicum repens</i>) treatments (sites away from snail kite nesting areas) have begun, and the 2008 vegetation map for Lake Istokpoga is being developed. Restoration efforts are planned to continue through 2009.	Ongoing

Table 10-10. Continued.

PROJECT NAME (INVESTIGATOR)	MAJOR OBJECTIVES/CONCLUSIONS	STATUS
Cow/Calf Water Quality BMP Demonstration (UF/IFAS)	This study is to evaluate the effectiveness of cow/calf production BMPs with regard to reducing TP loadings. Specific objectives include: (1) identify selected cow/calf BMPs and design a hydrologic monitoring network for evaluating BMP effectiveness at the watershed-scale for reducing TP discharges; (2) collect baseline (pre-BMP: 2003) and post-BMP (2004–2005) water quantity and quality data (surface and ground waters) and analyze the results to evaluate the effectiveness of the BMPs with regard to water quality and economics; (3) use the monitoring data to test and modify selected hydrologic simulation models for their effectiveness in simulating the effectiveness of BMPs; and (4) disseminate the results of the study to ranchers and state and federal agencies in the Lake Okeechobee Basin. The project started in September 2003 and is scheduled to run through October 2009.	Ongoing
Protocol Development to Evaluate the Effect of Water Table Management on Phosphorus Release to Drainage Water (UF/IFAS)	The thorough understanding of the potential phosphorus release from the soil profile is critical for the successful implementation of water table management. A body of literature is emerging that indicates raising the water table in upland soils may release absorbed TP from the soil into groundwater. This project is expected to develop the protocol needed to determine the potential for these releases and recommend BMPs that can be used to prevent or manage these releases. The project is scheduled to run through October 2009.	Ongoing
The Use of Composted Animal Waste (Cowpeat) as a Replacement for Canadian and Florida Peat in Potting Material (UF/IFAS)	These projects are phase two of the “cowpeat” dairy projects. A comparative study of the materials generated on the two cowpeat production projects to Canadian and Florida peat will be done on all of the major plant production areas found in Florida. Based on these comparison studies a standard will be developed to provide for consistent product for all commodities in the state horticulture industry. The study intends to determine both environmental and production benefits from the use of cowpeat versus Florida and Canadian peat. The project is planned for completion in June 2009.	Ongoing
Wetland BMP Research (UF/IFAS)	The study objectives are to (1) demonstrate and determine the efficacy of isolated wetlands located in land areas used for dairy and cow/calf operations on phosphorus assimilation and storage; (2) design and optimize on-farm or edge-of-farm treatment wetlands to maximize phosphorus removal performance (both mass removal per unit area basis, and effluent concentration basis) on land areas used for cow/calf operation; (3) review current hydrologic and TP models for adaptation to the Okeechobee Basin wetland systems and to predict phosphorus assimilation capacity of the basin; (4) develop phosphorus assimilation coefficients/algorithms for use in water quality models to demonstrate the effectiveness of isolated and constructed wetlands to store phosphorus; and (5) communicate the utility and effectiveness of isolated wetlands in phosphorus assimilation storage to dairy farmers and beef cattle ranchers through extension publications or other appropriate mechanisms. The project started in 2003 and is scheduled to run through calendar year 2009.	Ongoing
WAM BMP Assessment Tool and Model Upgrade (Soil and Water Engineering Technology, Inc.)	This project is expected to provide FDACS and other agencies with an assessment tool that will enable BMP programs to maximize water quality improvements in Florida waters while minimizing the economic burden on farmers and Florida taxpayers. The project is scheduled to run through 2009.	Ongoing
WAM Enhancement and Application in the Lake Okeechobee Watershed (Soil and Water Engineering Technology, Inc.)	The overall goal of this project is to develop an assessment tool that will evaluate various phosphorus control programs at the watershed level to maximize water quality improvements to meet the lake's Total Maximum Daily Load (TMDL) goal of 140 mt of TP per year. Specific objectives are to (1) update WAM input data sets to the latest District land use and phosphorus control efforts, (2) add an enhanced submodel to WAM to better represent internal lake processes in the Kissimmee Upper Chain of Lakes, (3) setup of the hydrography of the entire northern basins into an integrated flow network, (4) complete a full recalibration and verification of WAM for all of the northern Lake Okeechobee basins using all available monitoring data, and (5) evaluate the effectiveness of the field level BMPs and the basin/regional level phosphorus control projects or performance measures on phosphorus load reductions to the lake. The project is expected to be completed in May 2009.	Ongoing

Legacy Phosphorus Study

Legacy phosphorus is defined as phosphorus within the watershed that is present as the result of anthropogenic activities and has transport potential to Lake Okeechobee. The phosphorus budget study by Hiscock et al. (2003) and soils test data from various studies and routine sampling programs (Reddy et al., 1996) were used to quantify, map, assess mobility of, and identify abatement practices for, the legacy phosphorus in the northern Lake Okeechobee Watershed (SWET, 2008). It was estimated that about 170,000 mt of legacy phosphorus currently exists in the uplands (91 percent) and wetlands/streams (nine percent). Based on stream sediment studies the estimated legacy phosphorus in the sloughs, streams, and canals represent about another 860 mt while the larger lakes would have possibly another 5,000 mt of legacy phosphorus. This means there would be about 176,000 mt of legacy phosphorus within the studied watershed that is potentially available for transport to Lake Okeechobee. Including these site-specific levels, the flow conveyance network (which does not include isolated wetlands) contains legacy phosphorus that could sustain the current lake loading over a decade. It is likely that as much as 50 percent of this phosphorus will not be mobile due to the soil phosphorus storage capacity and the low mobility of legacy phosphorus that has moved to lower soil layers; nevertheless, these studies show that enough mobile legacy phosphorus exists in the watershed to maintain elevated levels going to Lake Okeechobee for many years. Therefore, the reduction of new sources of legacy phosphorus and its mobility to the lake through abatement practices are expected to be the only effective means of addressing this large-scale problem and must address upland, wetlands, and streams legacy phosphorus sources.

The abatement plan developed outlines specific phosphorus-control strategies at different spatial scales, anticipated phosphorus-reduction performances, and implementation costs. The phosphorus control practices used in the plan were categorized into one of the following spatial groupings that define the scale and type of phosphorus source to be addressed: (1) in-field practices that address the legacy phosphorus 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) facility practices used in non-soil-based areas that potentially discharge phosphorus into runoff, such as industrial sites, packing houses, and old landfills, and (6) regional practices that treat and/or retain stream flows within the tributary system where multiple upstream landowners drain to the system.

The approach taken for the plan was to first meet the tributary TMDL followed by regional treatment to obtain the additional reductions needed to meet the Lake Okeechobee TMDL. The Lake Okeechobee TMDL for TP load has been set at 140 mt/yr (FDEP, 2001), and the tributary TMDL for TP concentration has been set at 113 ppb for the northern Lake Okeechobee Watershed by the USEPA (<http://www.epa.gov/region4/water/tmdl/florida>). 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 historic discharge phosphorus concentrations for Lake Kissimmee and Lake Istokpoga. The method of applying phosphorus 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 phosphorus 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 (Bottcher, 2006). The next phosphorus control practice implemented was stormwater retention, which includes wetland restoration and water reuse, as well as standard urban retention and detention systems. Finally, chemical treatment was added to the retention based systems if the first two practices were not sufficient to

meet TMDL targets. Costs for the combined technologies to meet both the tributary and lake TMDLs are also included in the abatement plan (SWET, 2008).

Model Application to the Upper Kissimmee Region

The Chemicals, Runoff, and Erosion from Agricultural Systems – Water Table (CREAMS-WT) model is designed to simulate the hydrologic, nutrient, and management characteristics under the typical flat, sandy, and high-water table conditions in South Florida flatwoods watersheds. This model has been applied to the Lake Okeechobee Watershed and utilized as a modeling tool for land use change permit applications. The Upper Kissimmee Region, a part of the Lake Okeechobee Protection Plan area, was not included in the previous model domain. Recently, the model was used to simulate the Upper Kissimmee region, especially the Orlando area, where land use changes are occurring rapidly as this area contains a large portion of industrial/commercial area. A study intended to expand the model application domain to the Upper Kissimmee region was completed by the District.

Zhao et al. (2008) calibrated the CREAMS-WT input parameter files and further verified the model with measured data to justify the model's applicability for the entire Upper Kissimmee. These files were initially based on those data developed for the Lake Okeechobee Watershed CREAMS-WT application (Kiker et al., 1992; Zhang et al., 1999). The calibrated input parameter files can be applied to simulate the long-term annual flow and load series for basins within the region when combining with local rainfall data. The unit flow, unit load, and TP concentration datasets were developed to predict the long-term annual average flow and load for basins or a land parcel within the Upper Kissimmee region that have not been monitored.

Based on these results, two recommendations are made: first, the calibrated CREAMS-WT model should be applicable to simulate the long-term annual flow and load series for other basins in the Upper Kissimmee region by combining with local rainfall data. Second, within the Upper Kissimmee area, for basins or land parcels without measured local rainfall data, the average values of unit flow and load developed from this study are applicable to predict the long-term annual average flow and load.

ASSESSMENT OF BMP EFFECTIVENESS

A two-phased approach was used to assess urban and agricultural BMP effectiveness in accordance with the Lake Okeechobee Watershed Phosphorus Control Program requirement of NEEPP. The first phase required that the FDEP use best professional judgment in making the initial determination of BMP effectiveness. An interagency team worked with outside experts in the field and developed the initial BMP performance estimates for all land uses as part of the 2004 and 2007 LOPP development. This level of verification provided the necessary confidence to the coordinating agencies to immediately move forward in implementing BMPs without extensive data on their effectiveness. Implementation of BMPs from adopted and approved BMP manuals based on an FDACS farm assessment or a site-specific plan developed through the NRCS qualified for this phase. For the second phase, the SFWMD, FDACS, or the FDEP monitors water quality at representative sites to verify the effectiveness of BMPs. This monitoring is conducted at a basin scale through the District's ambient water quality monitoring network and the sub-basin scale by the District through the LOWOD and the USGS Load Monitoring Programs (**Figure 10-3**). Additional monitoring at the parcel level is conducted by UF/IFAS research demonstration projects designed to verify the effectiveness of a typical suite of BMPs (**Table 10-10**).

To assess the effectiveness of the agricultural BMPs on load reductions, the baseline conditions and long-term water quality trend pertaining to phosphorus and nitrogen concentrations are being studied. Specific objectives are to (1) identify representative monitoring sites and compile water quality data, (2) obtain the baseline conditions characterizing phosphorus and nitrogen concentrations in the monitored tributaries through basin statistical summaries, (3) use the Seasonal Kendall Tau test to determine the statistical significance of the trends in the time series of monthly average total phosphorus and nitrogen concentrations by station and basin, and (4) link the calculated water quality trends with current land use data to assess the effectiveness of BMPs on load reductions to Lake Okeechobee.

After evaluating the monitoring networks of different programs, the ambient monitoring network consisting of 35 sampling locations within the upper and lower tributaries in the basins immediately north of Lake Okeechobee and 16 additional sites located at the outfalls of historic dairy operations was selected because some of these sampling sites have been maintained by the District since 1972 (**Figure 10-3**). Only phosphorus data were collected at the 16 dairy sites. Two study periods were considered: a baseline period from CY1991–CY2001 and the BMP implementation period from CY2002–CY2007 under LOPA. A Seasonal Kendall Tau test was used to verify the statistical significance of the trends in the time series of TP and total nitrogen (TN) concentrations for the entire study period. Data collected in basin S-154 displayed a significant decreasing trend in terms of mean monthly TP concentrations. Most basins showed an increasing trend in mean monthly TN concentrations over the entire period of record (POR). Among the 35 long-term ambient monitoring sites, six sites had a significant decreasing trend, while 14 sites showed a significant increasing trend in terms of mean monthly TP concentrations for the baseline period. Among the 16 dairy sites, 11 sites displayed a decreasing trend for TP, with of which six of those showing a significant decreasing trend in monthly TP concentrations. The implementation of phosphorus-reduction projects including dairy BAT, including intensive measures such as edge-of-farm stormwater treatment may have helped with the concentration reductions. Other activities, such as conversion of land use to higher intensity agricultural production of row crops, may also have masked the effectiveness of the BMP programs. Under NEEPP, additional phosphorus control strategies have been identified for all drainage basins in the Lake Okeechobee Watershed. A combination of BMPs and public works projects are being initiated to achieve further reductions in nutrient loads.

WATER QUALITY MONITORING IN THE WATERSHED

Water quality monitoring is conducted through the Lake Okeechobee Watershed Assessment (LOWA) micro-basin monitoring (TP only), and through the District's ambient water quality monitoring program (both TP and TN) (**Figure 10-3**). In WY2004, the District restructured the LOWOD farm-level concentration monitoring network to the LOWA micro-basin level monitoring network, moving sampling sites throughout the watershed to develop baseline data. These data are used by coordinating agencies, specifically the FDACS, to direct technical service providers to areas exhibiting poor water quality. The site data collected under the program, along with data collected from the District's ambient monitoring network and the Lake Okeechobee inflow sites, are used to evaluate changes in TP concentrations throughout the watershed. If changes are observed, then the District can perform more intensive monitoring within the basin and micro-basins to identify phosphorus sources. If high TP source areas are detected and TP discharges within a micro-basin do not improve, then the coordinating agencies can require the implementation of additional BMPs or regional projects.

For the past five years (WY2004–WY2008), data have been collected at established LOWA micro-basin monitoring sites located in 14 drainage basins north of the lake (**Figure 10-3**). During WY2008, nine basins had average TP concentrations above their specified target concentration [Surface Water Improvement and Management (SWIM) Plan target] (SFWMD, 1989). Four basins did not have SWIM Plan targets, and one basin had an average TP concentration below its SWIM Plan target (**Table 10-11**). The WY2008 datasets included data from the LOWA stations as well as the ambient monitoring stations. Only sites with data collected during the WY2008 were included in this table and all flagged data were excluded.

As part of the baseline and trend analyses presented in the previous section, the statistical summary TP and TN data (in ppb) collected during the baseline and BMP implementation periods are presented in **Tables 10-12** and **10-13**, respectively. The S-191 basin, also known as Taylor Creek/Nubbin Slough Basin, is listed as two sub-basins: S-191TC and S-191NS due to sufficient sampling data in each area. The notched box-and-whisker plots (**Figure 10-4**) are used to summarize the statistical properties of the datasets at the basin level. These plots consist of the median, the lower quartile (25th percentile), the upper quartile (75th percentile), and the smallest and the largest values in the dataset. When examining the data by basin, median baseline TP concentrations were generally about the same as the implementation levels, except for basin S-154 where TP concentrations decreased during the implementation period (**Figure 10-4**). The S-154 monitoring sites are downstream of areas with relatively high levels of BMP implementation and there has also been a decrease in the overall intensity of upland use for agriculture throughout the basin. S-154 basin also had two dairy BAT projects implemented, a large operating ranch cooperating in a cow/calf BMP project, and two former dairy operations converted under the former dairy remediation program. The median TN concentrations during the baseline period were generally lower than the implementation period levels (**Figure 10-4**). Increases in TN at the tributary sites may be the result of large stores of bio-available nitrogen that have accumulated in soils and sediments. A clearer understanding of the current imports and exports of fertilizer in the watershed, as well as quantifiable information for bio-solid residual imports would provide much needed data in evaluating the successes of nutrient-reduction efforts.

Table 10-11. TP concentration data collected at both micro-basin sampling sites and the ambient monitoring sites in the Lake Okeechobee Watershed (May 2007–April 2008).

Basin	Mean (ppb)	Median (ppb)	Standard Deviation	Number of Samples	Number of Monitoring Sites	Basin SWIM Plan Concentration Target (ppb)
S-191 (Taylor Creek/Nubbin Slough)	496	392	409	301	40	180
S-133	102	61	100	44	5	180
S-154	971	340	1,345	116	12	180
S-65A	125	79	145	168	16	70
S-65BC	110	64	135	157	14	N/A
S-65D	526	131	1,089	174	16	180
S-65E	501	220	739	177	21	180
C-41A (Slough Ditch S-84)	315	168	318	96	7	100
C-41 (Harney Pond Canal S-71)	384	229	446	194	15	180
C-40 (Indian Prairie S-72)	224	177	191	78	5	180
Fisheating Creek	357	266	358	295	20	180
Arbuckle Creek	422	122	687	186	10	N/A
Lake Arbuckle	65	39	167	41	3	N/A
Upper Kissimmee	81	50	110	188	24	N/A

Table 10-12. Summary of total phosphorus data (in ppm) collected from the ambient monitoring stations during the calendar-year periods from 1991–2001 and 2002–2007.

Basin	Station	Summary Statistics for the Period from 1991-2001						Summary Statistics for the Period from 2002-2007					
		No of Samples	Mean	Standard Deviation	Min.	Median	Max.	No of Samples	Mean	Standard Deviation	Min.	Median	Max.
S-65A	KREA 79	68	0.050	0.032	0.017	0.043	0.228	69	0.078	0.030	0.031	0.072	0.172
	KREA 91	53	0.054	0.030	0.018	0.043	0.139	58	0.059	0.021	0.026	0.054	0.106
	KREA 92	63	0.066	0.034	0.026	0.057	0.206	70	0.062	0.022	0.023	0.060	0.112
	KREA 97	52	0.073	0.031	0.025	0.069	0.185	50	0.126	0.059	0.040	0.118	0.283
S-65BC	KREA 93	59	0.077	0.039	0.018	0.071	0.213	67	0.085	0.041	0.043	0.074	0.272
	KREA 94	54	0.108	0.099	0.029	0.085	0.641	68	0.085	0.041	0.046	0.074	0.273
	KREA 95	63	0.078	0.057	0.015	0.061	0.309	67	0.065	0.035	0.025	0.057	0.272
	KREA 98	41	0.066	0.040	0.017	0.060	0.176	66	0.083	0.042	0.032	0.071	0.242
S-65D	KREA 01	223	0.158	0.174	0.004	0.103	1.259	93	0.313	0.294	0.042	0.206	1.522
	KREA 04	141	0.191	0.175	0.030	0.138	1.191	77	0.136	0.068	0.039	0.123	0.320
	KREA 06A	228	0.237	0.138	0.050	0.208	0.970	78	0.286	0.158	0.057	0.253	0.758
	KREA 22	114	0.069	0.113	0.010	0.041	1.032	80	0.068	0.060	0.025	0.054	0.447
	KREA 23	90	0.044	0.048	0.007	0.027	0.320	71	0.121	0.168	0.019	0.055	0.928
S-65E	KREA 14	123	0.537	0.328	0.096	0.487	1.946	54	0.407	0.268	0.058	0.347	1.210
	KREA 17A	182	0.242	0.211	0.026	0.167	1.155	88	0.398	0.248	0.086	0.334	1.388
	KREA 19	392	0.581	0.760	0.035	0.219	4.005	118	0.537	0.495	0.038	0.395	2.050
	KREA 41A	263	0.549	0.632	0.054	0.332	6.547	64	0.452	0.512	0.034	0.212	2.360
S-154	KREA 20	90	2.266	1.126	0.050	2.114	6.550	20	1.059	0.571	0.184	1.120	2.423
	KREA 25	85	1.337	0.881	0.185	1.010	4.145	29	0.663	0.419	0.160	0.615	1.652
	KREA 28	335	1.395	0.728	0.367	1.257	4.940	84	0.899	0.528	0.250	0.748	2.510
	KREA 30A	203	1.114	0.596	0.129	0.967	3.869	25	0.618	0.268	0.167	0.518	1.140
S-191TC	TCNS 201	179	0.462	0.232	0.009	0.388	1.378	64	0.482	0.258	0.142	0.455	1.370
	TCNS 204	206	0.922	0.549	0.108	0.702	2.779	73	0.768	0.381	0.352	0.617	2.000
	TCNS 207	368	0.677	0.759	0.081	0.438	5.834	116	0.897	0.448	0.199	0.790	2.258
	TCNS 209	354	0.532	0.483	0.040	0.381	3.422	89	0.449	0.330	0.043	0.371	1.610
	TCNS 212	95	0.161	0.153	0.030	0.116	1.213	38	0.238	0.174	0.028	0.189	0.664
	TCNS 213	359	0.486	0.296	0.039	0.417	1.725	123	0.421	0.225	0.085	0.350	1.237
	TCNS 214	366	0.242	0.115	0.054	0.218	1.034	141	0.270	0.112	0.081	0.246	0.591
	TCNS 217	362	0.380	0.302	0.030	0.296	1.893	132	0.349	0.287	0.023	0.261	1.520
S-191NS	TCNS 220	181	0.615	0.289	0.236	0.543	1.788	66	0.620	0.450	0.249	0.482	2.860
	TCNS 222	341	0.579	0.230	0.079	0.537	1.458	84	0.507	0.222	0.222	0.446	1.580
	TCNS 228	313	0.512	0.274	0.091	0.444	2.183	88	0.502	0.260	0.138	0.401	1.160
	TCNS 230	310	0.407	0.251	0.080	0.341	1.861	67	0.614	0.268	0.196	0.591	1.440
	TCNS 233	360	0.390	0.260	0.069	0.298	1.758	101	0.646	0.391	0.176	0.556	2.237
	TCNS 249	174	0.457	0.396	0.045	0.315	2.379	30	0.230	0.167	0.063	0.175	0.739

Table 10-13. Summary of total nitrogen data (in ppm) collected from the ambient monitoring stations during the calendar-year periods from 1991–2001 and 2002–2007.

Basin	Station	Summary Statistics for the Period from 1991-2001						Summary Statistics for the Period from 2002-2007					
		No of Samples	Mean	Standard Deviation	Min.	Median	Max.	No of Samples	Mean	Standard Deviation	Min.	Median	Max.
S-65A	KREA 79	65	1.259	0.414	0.580	1.140	2.290	67	1.288	0.406	0.790	1.220	2.850
	KREA 91	50	1.395	0.495	0.250	1.310	2.860	57	1.398	0.355	0.820	1.320	2.880
	KREA 92	59	1.114	0.281	0.510	1.080	1.790	68	1.099	0.123	0.920	1.085	1.520
	KREA 97	50	1.281	0.325	0.550	1.275	2.000	49	1.341	0.285	0.960	1.250	2.580
S-65BC	KREA 93	55	1.442	0.465	0.710	1.300	2.820	65	1.266	0.276	0.880	1.190	2.110
	KREA 94	48	1.417	0.463	0.820	1.250	2.950	66	1.257	0.286	0.870	1.180	2.140
	KREA 95	59	1.291	0.358	0.770	1.210	2.340	66	1.128	0.214	0.680	1.085	1.790
	KREA 98	41	1.373	0.387	0.740	1.330	2.340	64	1.292	0.279	1.010	1.210	2.380
S-65D	KREA 01	162	1.436	0.564	0.250	1.305	5.400	85	1.617	0.429	0.880	1.570	2.870
	KREA 04	72	1.358	0.401	0.520	1.370	2.690	75	1.498	0.382	0.910	1.480	3.150
	KREA 06A	33	1.355	0.383	0.250	1.300	2.280	46	1.529	0.671	0.860	1.390	4.890
	KREA 22	104	1.443	1.035	0.510	1.245	8.980	73	1.428	0.357	0.590	1.360	2.810
	KREA 23	80	1.322	0.352	0.640	1.265	2.370	63	1.459	0.542	0.950	1.290	4.080
S-65E	KREA 14	--NA--	--NA--	--NA--	--NA--	--NA--	--NA--	34	2.116	0.645	1.140	1.940	4.200
	KREA 17A	112	1.413	0.381	0.250	1.350	2.970	86	1.782	0.432	0.850	1.710	3.140
	KREA 19	40	2.112	0.719	0.850	2.115	3.380	84	2.145	0.856	0.910	2.020	4.070
	KREA 41A	29	2.319	1.430	0.690	1.850	8.890	37	2.785	0.910	0.900	2.710	4.760
S-154	KREA 20	55	2.625	0.971	1.160	2.440	6.010	18	2.976	1.489	0.620	2.920	7.060
	KREA 25	77	2.292	0.683	0.600	2.160	4.180	28	2.214	0.521	1.120	2.280	3.300
	KREA 28	326	2.158	0.565	0.250	2.120	4.210	160	2.251	0.769	1.260	2.170	6.510
	KREA 30A	201	1.973	0.493	0.620	1.900	4.480	25	1.874	0.293	1.270	1.910	2.470
S-191TC	TCNS 201	113	1.492	0.571	0.520	1.480	4.290	57	1.609	0.599	0.650	1.630	2.830
	TCNS 204	25	2.574	1.197	1.500	2.330	6.740	45	3.659	0.755	2.200	3.520	5.790
	TCNS 207	324	2.013	2.644	0.250	1.450	27.860	112	3.077	2.375	0.750	2.410	22.920
	TCNS 209	335	1.613	1.680	0.250	1.360	17.560	89	1.773	0.609	0.660	1.730	3.300
	TCNS 212	19	1.821	0.536	0.810	1.760	2.730	24	1.642	0.554	0.990	1.570	2.690
	TCNS 213	323	1.689	0.909	0.250	1.520	9.270	124	2.014	0.657	0.800	1.925	3.960
	TCNS 214	359	1.250	0.601	0.250	1.200	3.740	138	1.210	0.617	0.330	1.035	2.890
	TCNS 217	345	2.319	5.743	0.250	1.580	89.620	126	1.277	0.593	0.430	1.090	3.900
S-191NS	TCNS 220	31	2.694	1.105	1.630	2.410	5.740	49	3.160	1.546	1.750	2.850	10.830
	TCNS 222	337	1.912	0.736	0.250	1.800	9.680	82	2.047	0.529	0.950	1.980	4.340
	TCNS 228	306	2.299	0.915	0.250	2.200	9.030	87	2.313	0.935	0.980	2.230	6.370
	TCNS 230	304	1.786	0.527	0.250	1.705	4.600	65	2.045	0.508	1.090	1.970	3.950
	TCNS 233	354	1.758	0.547	0.250	1.675	4.320	100	2.324	1.793	1.060	1.965	16.130
	TCNS 249	32	1.102	0.643	0.250	1.160	2.960	14	1.261	0.679	0.570	1.030	3.250

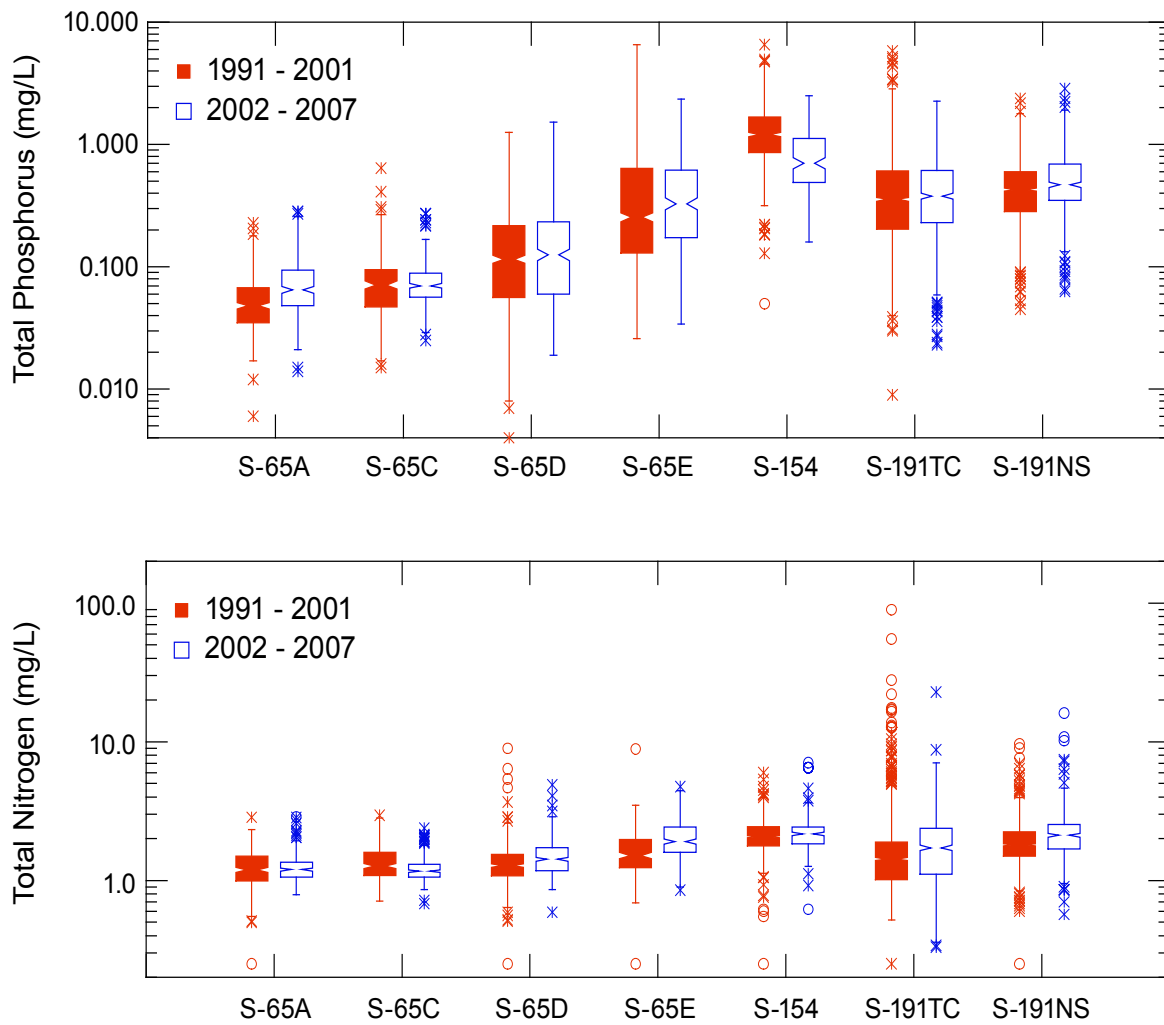


Figure 10-4. Notched box-and-whisker plot of total phosphorus (top) and total nitrogen (bottom) concentrations in the northern tributary basins of Lake Okeechobee for the calendar-year periods 1991–2001 and 2002–2007.

LAKE STATUS

LAKE PERFORMANCE MEASURES

Measurements of TP, chlorophyll, phytoplankton, submerged aquatic vegetation (SAV), and water levels have been adopted as quantitative performance measures for LOPA (Section 373.4595, F.S.) These measures describe the status of the ecosystem and its responses to implemented restoration programs. Measures are five-year averages; this ensures consistency with TMDL reporting, reduces the effect of year-to-year variation attributed to climate and hydrology, and helps to reveal underlying trends. These values are compared to quantitative restoration goals (**Table 10-14**). The TP load is the only goal that is to be met by a set date, 2015, as specified in the phosphorus TMDL (FDEP, 2001). The Lake Okeechobee Protection Program Annual Report provides a technical foundation for these restoration goals. The WY2008 averaged observations are reported and document water quality and lake level conditions.

Of the 11 performance measures that can be compared to five-year (WY2004–WY2008) averages, two reached their goal this water year (**Table 10-14**): (1) the diatom-to-cyanobacteria ratio was greater than 1.5, and (2) algal blooms [chlorophyll *a* > 40 micrograms per liter ($\mu\text{g l}^{-1}$)] occurred in less than five percent of the samples. The shift in the diatom-to-cyanobacteria ratio occurred in the fall/winter period overlapping calendar years 2003 and 2004 (prior to the hurricane impacts of fall 2004). The reasons for the shift are unclear and are under investigation. Lowered algal blooms could be attributed primarily to the turbid water conditions. In WY2008, the lake stage never exceeded extreme high levels because of the drought.

While other performance measures did not meet their targets, there were a few that improved over the previous water year. The five-year average TP load to the lake declined from 630 mt/yr in WY2007 to 551 mt/yr in WY2008. This decline can be attributed to the lower flows to the lake in the past two years: 203 mt (WY2007) and 246 mt (WY2008), respectively, which offset the large loads in WY2005 and WY2006.

Water clarity in the nearshore region during the May through September (annual wet season) period for WY2004–WY2008 increased, with the Secchi disk being visible on the bottom of the water column in 15 percent of the observations. This increase shown in the five-year average is attributed to WY2008, when 94 percent of the observations showed a visible Secchi disk on the bottom of the water column. This was most likely a result of shallower water depths resulting from drought. Nearshore TP also dropped in WY2008 to 47 ppb, while the five-year average dropped from 120 ppb in WY2007 to 114 ppb in WY2008. In part, this drop may be attributed to SAV which increased 10-fold between the August 2006 and August 2007 mapping surveys.

WATER SHORTAGE MANAGEMENT

The two-year regional drought (see Chapter 2 of this volume) resulted in low flows to, reduced water levels in, and reduced discharges from Lake Okeechobee. In WY2008, total flow to the lake was 1,012,785 ac-ft (124,930 ha-m) compared to the 15-year annual average (CY1991–CY2005) of 2,535,572 ac-ft (312,758 ha-m, see **Tables 10-2** and **10-3**). No release of water occurred from Lake Kissimmee from December 1, 2006–July 20, 2007. This contributed to the low water year flow volume of 317,060 ac-ft (39,111 ha-m) at structure S-65E, which was 77 percent less than the 15-year annual average of 1,333,088 ac-ft (164,434 ha-m). For the 15-year annual average, the Kissimmee River outflow made up 53 percent of the surface flow to the lake, while in WY2008 this outflow was only 31 percent of the surface flow to the lake.

Table 10-14. Summary of Lake Okeechobee rehabilitation performance measures, rehabilitation program goals, and lake conditions. Unless otherwise indicated, conditions for WY2007 are listed with five-year annual averages (WY2004–WY2008), as specified in the Restoration Assessment Plan of the Lake Okeechobee Protection Program.

Performance Measure	Goal	Five-Year Average	WY2008 Average
Total Phosphorus (TP) load	140 mt/yr (to be met by 2015)	558 mt/yr	246 mt/yr
Inorganic Nitrogen Load	N/A	931 mt/yr	834 mt/yr
Pelagic TP	40 ppb	184 ppb	191 ppb
Pelagic TN	N/A	1.69 ppm	1.59 ppm
Pelagic SRP	N/A	60 ppb	60 ppb
Pelagic DIN	N/A	302 ppb	159 ppb
Pelagic TN:TP	> 22:1	9:1	8.3:1
Pelagic DIN:SRP	> 10:1	5.2:1	2.6:1
Plankton nutrient limitation	Phosphorus > Nitrogen	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus
Diatoms:cyanobacteria ratio ^a	> 1.5	7.7	N/A
Algal bloom frequency	< 5% of pelagic chlorophyll <i>a</i> exceeding 40 µg/L	4.80%	0.00%
Water clarity	Secchi disk visible on Lake bottom at all nearshore SAV sampling locations from May–September	15.00%	94.00%
Nearshore TP	Below 40 ppb	114 ppb	47 ppb
Submerged aquatic vegetation (SAV) ^b	Total SAV > 40,000 acres	25,602 acres total	28,180 acres total
		11,910 acres vascular	494 acres vascular
	Vascular SAV > 20,000 acres	N/A	Goal not attained
Extremes in low lake stage (current water year)	Maintain stages above 10 ft	N/A	Goal attained
Extremes in high lake stage (current water year)	Maintain stages below 17 ft; stage not exceeding 15 ft for more than 4 months	N/A	Goal not attained
Spring recession (January to June 2007)	Stage recession from near 15.5 ft in January to near 12.5 ft in June	N/A	Goal not attained

^a Mean (WY2004–WY2007)

^b Mean yearly acreages (from 2003–2007 maps)

N/A - Evaluated in current water year only

Water levels were below the water supply-side management schedule throughout WY2008 (**Figure 10-5**). Numerous actions were taken to reduce water consumption and maintain water supply. Water restrictions were increased over time beginning with Phase I in March 2007, which reduced residential lawn watering to three days a week and golf course and agricultural irrigation by 15 percent, Phase II in May 2007, which reduced lawn watering to two days a week and golf course and agricultural irrigation by 30 percent, and a modified Phase III, which reduced lawn watering to one day a week and golf course and agricultural irrigation by 45 percent. Fourteen temporary forward pumps were deployed at S-351, S-352, and S-354 on March 30, April 6, and April 13, 2007, respectively, to maintain water supply to the Everglades Agriculture Area (EAA). These pumps allow water to move from the lake to the canals when lake water levels are below 10.2 ft (3.1 m) NGVD, at which point gravity flow to the canals in the EAA is extremely limited. Water levels continued to drop to their lowest point on record (8.82 ft NGVD on July 2, 2007). Day-of-year record lows were set from July 2, 2007–March 18, 2008, when water levels increased to 10.7 ft (3.07 m) NGVD. On January 20, 2008, modified Phase III water restrictions were revised to allow non-irrigation uses (e.g., washing cars and boats) without permits. On April 14, 2008, twice weekly watering was again authorized.

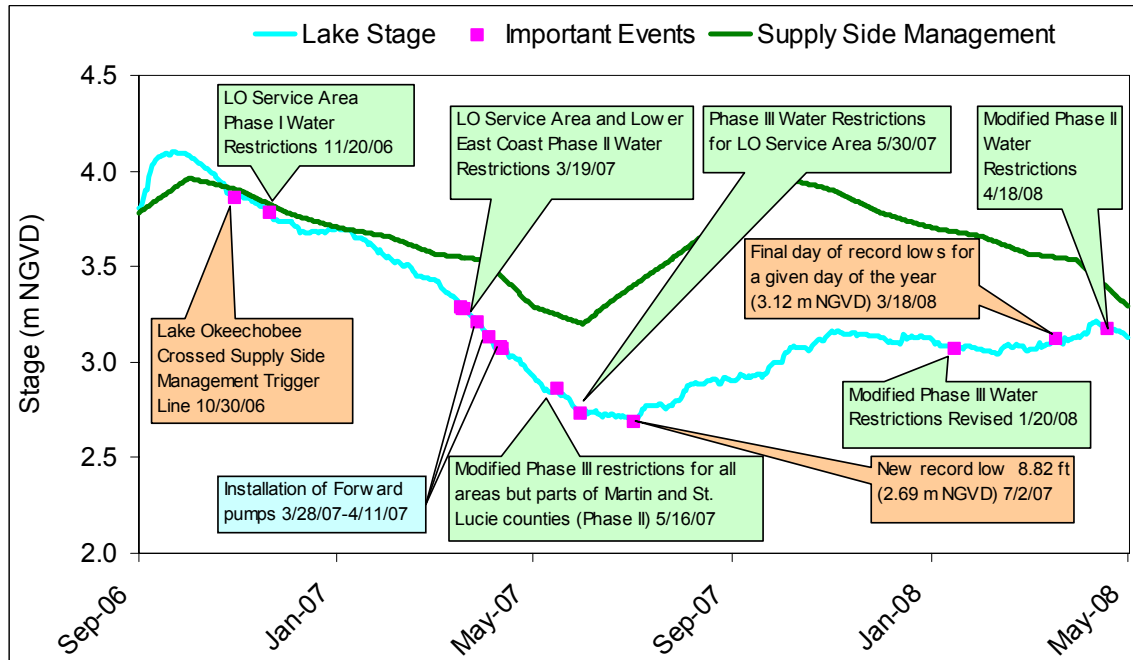


Figure 10-5. Lake Okeechobee stage, supply-side management trigger line, and important water-supply management events in the past year.

Discharges from the lake to the estuaries and the agricultural region in WY2008 were 177,031 ac-ft (21,836 ha-m), which is approximately a tenth of the 15-year annual average (1,785,977 ac-ft or 220,297 ha-m). Over 60 percent of the discharge went south to the EAA, 28 percent to the Caloosahatchee Basin (S-77), and eight percent to the St. Lucie Basin (S-308 in **Figure 10-6**). Of the water discharged to the St. Lucie Basin (13,687 ac-ft, or 1,688 ha-m), none was discharged into the estuary.

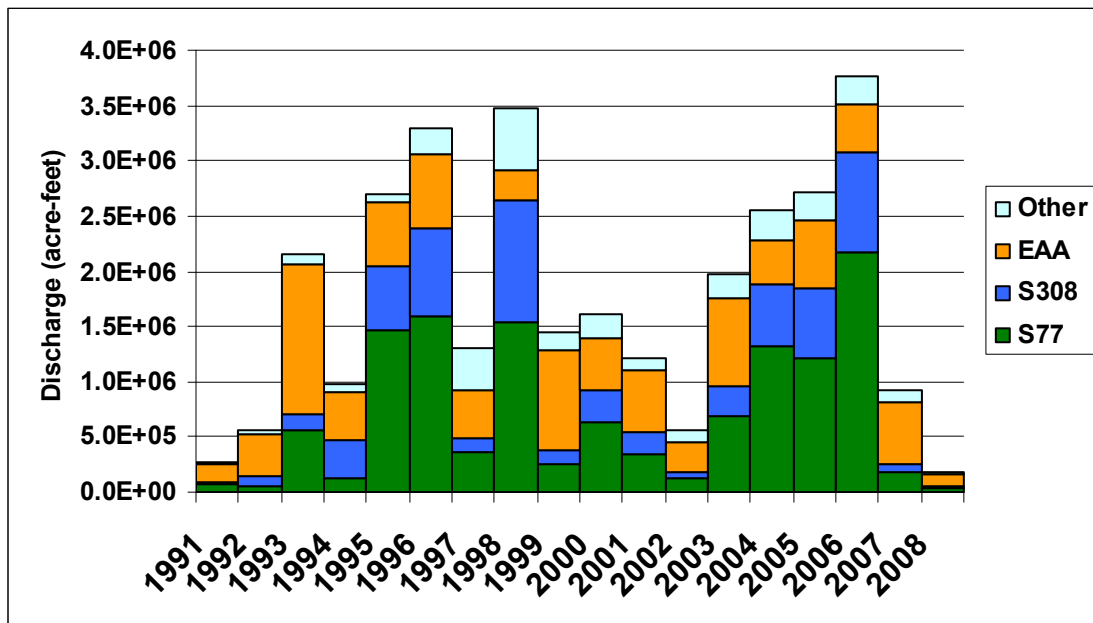


Figure 10-6. Discharges from Lake Okeechobee from WY1991 to WY2008.

PHOSPHORUS BUDGET

The drought and the water management response directly influenced the phosphorus budget for WY2008 (James et al., 1995; Havens and James, 2005; for a description of budget computations). Total TP loads to the lake from tributaries and atmospheric deposition (estimated as 35 mt/yr) (FDEP, 2001) in this year totaled only 246 mt (**Table 10-15; Figure 10-7, panel A**). This is approximately the same as the previous year and nearly one-third of the average in the past 10 years. Mean lake TP mass in WY2008 was also similar to WY2007 due to the low water levels (**Table 10-15**). However, loads out of the lake were much less in WY2008 than in previous years due to the lower water discharge from the lake (**Figure 10-6**). The net load (inputs–outputs) in WY2008 was higher than in WY2007 resulting in increased retention of phosphorus in the lake (**Table 10-15**). A large part of this retention resulted in the net increase of 94 mt of phosphorus in the water column lake mass from the beginning of WY2008 to the end of the water year. The remaining 124 mt was estimated as sediment accumulation.

Phosphorus concentrations remained high in WY2008 with a yearly average of 191 ppb (**Figure 10-7, panel B**). This value is similar to those of the past four water years which ranged from 223 ppb in WY2005 to 176 ppb in WY2007. The five-year (WY2004–WY2008) average is 185 ppb. While the values in the most recent two water years are lower than the two hurricane-impacted years, values have not returned to pre-hurricane conditions. This resistance is attributed to an increase in the layer of easily resuspended sediments that was produced by hurricanes Frances and Jeanne in September 2004, and Hurricane Wilma in October 2005 (James et al., 2008). These easily resuspended sediments, which contain a large pool of phosphorus, have maintained the higher TP concentrations in the water column. In the past three of four years, the average in-lake concentration has exceeded the inflow concentration, suggesting that less phosphorus is accumulating in the sediments.

The rolling five-year average of inflow TP concentration has remained between 200 and 150 ppb for the periods ending within the last five water years (**Figure 10-7**, panel B). The average values for each water year ranged from 140 ppb in WY2003 to 238 ppb in WY2007. The TP inflow concentration dropped to 169 ppb in WY2008. This drop can be attributed to the relatively larger amounts of water input from Lake Kissimmee and the L-8 canal, which contain less TP than most of the other inflow waters to the lake (**Table 10-2**).

Table 10-15. Phosphorus budget (mt) for Lake Okeechobee for the most recent 10 water years.

May 1–April 30 Water Year	Mean Lake TP Mass	Net Change in Lake Content ^a	Load (mt) In ^b	Load (mt) Out	Net (mt) Load ^c	Sediment Accumulation ^d	Net Sedimentation Coefficient (σ_v)
1999	532	-543	312	241	71	614	1.15
2000	735	106	685	310	375	269	0.37
2001	383	-320	134	202	-68	252	0.66
2002	432	264	624	73	551	287	0.66
2003	594	143	639	310	329	186	0.31
2004	578	113	555	292	263	150	0.26
2005	1,106	272	967	567	400	128	0.12
2006	1,104	-195	808	780	28	223	0.20
2007	594	-311	203	181	22	333	0.56
2008	463	94	246	28	218	124	0.27
Average	652	-38	517	298	219	257	0.46

^a Net change from the start (May 1) through the end (April 30) of each Water Year

^b Includes 35 mt/yr to account for atmospheric deposition

^c Difference between load in and load out

^d Difference between net change in lake content and net load (positive value is accumulation in sediments)

The net sedimentation coefficient, σ_y (per year), of the phosphorus budget is the amount of TP that accumulates in the sediment per year divided by the average lake water TP mass (**Table 10-15; Figure 10-7**, panel C). A low σ_y indicates that the lake absorbs less excess TP loads from the watershed. For WY2008, the σ_y value was 0.27 per year, which is less than the 10-year average of 0.46 per year (**Table 10-15**). This lower net sedimentation coefficient is a result, in part, of the small loads to the lake particularly in comparison to the lake mass. A declining trend has been observed for σ_y since the 1970s (**Figure 10-7**, panel C; James et al., 1995a; Janus et al., 1990). WY2008 is very similar to the previous five years for the net sediment coefficient.

The overall reduction in the net sedimentation coefficient may be due to saturation of phosphorus-binding sites on lake sediment particles (Fisher et al., 2001) and/or a reduction of water-column calcium (James et al., 1995b; see the *Other Water Quality Concerns* section of this chapter), an element that plays a key role in sequestration of TP in sediments of Lake Okeechobee (Olila and Reddy, 1993; Moore and Reddy, 1994). Possible explanations for the reduction of calcium in the water column are a reduction of external calcium loads (James et al., 1995b) or reduced contact of the water column with the underlying limestone formation (Parker et al., 1955) as the mud sediment has increased in area (Havens and James, 1999). Another explanation is an increase in calcium absorption to the increased amounts of inorganic phosphorus that forms calcium phosphate. This form of phosphorus is insoluble and is found in mud sediments (Reddy et al., 1995).

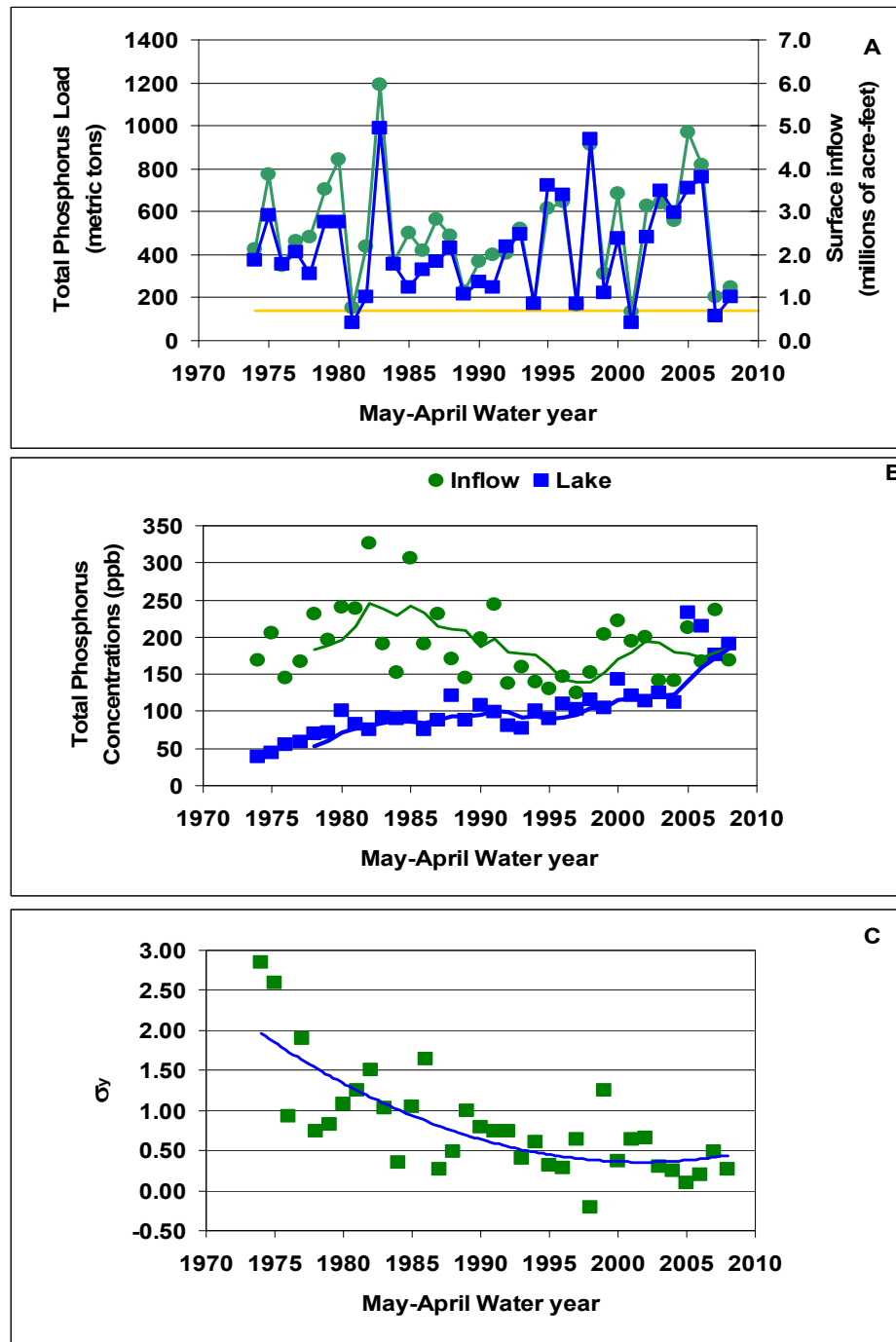


Figure 10-7. Timelines of (panel A) water year phosphorus load and inflow entering Lake Okeechobee from its tributaries, (panel B) inflow and lake average TP concentrations (five-year moving average trendlines), and (panel C) net sedimentation coefficient (σ_y) calculated from the WY2008 phosphorus budget of Lake Okeechobee. (Trendline is a second-order polynomial.)

Calcium typically precipitates phosphorus in a pH range that is only encountered in the lake in dense beds of SAV, or in the midst of phytoplankton bloom activity. Calcium is ineffective in precipitating phosphorus under conditions similar to those that prevail in the open water region of the lake. Nevertheless, the District is currently investigating calcium and other chemical compounds as potential methods for sequestering phosphorus. A study concluded in 2003 suggested that in-lake chemical treatment may be considered an option if in-lake water quality does not respond to external load reductions (Blasland Bouck and Lee, Inc., 2003). Bench-scale tests conducted this past year suggested that ferric chloride (FeCl_3) and aluminum hydroxide [$\text{Al}(\text{OH})_3$] both hold promise as phosphorus-sequestering agents (Golder Associates, Inc., 2008). A field-scale test is planned for fiscal year 2009 (FY2009) (October 1, 2008–September 30, 2009).

Algal Biomass and Toxins

Biomass and taxonomic composition of bloom-forming cyanobacteria in Lake Okeechobee have been monitored monthly since July 2003 at nine nearshore sites that have historically been susceptible to algal bloom formation (**Figure 10-8**). Water-column chlorophyll *a*, TN, and TP concentrations are also monitored. Although there are no established state or federal standards for cyanobacterial toxins, their potential health risks are widely recognized. Therefore, in May 2004, cyanobacterial toxin analysis was initiated as an additional component of this routine monitoring project. Water samples from five of the nine shoreline stations are analyzed for the presence of cyanotoxins (microcystin, cylindrospermopsin, and anatoxin-a).

During summer 2005, many water bodies located within the SFWMD basin experienced prolific cyanobacterial blooms. In Lake Okeechobee, chlorophyll *a* and microcystin toxin concentrations were elevated from August to October 2005, with the highest concentrations observed in the Harney Pond/Fisheating Bay area (**Figure 10-9**). Hurricane Wilma struck in October 2005, and a significant decrease in both measures was immediately observed, probably as a result of water-column instability caused by wind and seiche action. Chlorophyll *a* levels have remained below 25 milligrams per cubic meter (mg/m^3) and microcystin levels have been below the analytical limit of detection (0.2 ppb) since Hurricane Wilma. The high suspended solids and resulting low light levels that persisted after the hurricane likely contributed to the lack of algal bloom formations and low toxin levels.

Current drought conditions have resulted in lower lake levels, lower suspended solids, and improved light levels in the nearshore area. Although these conditions have the potential to favor bloom formations, no algal blooms were reported during 2007; only one minor isolated surface bloom occurred in the south central/southeastern region of the lake in late April 2008.

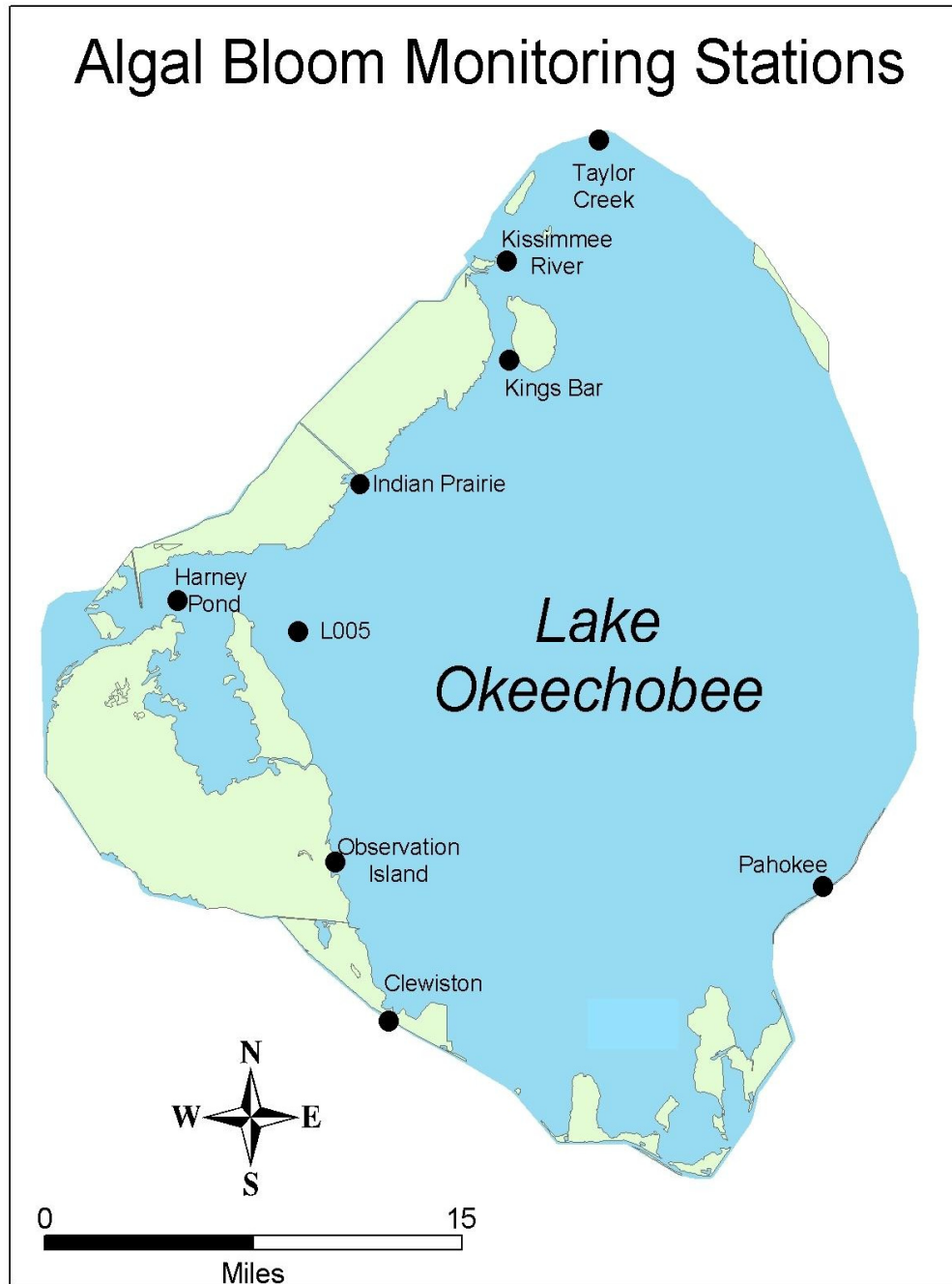


Figure 10-8. Monthly sampling locations for algal bloom and microcystin toxin analyses.

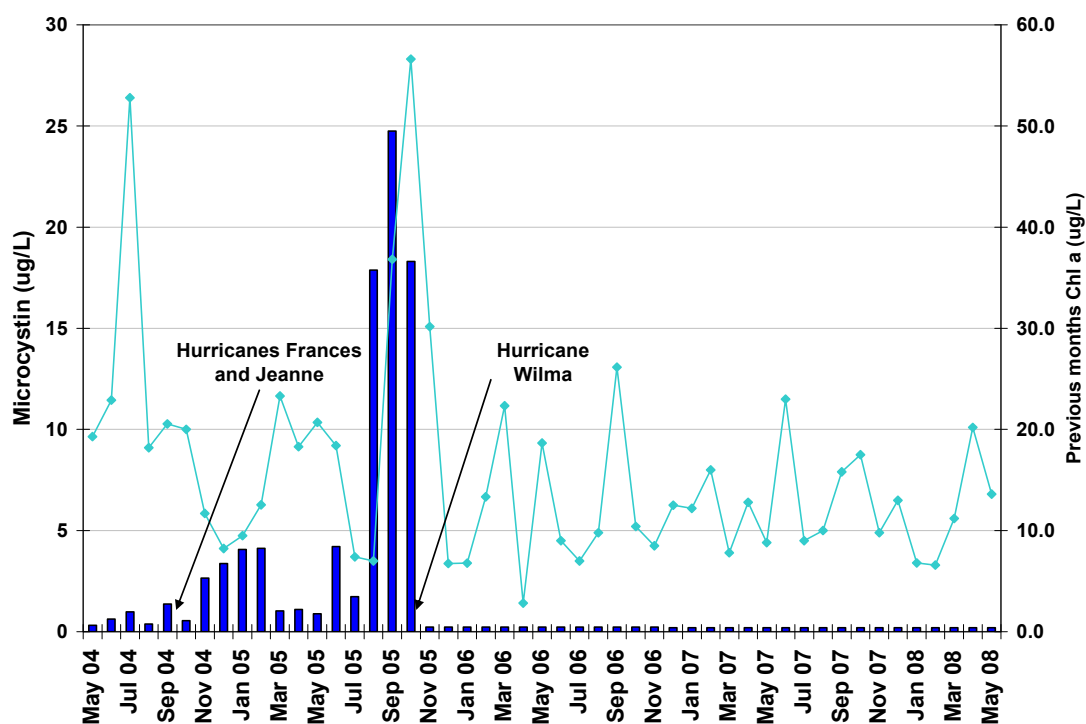


Figure 10-9. Microcystin and chlorophyll *a* concentrations in Lake Okeechobee.

OTHER WATER QUALITY CONCERNS

Pesticides

The District maintains a pesticide monitoring program to meet various permit, legal, and other mandated requirements, including Class I (drinking water) criteria of Chapter 62-302, F.A.C. On a quarterly basis for water and semi-annual basis for sediments, samples are measured for 67 pesticides and their breakdown products at sites throughout the District. Additional information on the pesticide monitoring program can be found on the District's web site at www.sfwmd.gov under the *What We Do, Environmental Monitoring, Reports* section, and the *Pesticide* tab.

For Lake Okeechobee, pesticides are monitored at S-65E, S-191, Fisheating Creek (FEC), S-2, S-3, and S-4. The data and further analysis are included in Appendix 10-1 of this volume. In the previous four sampling reports (May, September, December 2007, and March 2008) atrazine and atrazine breakdown products, bromacil, heazionine, and simazine, were detected in at least one sample from the three northern sample sites (S-65E, S-191, and FEC) (**Table 10-16**). In addition, ametryn, norflurazon, and metolachlor were also detected in at least one water sample from the three southern sample sites (S-2, S-3, and S-4). The concentrations of most of these pesticides were below the practical quantitation limit for the analytical procedure.

The observed concentration of each is compared to the appropriate criterion outlined in Rule 62-302.530, F.A.C. If a pesticide compound is not specifically listed, acute and chronic toxicity criterion are calculated as one-third and one-twentieth, respectively, of the amount lethal to 50 percent of the test organisms in 96 hours, using the lowest technical grade EC50 or LC50. The

technical grade EC50 is a concentration at which 50 percent of the aquatic species tested exhibit a toxic effect within a short (acute) exposure period; the LC50 technical grade is a concentration at which 50 percent of the aquatic animals tested die within a short (acute) exposure period. These technical grades are assigned as reported in the summarized literature for the species significant to the indigenous aquatic community (62-302.200, F.A.C.) These values are listed for the water flea (*Daphnia magna*), which is the most susceptible test organism for these pesticides (**Table 10-16**). Based on excursion categories recommended for the Everglades Protection Area (Weaver and Payne, 2005) all sites where the pesticide was detected are to be labeled as potential concern, however, because none of the concentrations were above the chronic toxicity criteria during the previous four reporting periods, no sites were labeled thus.

Table 10-16. Pesticide residues (ppb) above the method detection limit found in surface water samples collected by SFWMD at Okeechobee sampling sites in May, September, and December 2007, and March 2008 (from Pfeuffer, 20007a, b, c) and chronic toxicity values for the water flea (*Daphnia magna*).

Date	Site	Flow	Ametryn	Atrazine	Atrazine Desethyl	Atrazine Desisopropyl	Bromacil	Hexazinone	Norflurazon	Simazine	Metolachlor	Number of Compounds Detected at Site
5/15/07	FECRSR78	N	BDL	0.12	0.017 ^b	BDL	BDL	1.1	BDL	0.016 ^b	BDL	4
9/11/07	FECRSR78	N	BDL	BDL	BDL	BDL	BDL	0.049 ^b	BDL	BDL	BDL	1
12/11/07	FECRSR78	N	BDL	BDL	BDL	BDL	BDL	0.29	BDL	BDL	BDL	1
3/18/08	FECRSR78	N	BDL	0.018 ^b	BDL	BDL	BDL	0.066 ^b	BDL	BDL	BDL	2
5/14/07	S191	N	BDL	0.048	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1
9/11/07	S191	N	BDL	0.28	0.037 ^b	BDL	BDL	BDL	BDL	BDL	BDL	2
12/10/07	S191	N	BDL	0.20	0.028 ^b	BDL	BDL	BDL	BDL	BDL	BDL	2
3/17/08	S191	N	BDL	0.28	0.018 ^b	BDL	0.052 ^b	BDL	BDL	BDL	BDL	3
5/15/07	S2	N	BDL	0.23 ^a	0.044 ^a	0.013 ^{a,b}	BDL	BDL	BDL	0.014 ^{a,b}	BDL	4
9/10/07	S2	N	0.059	0.58	0.024 ^b	BDL	0.049 ^b	0.027 ^b	0.029 ^b	BDL	BDL	6
12/11/07	S2	N	0.048 ^a	0.29 ^a	0.015 ^{a,b}	BDL	BDL	BDL	BDL	BDL	BDL	3
3/18/08	S2	N	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0
5/15/07	S3	N	BDL	0.25	0.045	0.014 ^b	BDL	BDL	BDL	0.014 ^b	BDL	4
9/10/07	S3	N	0.021 ^b	0.56	0.032 ^b	BDL	0.075 ^b	0.028 ^b	0.037 ^b	0.012 ^b	BDL	7
12/11/07	S3	N	0.031 ^b	0.23	0.018 ^b	BDL	BDL	BDL	BDL	0.019 ^b	BDL	4
3/18/08	S3	N	0.037 ^b	1.1	0.040	BDL	BDL	BDL	BDL	BDL	0.084 ^b	4
5/15/07	S4	N	BDL	0.24	0.046	0.013 ^b	BDL	0.02 ^b	BDL	0.015 ^b	BDL	5
9/10/07	S4	N	0.066	0.069	BDL	BDL	BDL	0.41	BDL	BDL	BDL	3
12/11/07	S4	N	0.017 ^b	0.19	0.039 ^b	BDL	BDL	0.044 ^b	BDL	0.010 ^b	BDL	5
3/18/08	S4	N	0.045 ^a	2.7 ^a	0.061 ^a	BDL	BDL	0.070 ^{a,b}	BDL	BDL	BDL	4
5/14/07	S65E	N	BDL	BDL	BDL	BDL	0.089 ^b	BDL	BDL	0.025 ^b	BDL	2
9/11/07	S65E	Y	BDL	0.028 ^b	0.023 ^b	BDL	BDL	BDL	BDL	BDL	BDL	2
12/10/07	S65E	Y	BDL	0.028 ^b	BDL	BDL	BDL	0.039 ^b	BDL	BDL	BDL	2
3/17/08	S65E	N	BDL	0.041	BDL	BDL	0.053 ^b	BDL	BDL	BDL	BDL	2
Total number of compounds detected			8	20	15	3	5	11	2	8	1	56
Chronic toxicity of <i>Daphnia magna</i>			1,400 (c)	345 (c)	N/A	N/A	6,050 (d)	7,580 (c)	750 (c)	55 (c)	1,175(c)	

N - no Y - yes R - reverse; BDL denotes that the result is below the method dection limit

a - results are the average of replicate samples

b - value reported is less than the practical quantitation limit, and greater than or equal to the method detection limit

c - U.S. Environmental Protection Agency (1991)

d - U.S. Environmental Protection Agency (1996)

Sediment samples taken in May and December 2007, and March 2008, showed detectable concentrations of DDE and DDD at S2, S3, and S4 (**Table 10-17**). DDT (dichloro-diphenyl-trichloroethane) was detected at S3 in March 2008 at a level below the practical quantitation limit. DDE is an abbreviation for dichlorodiphenyldichloroethylene [2, 2-bis (4-chlorophenyl)-1, 1-dichloroethene]. This compound is an environmental dehydrochlorination product of DDT, a popular insecticide for which the USEPA cancelled all uses in 1973. The large volume of DDT used, the persistence of DDT, DDE, and another metabolite, DDD (dichlorodiphenyldichloroethane), and the large hydrophobicity of these compounds account for the frequent detections in sediments. The latter attribute also results in a significant bioconcentration factor. In sufficient quantities, these residues have reproductive effects in wildlife and carcinogenic effects in many mammals.

Table 10-17. Pesticide residues (µg/kg) above the method detection limit found in sediment samples collected at Okeechobee sampling sites in May and December 2007 (from Pfeuffer 2007a, c). Values in bold and italicized are above the Probable Effects Concentration.

Date	Site	ametryn	DDD-P,P'	DDE-P,P'	DDT-P,P'	Number of Compounds Detected at Site
5/15/2007	S2	BDL	19 ^b	51^b	BDL	2
12/11/2007	S2	BDL	19 ^{a,b}	65^a	BDL	2
3/18/2008	S2	BDL	25 ^{a,b}	79	BDL	2
5/15/2007	S3	BDL	5.2 ^{a,b}	18	BDL	2
12/11/2007	S3	BDL	27	50	BDL	2
3/18/2008	S3	4.3 ^b	22	93	6.5 ^b	4
12/11/2007	S4	BDL	BDL	5.4 ^b	BDL	1
3/18/2008	S4	11 ^{a,b}	BDL	15 ^{a,b}	BDL	2

BDL -Below Detection Limit

a- average of replicate samples

b- below quantitation limit

The DDD sediment concentrations detected range from 5.2 to 27 micrograms per kilogram (µg/kg) (**Table 10-17**). Any concentration which would fall below the Threshold Effects Concentration (TEC-4.9 µg/kg) should not impact sediment-dwelling organisms while concentrations above the Probable Effects Concentration (PEC-28 µg/kg), frequently or always have the possibility for impacting sediment-dwelling organisms (MacDonald Environmental Sciences, Ltd. and USGS, 2003). The sediment concentrations detected at S-2 and S-3 were less than the PEC and did not exceed the level of concern. DDD was not detected in the surface water.

DDE values ranged from 5.4 to 65 µg/kg in these sediments. The TEC is 3.2 µg/kg and the PEC is 31 µg/kg for DDE in freshwater sediments. The concentrations of DDE detected at S-2 and S-3 exceeded the PEC and frequently or always have the possibility for impacting sediment-dwelling organisms. DDE was not detected in the surface water.

Herbicides are the only form of pesticides used by the SFWMD on Lake Okeechobee. These herbicides are used to control exotic and invasive species. The District has conducted a number of studies that tested herbicide levels shortly after treatment (Pfeuffer 1988a, b; 1990). Often the herbicides were at or near the detection limit of the analysis. The SFWMD also has studied some effects of herbicides on lake fauna. Some negative effects have been observed on buttonbush (*Cephalanthus occidentalis*) when treating torpedograss in mixed stands; however, this problem

has been largely resolved by treating these stands in winter, during the period of buttonbush dormancy. The District also is investigating the potential negative impacts on bulrush (*Scirpus californicus*) from the spraying of the exotic water hyacinth (*Eichhornia crassipes*) in bulrush stands (see the *Emergent Aquatic Vegetation* section in this chapter). Overall, however, exotic vegetation control activities tend to result in improvements in littoral zone plant community structure, which has important indirect benefits to Lake Okeechobee wildlife (see the *Vegetation Management* section of this chapter).

Calcium Conductivity and Sulfate

James et al. (1995b) noted a declining trend of calcium in Lake Okeechobee and hypothesized that this could be attributed to reduced loading from back pumping into the lake from the EAA. Although this hypothesis has not been confirmed, the trend is consistent with a decline of all ion and ionic related measurements of Lake Okeechobee's water column including calcium, sulfate, and conductivity (**Figure 10-10**). In WY2008 all of these parameters had increased over the previous year due to reductions of lake volume from evapotranspiration. Similar increases during droughts occurred in 1982, 1990, and 2001.

As with other ions in the lake, sulfate has declined from over 60 ppm in the early 1970s to under 30 ppm in recent years. A preliminary investigation of the sulfate budget for Lake Okeechobee was conducted this year (McCormick and James, 2008; **Figure 10-11**, panel A). Potential sulfate sources to the lake include groundwater discharge, atmospheric deposition, and tributary inflows. Groundwater across portions of South Florida is naturally high in sulfate and is considered a potentially important sulfate source in some areas. Direct groundwater discharges to the lake have not been quantified, but the lake's chloride budget indicates that they are minimal. Therefore, sulfate inputs from groundwater were assumed to be negligible. Available data on rainfall sulfate concentrations and dry deposition rates in South Florida were used to estimate an average atmospheric deposition rate of sulfate to the lake of approximately 2,000 mt/yr. By contrast, annual surface-water inputs varied between 34,000 and 161,000 mt during the period of record and, thus, contributed most of the sulfate entering the lake.

In-lake sulfate concentrations are sensitive to changes in surface water inputs, again supporting the importance of the watershed as the primary sulfate source to the lake. Fluctuations in annual in-lake concentrations are significantly correlated with changes in inflow concentrations (**Figure 10-11**, panel B, $r^2 = 0.363$, $p < 0.001$, Pearson coefficient). This relationship is due primarily to variation in loading rates from the EAA, which discharges water that is especially high in sulfate. Discharges from the EAA have declined since the early 1980s, and this trend is associated with a corresponding decline in lake sulfate concentrations.

Sulfate budget calculations for the lake indicate negligible internal sulfate inputs or losses. However, in-lake sulfate concentrations average 12.4 ppm higher than inflow concentrations. This 39 percent discrepancy can be explained by evaporative losses of lake water, which exceed rainfall by nearly the same amount. The lack of significant internal losses is consistent with the general condition of the lake's sediments, which would not be expected to support sulfate reduction. The residence time for sulfate in the lake is 2.6 years, which is similar to that for the conservative ion chloride. This short residence time, coupled with the lack of internal transformation or storage, contributes to the sensitivity of in-lake sulfate concentrations to external loading.

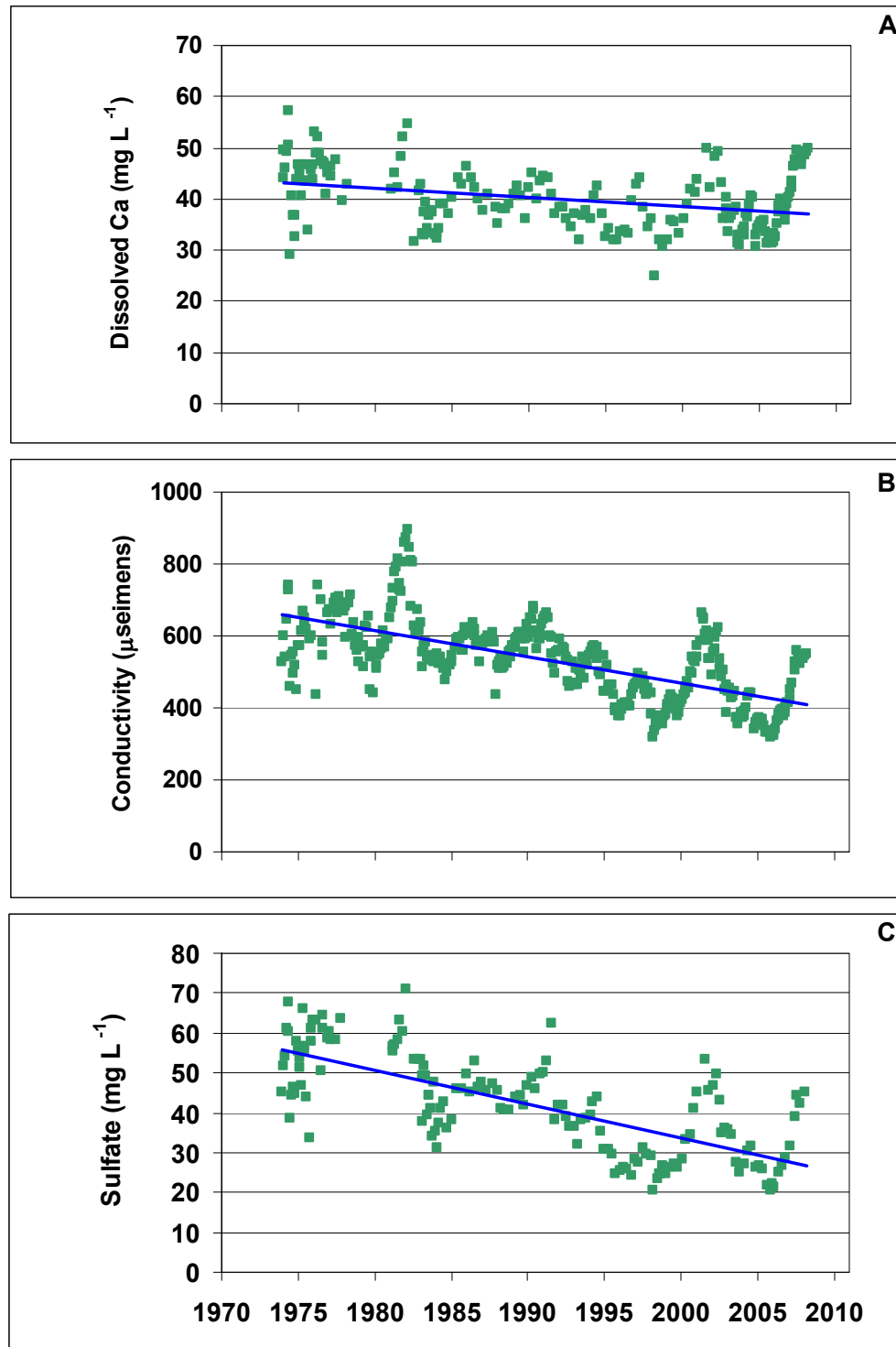


Figure 10-10. Monthly average values of (A) calcium ($r^2=0.12$), (B) specific conductivity ($r^2=0.43$) and (C) sulfate ($r^2=0.53$) at the eight long-term monitoring stations (L001 through L008). The blue line is a linear regression of the average values over time.

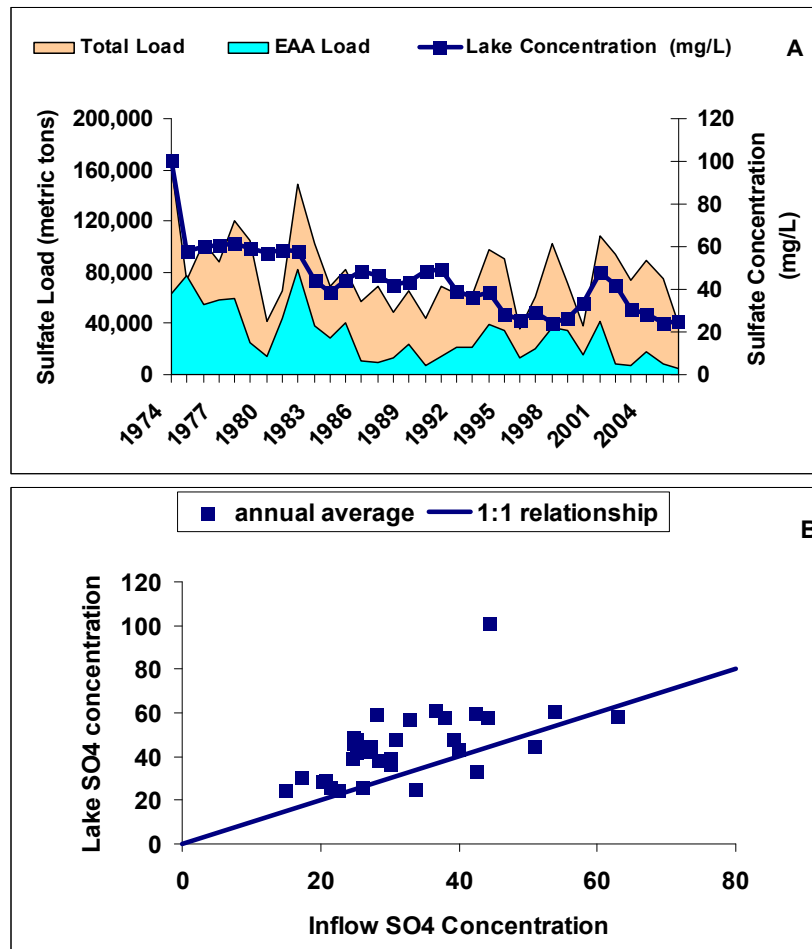


Figure 10-11. Estimated annual loads of sulfate to Lake Okeechobee and annual average in-lake concentration of sulfate (panel A), and relationship between annual inflow-weighted concentration of sulfate and annual in-lake sulfate concentration (panel B).

These analyses indicate that Lake Okeechobee is neither a significant source nor sink for sulfate within the watershed. Rather, the lake functions primarily as a temporary reservoir for and concentrator of sulfate supplied from the watershed. If future management actions are deemed necessary to reduce sulfate loads within the watershed, these reductions should quickly be reflected in a decline in lake sulfate concentrations.

Mercury

Mercury is a concern in Florida waters, especially for fish consumption. Measurements of mercury in Lake Okeechobee fish have found 0.285 ± 0.126 ppm (N = 22) in largemouth bass (*Micropterus salmoides*) and 0.093 ± 0.045 ppm (N = 29) in bluegill (*Leopmis macrochirus*). The Florida Department of Health's Fish Consumption Health Advisories for 2007 states that children and women of childbearing age should eat no more than one portion (six ounces) per month of bowfin (*Amia calva*), gar (*Belone belone*) or largemouth bass greater than 18 inches in size, no more than one portion per week of black crappie (*Pomoxis* spp.), bluegill or largemouth bass

smaller than 13 inches in length, and no more than two portions a week of brown bullhead (*Ameiurus nebulosus*), channel catfish (*Ictalurus punctatus*), white catfish (*Ameiurus catus*) or redear sunfish (*Lepomis microlophus*) caught from Lake Okeechobee (FDOH, 2007). For an expansive discussion of mercury and sulfur in South Florida, see Chapter 3B of this volume.

SUBMERGED AQUATIC VEGETATION

The District carries out a comprehensive program to monitor the health of submerged aquatic vegetation (SAV) communities. SAV is sampled in two projects that vary in temporal and spatial scales. On an a monthly basis, SAV is sampled along 16 transects that extend from the Lake Okeechobee shoreline to deeper water in the south, west, and north nearshore regions known to support SAV under favorable conditions. On a yearly basis, the entire nearshore region is mapped to determine the spatial extent of each SAV species.

Routine monthly transect samplings indicate that SAV biomass declined substantially in response to the hurricanes in 2004 and 2005 (**Figure 10-12**). In the months prior to the 2004 hurricanes, average SAV biomass ranged from 19.1 grams per square meter, dry weight (g dry wt. m²) to 37.6 g dry wt. m². Immediately after the 2004 hurricanes, average SAV biomass declined to about 5.4 g dry wt. m², probably as a result of direct wind, wave, seiche, and lake-stage impacts. Further declines occurred as a result of Hurricane Wilma in 2005, with biomass averaging less than 1.0 g dry wt. m². Biomass values remained low throughout 2006 and into early 2007. The lack of post-hurricane SAV recovery during this time period was attributed to a combination of high lake levels, high suspended solids, and low light levels brought on by the 2004 hurricanes and perpetuated by the 2005 hurricane. The spatial extent of the hurricane damage to the SAV is evident from the results of the annual mapping surveys (**Figure 10-13**). SAV coverage declined from 54,875 ac in late summer 2004 (pre hurricanes Frances and Jeanne) to 10,872 ac in late summer 2005 (post hurricanes Frances and Jeanne). A further reduction in coverage occurred post-Hurricane Wilma with SAV occupying less than 3,000 ac in late summer 2006.

Since the beginning of WY2007, the lake has experienced more severe drought conditions than that of the 2000–2001 drought years. Many of the nearshore transect sites dried out during the spring and early summer of 2007, however, the low water levels led to improved light conditions at the more lakeward transect sites. In response to these improved conditions, average SAV biomass slowly increased during the late summer and fall of 2007 and peaked at 9.1 g dry wt. m² in October 2007 (**Figure 10-12**). An increase in the total acreage of SAV to 28,180 ac was documented during the annual mapping (**Figure 10-13**); however the increase was due to the growth of musk grass (*Chara* sp.), a non-vascular species. Musk grass expanded rapidly across the nearshore areas beginning in the southern region and spread around to the western regions, accounting for 98 percent of the SAV community by the fall of 2007 (**Figure 10-14**). Musk grass biomass declined during the winter months especially along the western shoreline where the vascular species eelgrass (*Vallisneria americana*) began to slowly recolonize. Currently, sparse to moderate beds of *Chara* dominate the southern region and sparse to moderate beds of small eelgrass are expanding in areal coverage in the western, and to a lesser extent, in the northern regions. The full extent of SAV recovery from the current drought conditions may not be known for up to two to three years post-drought.

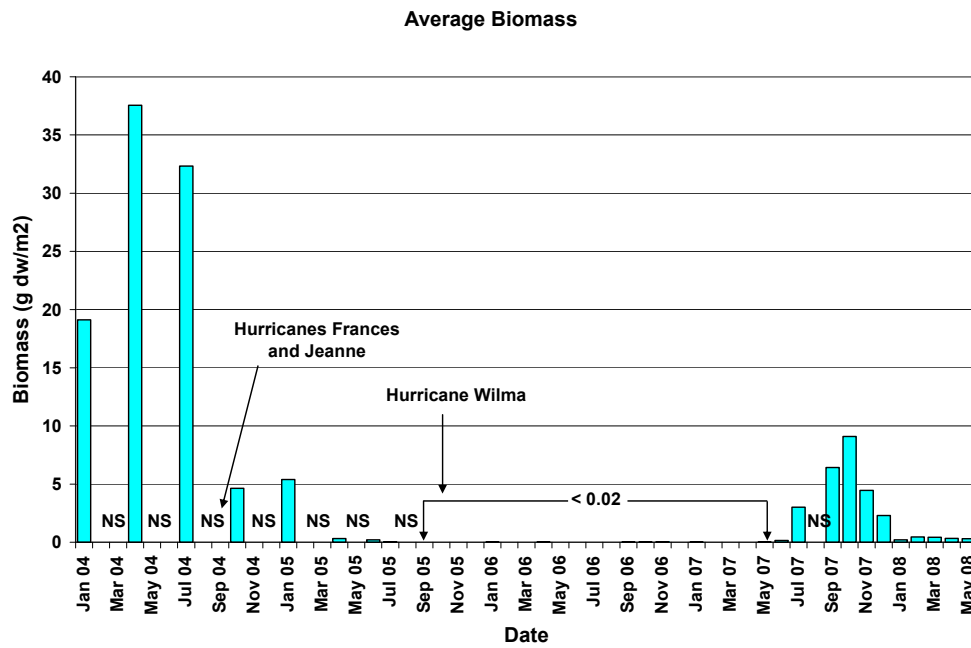


Figure 10-12. Results of monthly SAV transect sampling January 2004 through May 2008.

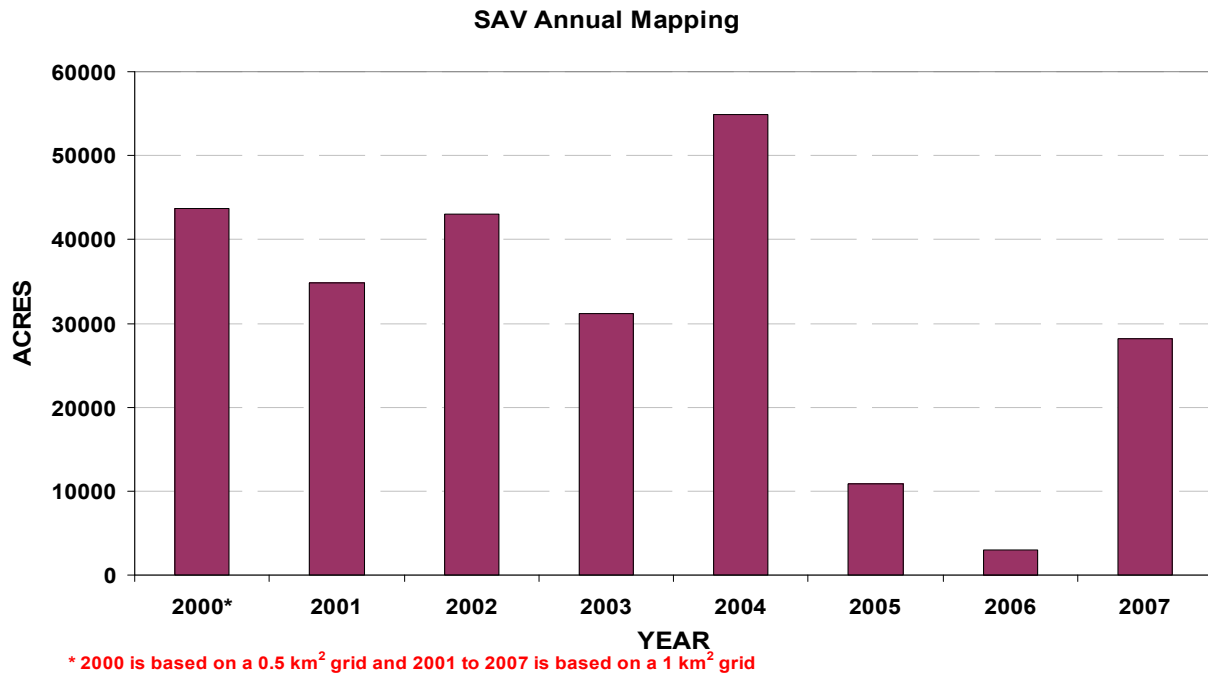


Figure 10-13. Total acres of SAV (vascular and non-vascular species) from the annual mapping for 2000 through 2007.

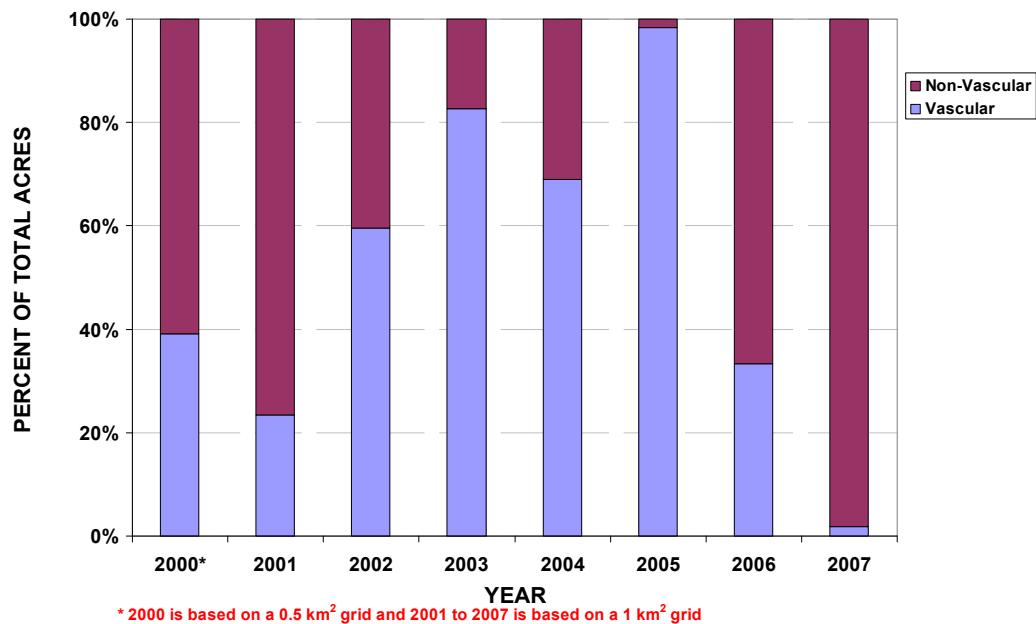


Figure 10-14. Percent of total acres of vascular and non-vascular species from the annual SAV mapping results for 2000 through 2007.

LAKE RESEARCH AND BIOMONITORING

SUBMERGED AQUATIC VEGETATION

Due to the drought conditions and low SAV acreages found in CY2006, research on SAV this year focused on (1) quantifying propagule viability in different areas of the lake, (2) assessing the effect of repeated and/or long-term drying on propagules viability, and (3) defining the effects of sediment scraping on propagule viability.

Ninety surficial lake bottom sediment cores, 30 from South Bay, 30 from Harney Pond, and 30 from Kings Bar were collected on October 23–24, 2007 (**Figure 10-15**). Eighteen of these cores were randomly selected (six cores from each location) and incubated in a growth chamber, at 28 degrees Celsius (C) on a 13L:11D h photoperiod under fluorescent light (425–675 nm), for 186 days following the methods of Grimshaw (2004).

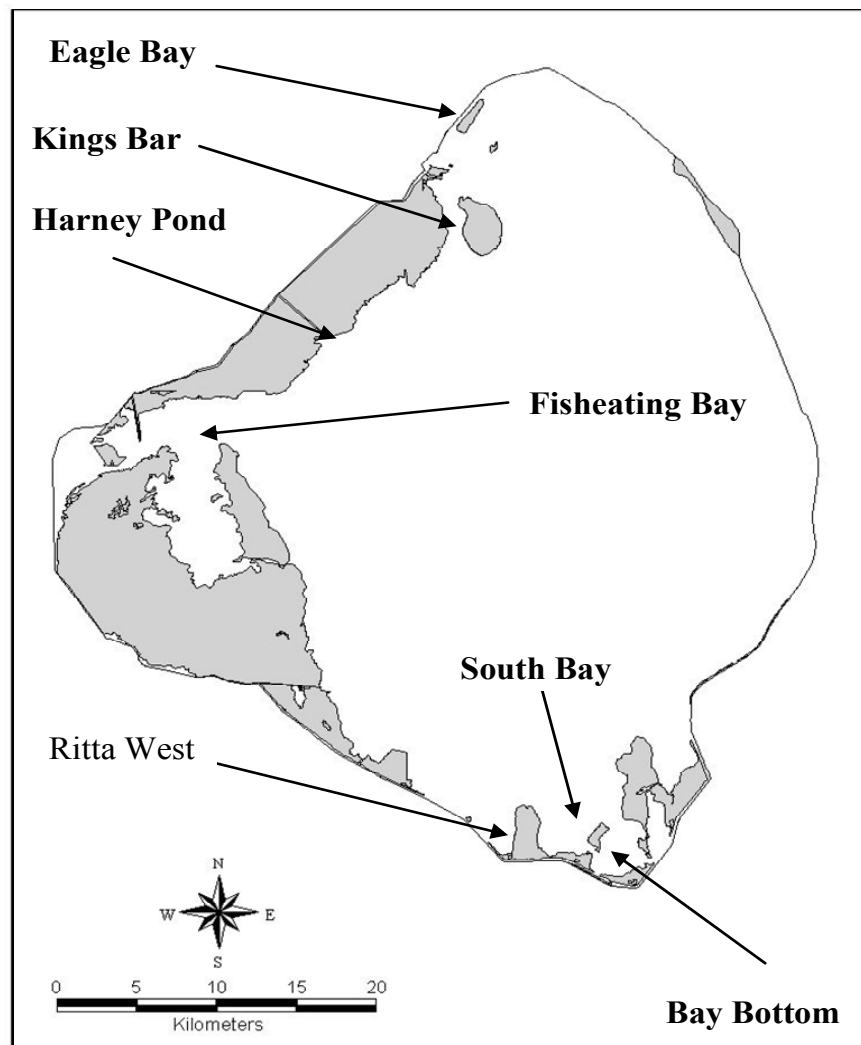


Figure 10-15. Location of seed bank germination studies in Lake Okeechobee.

Seedling emergence and recruitment from continually hydrated cores was monitored on day 97 and upon completion of the incubation. Mean plant densities ranged from 0 to 244 plants/m² on day 97 and 0 to 251 plants/m² on day 186 (**Table 10-18**). With the exception of one eelgrass that emerged from a Kings Bar core, all other emergences were *Chara zeylanica*. SAV densities and emergence rates were quite low in this study compared to those measured in the summer of 2005 (Grimshaw, unpublished). These results are consistent with the SAV monitoring results that found a majority of the SAV regrowth was various species of musk grass.

Table 10-18. Densities of SAV, expressed as plants per square meter, that emerged from continually hydrated surficial bottom sediment cores from selected locations in Lake Okeechobee.

Location	2005 ^a	2007 ^b	2007 ^c
Bay Bottom	1033±193	N/E	N/E
Ritta West	6083±632	N/E	N/E
South Bay	N/E	244±100	251±154
Harney Pond	167±42	0±0	0±0
Kings Bar	167±77	35±35	42±42

a-day 64; n=15.

b-day 97; n=6.

c-day 186; n=6.

N/E - No emergent vegetation observed

Values are the mean ± the standard error of the mean

The cause or causes of these temporal differences in SAV plant densities and emergence rates are presently unclear. Temporally varying environmental parameters known to potentially affect SAV emergence and recruitment include sediment temperature, sediment nutrient and photosynthetic active solar radiation (PAR) levels, and the oxidation-reduction potential of the lake bottom sediments, as well as fungal pathogens, herbivores, and seed predators (Haag, 1983; Leck, 1989; Hartled et al., 1993). Surficial seed banks in Lake Okeechobee may be depleted by hurricane-induced sediment mixing, transport, and deposition that can cause the resuspension, horizontal displacement, and burial of seeds, respectively. Droughts may also affect the viability of surficial SAV seed banks, particularly in species not adapted to environments with repetitive cycles of desiccation and hydration. Because of low lake levels, it is possible that sediment cores were taken from areas containing less seed bank (i.e., under normal water conditions these areas may be open water). Also, a substantially greater amount of white aquatic fungus was observed in 2007 than in the 2005 experiment (Grimshaw, personal observation).

On November 21, 2007, 12 surficial lake bottom sediment cores were collected from littoral areas of Eagle Bay, located at the north end of the lake (**Figure 10-15**). Cores were randomly collected along transects established in areas where bottom sediments had (scraped) and had not (unscraped) been removed (see SFER 2008 – Volume I, Chapter 10). At the laboratory, each core was placed individually within a 2.5 (liter) L translucent plastic bucket filled with deionized water, and then covered with plastic film. All 12 buckets with cores were then placed in a growth chamber at 28 C° on a 13L:11D h photoperiod under fluorescent light [425-67 nanometers (nm)] for 186 days using the methods of Grimshaw (2004). SAV plant densities and emergence rates were monitored on day 69, and upon completion of the experiment.

Most of the emergence of SAV plants occurred in cores from scraped areas, but treatment differences were not statistically significant because of the high variance and low emergence

(Table 10-19). Unfortunately, low SAV densities and emergence rates precluded a more substantial statistical evaluation of the effect of enriched surficial lake bottom sediment (muck) removal at the littoral zone on the viability of the newly exposed and undisturbed portions of any remaining SAV seed bank.

Table 10-19. Densities of SAV, expressed as plants per square meter, which emerged from lake bottom sediment cores collected from scraped and unscraped littoral areas of Eagle Bay. Scraped littoral areas are those where surficial lake bottom sediments have been removed, while intact surficial lake bottom sediments remain in unscraped littoral areas.

Treatment	Day 69	Day 186
Scraped	105±105	209±209
Unscraped	0±0	0±0

Values are the mean ± the standard error of the mean

N=6

EMERGENT AQUATIC VEGETATION

Vegetation Maps

A baseline vegetation map describing the distribution and areal coverage of vegetation in Lake Okeechobee's marsh was developed in the early 1970s (Pesnell and Brown, 1977). A second and more detailed vegetation map was developed in 1996. The most recent geographic information systems (GIS) map was developed using color infrared aerial photography collected in 2003 (**Figure 10-16**). Analysis of these maps indicates that there have been a number of changes in the littoral landscape.

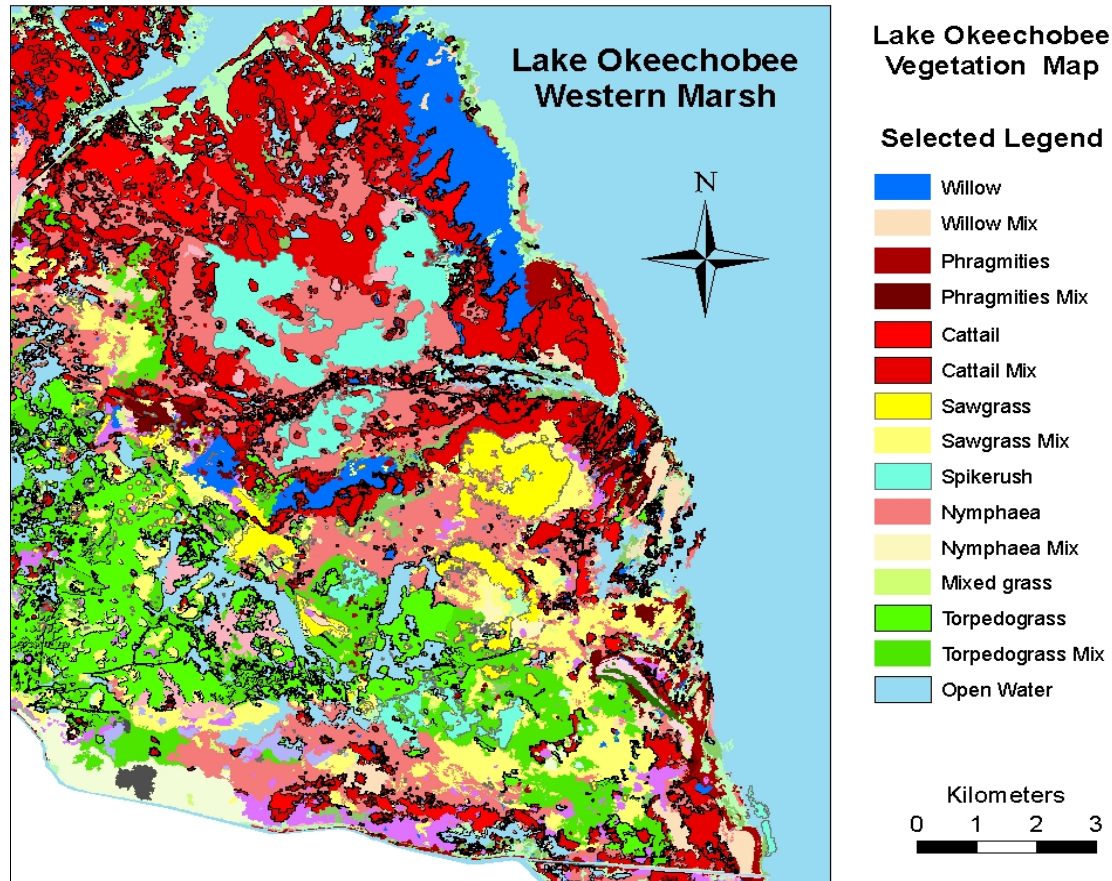


Figure 10-16. Vegetation map (2003) showing the distribution of the primary emergent plant communities located in Lake Okeechobee's central marsh east of the City of Moore Haven.

In the 1970s, cattail was located primarily along the lakeward edge of the marsh and covered less than 20,000 ac (8,094 ha). The dominant emergent vegetation in the interior marsh included beakrush (*Rhynchospora tracyi*), spikerush (*Eleocharis cellulosa*), mixed grasses, and cord grass (*Spartina bakeri*). By 1996, cattail coverage increased to nearly 25,000 ac (10,117 ha) and was established in some areas of Moonshine Bay. In the upper elevation regions of the interior marsh (shorter hydroperiod region), the exotic species torpedograss (*Panicum repens*) displaced more than 13,000 ac (5,261 ha) of beakrush and spikerush. In regions with longer hydroperiods (e.g., Moonshine Bay), the coverage of fragrant water lily increased to greater than 8,000 ac (3,237 ha). In 2003, cattail coverage decreased to 23,840 ac (9,648 ha). The reduction in cattail

coverage was attributed to large-scale fires that burned much of the emergent marsh and a record drought of 2001–2002. Although the total acreage of cattail decreased in 2003, the distribution of cattail expanded in Moonshine Bay. At elevations generally greater than 13.5 ft (4.1 m) NGVD, torpedograss coverage increased to greater than 17,000 ac (6,880 ha) despite the treatment of 10,000 ac (4,047 ha) of torpedograss from 2000 through 2002. The distribution of fragrant water lily increased to nearly 11,000 ac (4,452 ha). Although fragrant water lily is native, excessive growth of this plant may not be desirable because large amounts of flocculent detrital material can accumulate in dense lily beds. A detailed 2007 vegetation map will be available in the near future.

The current drought created dry conditions that exposed the lake's 100,000-acre marsh. During May and June 2008, more than 40,000 ac of emergent vegetation, primarily in the Moore Haven region of the western marsh, burned as a result of arson and wildfires. The recent fires burned mostly grasses and terrestrial vegetation (**Figures 10-17** and **10-18**) that established following wildfires that burned most of the marsh in 2007. The growth and expansion of cattail in the interior regions of the marsh has been inhibited by extremely dry conditions. However, cattail is expanding along the shoreline near the current water interface. A wide band of spikerush also has established along the outer edge of the marsh from Clewiston north to Pierce Canal (**Figure 10-19**). Similar changes were observed following the 2001 drought.



Figure 10-17. Grass fire in the marsh near Moore Haven in May 2008 (photo by the SFWMD).



Figure 10-18. Marsh fire south of Fisheating Bay in June 2008 (photo by the SFWMD).



Figure 10-19. Spikerush (*Eleocharis cellulosa*) along the shore of Western Lake Okeechobee looking south from the south tip of Observation Island towards Clewiston (photo by the SFWMD).

EXOTIC PLANTS

Fire eliminated most of the aboveground torpedograss biomass in the western marsh in 2007 and 2008. However, in many areas torpedograss reestablished from underground rhizomes that were insulated from the damaging effects of fire. Previous torpedograss vegetation management work in Lake Okeechobee indicates that treatment efficacy is often greatest when small but actively growing torpedograss is treated during periods when the marsh is mostly dry (**Figure 10-20**). Although most of the marsh is still exposed, torpedograss has been actively growing in response to recent spring and summer rain events. To take advantage of the favorable treatment conditions, more than 4,500 ac of torpedograss were treated in CY2008, and additional treatments are planned. Treatment efficacy and successional changes in the marsh landscape will be monitored and documented with future mapping projects.



Figure 10-20. Torpedograss (*Panicum repens*) treated during summer 2006 under dry marsh conditions (July 2007) (photo by the SFWMD). Treatment efficacy was nearly 100 percent.

A new exotic plant in Lake Okeechobee is South American watergrass (*Luziola subintegra*). A population of this species was first identified near the mouth of Fisheating Bay as the dry lake bottom rehydrated in fall 2007. The taxonomic identity of specimens collected from this location was confirmed by the University of South Florida Herbarium in December 2007. This is the first report of this species in the United States. A previous report of this species outside its suspected native range in South America was made in Cuba in the 1920s. The pathway of introduction of this species to South Florida is unknown.

There are few reports on the geographic distribution of this species and no published information on its physiology and ecology. The plant exhibits both a terrestrial and aquatic growth habit. Its terrestrial growth habit suggests that it is not a good competitor on land. By contrast, it grows rapidly in shallow water to form dense mats several hectares in size (**Figure 10-21**) that appear to exclude other plant species, even other exotics such as water hyacinth. In the water, immature plants exhibit a semi-floating growth habitat with no aerial leaves. Mature plants are emergent and reach a height of 2 ft. Plants have separate male and female panicles and produce a heavy seed set, but the viability of the seeds is not yet known. Other morphological adaptations include a stoloniferous growth habit and the ability to disperse by fragmentation of rooted nodes.

Initial herbicide applications were mixed in their effectiveness to control this population. An initial application of glyphosate effectively controlled mature plants but had little effect on immature plants. Mixtures of different herbicides were tested and improved control was achieved with a combination of glyphosate and imazapyr. Repeated applications with this mixture should successfully eradicate this species from treated sites.

Based on its aggressive aquatic growth habitat and its resistance to conventional herbicide treatment methods, South American watergrass is considered a potentially serious invasive threat to the lake. The SFWMD plans to obtain more information on the life history and ecological traits of this exotic plant. Controlled experiments will be conducted to determine seed viability, growth rate, and competitive ability under different environmental conditions (e.g., hydrologic regimes, substrate, and nutrients). The resistance of different life stages to various herbicide mixtures will also be tested. Field surveys will be conducted to determine the distribution of this species in the lake and in the Fisheating Bay watershed to guide control efforts and hopefully to provide clues as to the location of introduction and method of transport.



Figure 10-21. A South American watergrass (*Luziola subintegra*) mat in Fisheating Bay (photo by the SFWMD).

MACROINVERTEBRATES

The twice yearly summer and winter macroinvertebrate sampling of a three-year baseline monitoring study was completed in February 2008. The final dataset (February 2008 collection) is expected to be analyzed during WY2009; and the entire dataset is expected to be compared to historical data collected between 1987 and 1996 to examine community composition and temporal trends. The data analysis is planned for completion by September 30, 2008. Triplicate samples were collected with a petite Ponar[®] dredge from the same 18 nearshore and pelagic sites sampled by Warren et al. (1995) in August and February of 2005 and 2006. Due to historically low lake levels in 2007, the summer sampling that year was delayed until October, to allow sufficient time for nearshore macroinvertebrate communities to reestablish at previously dry sites. Six sites were sampled in each of the three dominant sediment types (mud, peat, and sand) and the location of replicate sites in each sediment type were determined to provide a range of water depths. A total of 144 taxa have been collected to date.

Pollution-tolerant segmented worms (*Oligochaetes* spp.) continued to dominate the community assemblage, comprising 64 and 35 percent of the total number of organisms during years one and two, respectively. Clams and mussels (*Pelecypods* spp.) accounted for nine percent of the total number of organisms during year one, and were the second-most abundant organisms during year two, comprising 26 percent of the total abundance. The peat sediment in the southern region had the most densely populated, species-rich and diverse community, followed by the sand and mud zones, respectively. The total number of organisms, species diversity, and species richness increased from years one to year two of the study, but were still below those observed between 1987 and 1996. During the historical study period, *Oligochaetes* dominated the community assemblage (49 percent), followed by midge fly larvae (*Chironomids* spp., 27 percent). *Pelecypods* only accounted for two percent of the community abundance between 1987 and 1996. The loss of *Chironomids* as a dominant community group may have impacts on the fish community, as *Chironomids* are considered to be important prey items for fish (Warren et al., 2007). Overall, the macroinvertebrate assemblage continues to reflect poor water quality, but continued improvements in community quality descriptors were observed during the study period.

FLORIDA APPLE SNAIL

Lake Okeechobee, once designated by USFWS as ‘critical habitat’ (<http://www.fws.gov/endangered/listing/index.html>) for the endangered snail kite (*Rostrhamus sociabilis*), has not been used by this species in the past two decades due to hydrological conditions that do not support foraging and nesting. The Florida apple snail (*Pomacea paludosa*) (**Figure 10-22**), the primary food resource of the snail kite, has been severely impacted by the extreme high and low water conditions that have been occurring more frequently within the lake. For instance, from 1996 to 2000, Lake Okeechobee was managed primarily for water supply purposes and experienced lake stages above 17 ft NGVD. These high lake stages reduced available emergent habitat and food resources required by the apple snail and were followed by a drought during CY2000–CY2001 that left the littoral zone exposed for over one year, further decimating an already stressed apple snail population. A second period of high water ensued and culminated in the 2004 and 2005 hurricanes, which further damaged emergent vegetation. Systematic sampling conducted in 2005 in Lake Okeechobee confirmed that apple snails were nearly absent from the littoral zone four years following the drought and indicated that population recovery might require several years of suitable habitat conditions. A second drought beginning in 2006 and continuing to the present has again left the littoral zone dry and is thought to have essentially eliminated snails from most of the marsh.

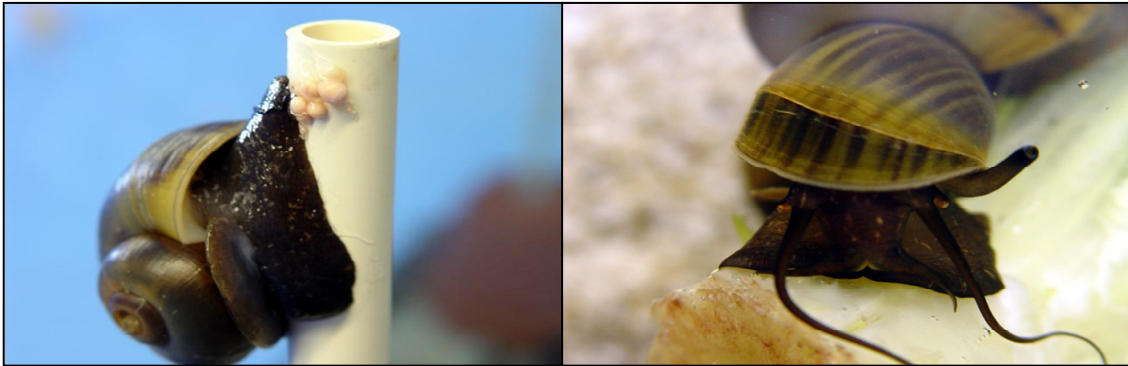


Figure 10-22. The Florida apple snail (*Pomacea paludosa*) (photo by the Harbor Branch Oceanographic Institute, provided under SFWMD contract).

Apple Snail Surveys

Following reflooding of the outer edge of the lake's littoral zone in spring 2008, the District initiated a monthly apple snail egg survey to determine whether a sufficient source of apple snails still exists to facilitate population recovery in the lake. The presence of egg clusters was used to identify locations containing breeding adult snails. Transects spaced a quarter-mile apart were surveyed once a month for three months, from April through June 2008, throughout Moore Haven Marsh, Indian Prairie, and Fisheating Bay (**Figure 10-23**). Global positioning system (GPS) was used to navigate to a point on each transect located closest to the outer fringe of vegetation, and the transect was surveyed perpendicular to the shoreline until the water depth became too shallow (usually around 10 cm of water) to continue the survey.

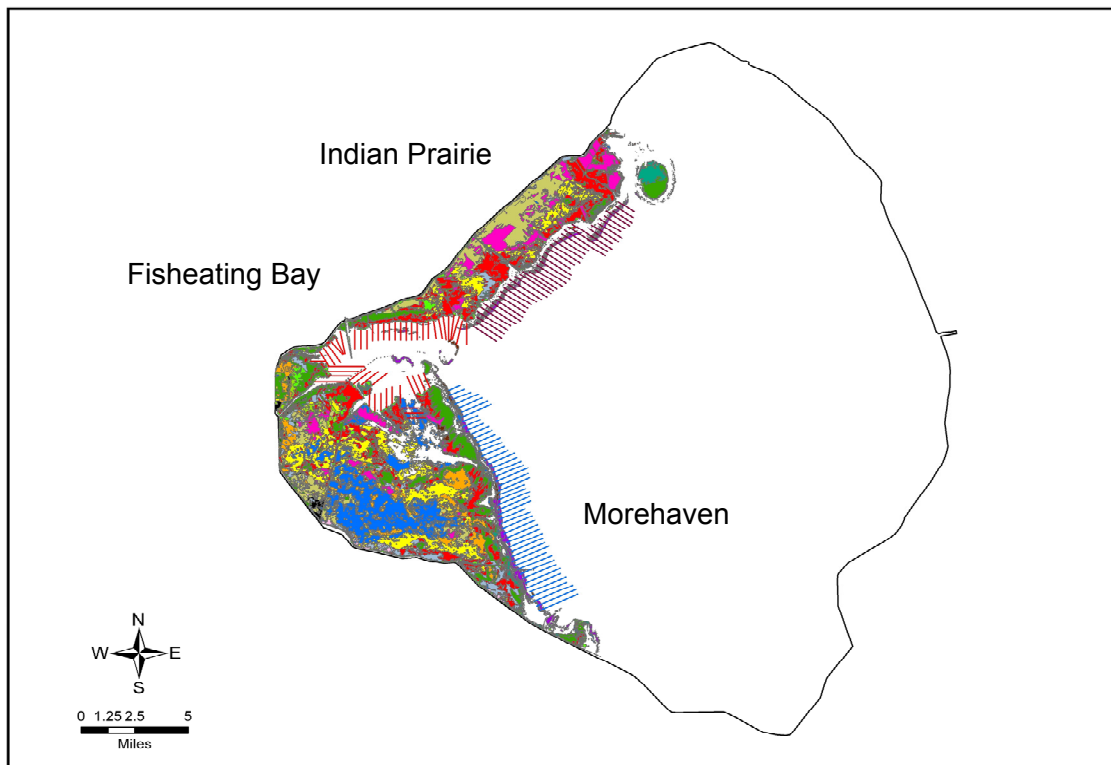


Figure 10-23. Location of the apple snail transects in Lake Okeechobee. Transect surveys were conducted in April, May, and June 2008.

Apple snails were absent from most of the littoral zone. During three months of surveying during the peak of the apple snail reproductive cycle, only three adjacent transects near Indian Prairie Canal contained egg clusters. A total of 29 egg clusters were found over the three-month period along these transects. Although the number of egg clusters does not always correlate well with the number of adults residing in an area, the extremely low number of clusters found in these surveys indicates an acutely diminished population. The small population and the poor dispersal capabilities of this species could prolong its recovery and, thus, use of the lake by snail kites for several years.

Apple Snail Recovery Plan

In response to potential exceedance of the minimum flow and level (MFL) criteria mandated for Lake Okeechobee, the District funded a recovery plan to offset the harm caused to apple snail populations by extreme low lake levels. Cumulative effects on species higher up the food chain from the decline of apple snails during times of prolonged drought could potentially be alleviated through the enhancement of apple snail stocks. Theoretically, stocking small areas within Lake Okeechobee with apple snails would increase the available source population and would facilitate population growth in interior marshes of the Lake historically used by snail kites. This type of management strategy would significantly reduce the recovery time of apple snail populations following severe hydrological conditions.

Although stock enhancement is a popular method for dealing with aquatic species of concern, there are many challenges concerning apple-snail production. The Florida apple snail has never been artificially propagated on a large scale, and there are gaps in our understanding of its requirements for growth and reproduction. The objective of the apple snail recovery plan is to determine if aquaculture technology can be used to produce apple snails on a scale large enough to stock the littoral zone of Lake Okeechobee. Project goals include determining: (1) growth under captive conditions, (2) reproduction in captivity, and (3) an appropriate strategy for release.

Apple snails in the wild are found at relatively low densities (0.05 to 1 snail/m²), therefore, the large size (roughly 400 km²) of the Lake Okeechobee littoral zone means that the introduction of thousands of snails is necessary to successfully stock even small areas at natural densities. Additionally, past research has shown that apple snails exhibit density-dependent growth. As such, laboratory rearing space could be a key factor limiting the success of this pilot project. Density experiments were conducted to determine the ideal stocking density necessary to produce growth rates similar to those in the wild. Experiments were conducted using a small recirculating water system consisting of two troughs and a sump pump. Each trough was divided into nine identical sections (0.22 m²) with three replicates per treatment. Apple snail egg clutches were collected from the wild in August and October 2007 and were hatched in captivity. Captive snails were reared on a diet of Romaine lettuce (*Lactuca sativa* L. var. *longifolia*). Once snails reached approximately 11 millimeters (mm) they were stocked into one of six density treatments ranging from 10 snails/m² to 100 snails/m² for a period of two months.

No statistically significant difference in growth rate was found among the six density treatments (**Figure 10-24**). Snails grew an average of 2 mm per week (mm/wk) at all stocking densities over the 60-day experiment, a rate which is comparable to growth rates seen in the wild (3 mm/wk). Although growth tended to be higher in the lowest density treatments, the relative difference in the total number of snails produced among treatments needs to be taken into consideration since the goal is large-scale production. For instance, the smallest density treatment produced nine adult snails whereas the largest density treatment produced 40 snails using the same amount space with little difference in the average growth rate (**Figure 10-25**). When space is a limiting factor for culture success, the density treatment that produces the largest number of snails is preferred. This experiment indicates that the production of snails to the 20–30mm size class can be accomplished when stocking at the 100 snails/m² density level.

Approximately 500 adults from the initial August and October snail collections were retained as broodstock to determine whether they would spawn in captivity. This initial population of snails was considered the phosphorus generation. Adult snails (30 mm) cultured from the August wild egg clutches (P1) started breeding and laying eggs in captivity on October 20, 2007, and eventually produced over 1,000 juveniles in the laboratory (F1). On February 13, 2008, the first F2 egg clutch was laid. Since that time, over 3,000 F2 juveniles have hatched in captivity.

Further, the third generation of captive raised snails began on June 25, 2008, when the first F3 egg clutch was laid.

Research has shown that in the wild, female apple snails lay approximately one egg clutch per week. The 250 adult female apple snails cultured from the August wild egg clutches produced a maximum of only 138 egg clutches in a single month or about 0.14 clutches/female/wk (**Figure 10-26**), far less than what is seen under natural conditions. Snails cultured from the October wild egg clutches exhibited almost no reproduction. The late date of collection of these broodstock individuals may have contributed to their low reproductive output. The captive reared F1 snails showed higher reproductive rates (a maximum of 375 egg clutches in a single month), but still fell short of being comparable to wild egg production. Furthermore, the hatch rate of captive reared egg clutches was quite low. In natural populations, hatch rates range from 50 to 90 percent depending on environmental conditions (e.g., hydrology, temperature) and the time of egg clutch development (i.e., egg clutches produced later in the breeding season seem to have lower hatch rates). Under presumed ideal hatching conditions in the laboratory (e.g., water high in Ca^+ ions, high water temperature, and 14/12-hour day-to-night cycle), the maximum egg clutch hatch rate was only 27 percent (**Figure 10-27**).

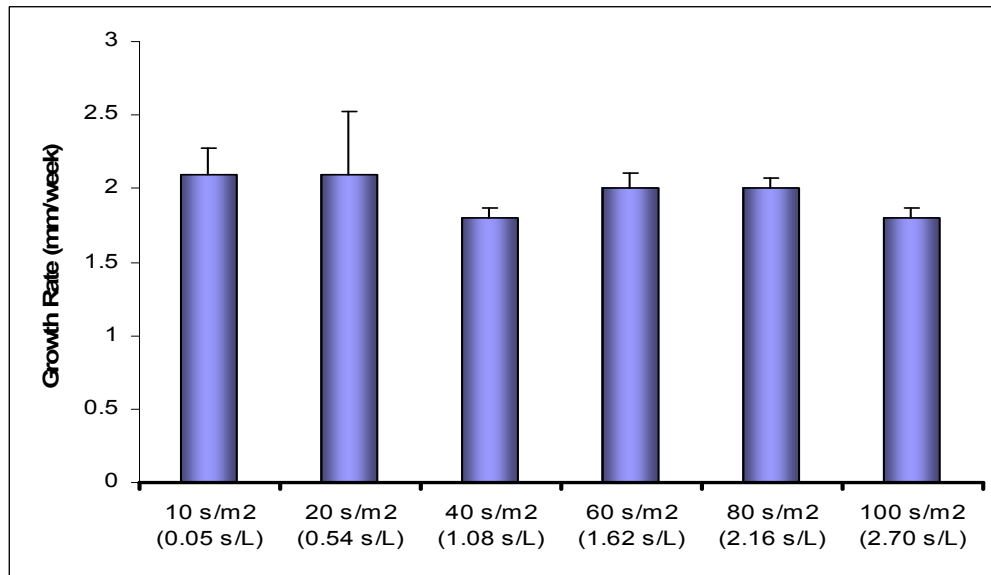


Figure 10-24. Average weekly growth rate ($\pm$ SD) of juvenile apple snails stocked at varying densities for two + months.

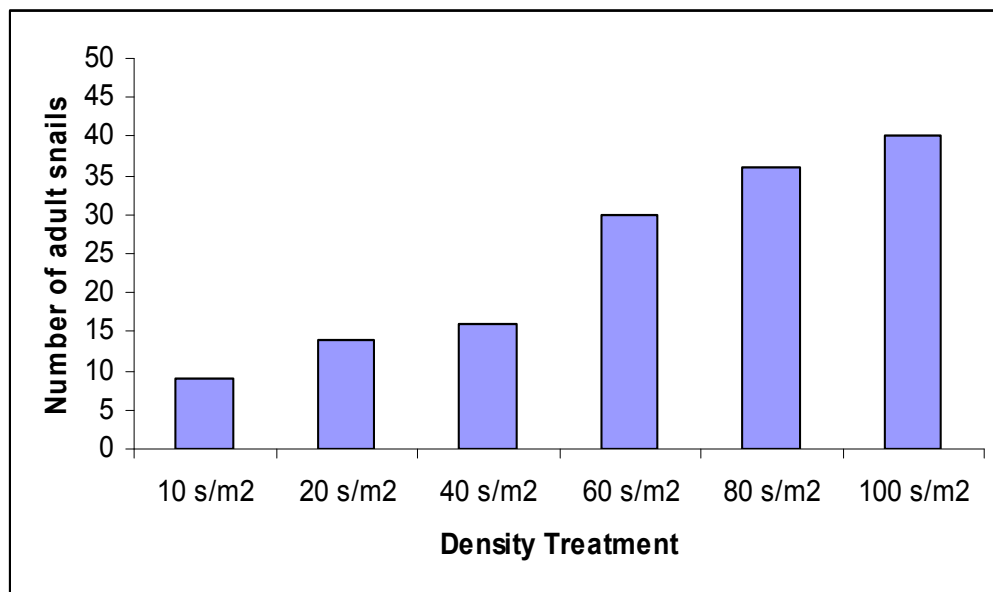


Figure 10-25. The number of snails that reached adult size (≥ 24 mm) in each density treatment.

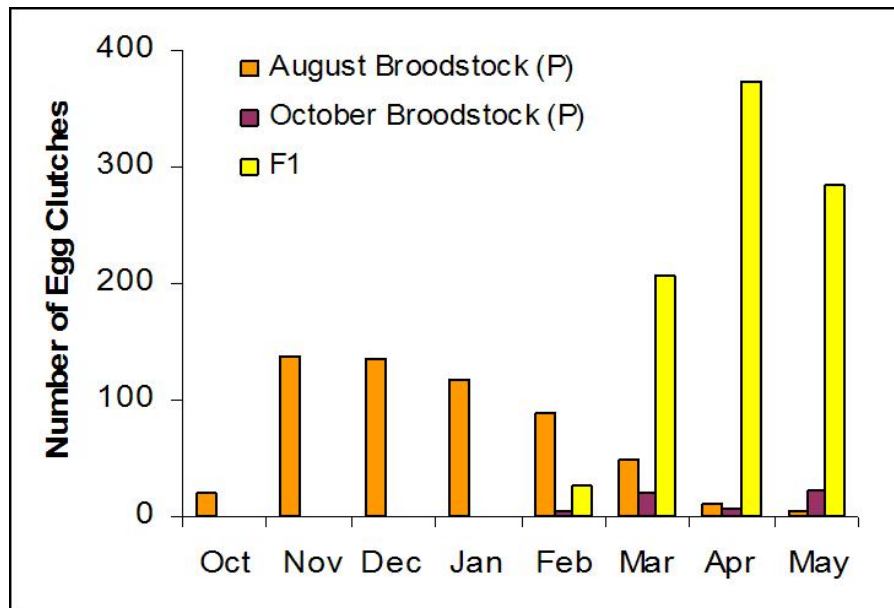


Figure 10-26. The number of egg clutches produced by apple snails reared in captivity from October 2007–May 2008.

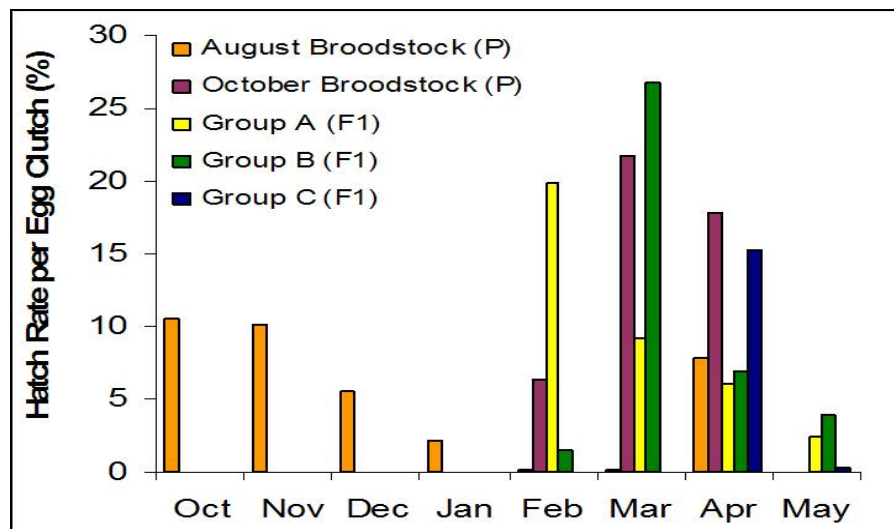


Figure 10-27. The average hatch rate percentage of egg clutches produced by captive reared broodstock. F1 generation snails were grouped by age. Thus, Groups A, B, and C represent snails that reached sexual maturity at different time stages. In all groups, hatch rate decreases with time.

Several future studies are planned to better understand these reproductive issues. Use of Romaine lettuce as a food source may limit reproductive output in captivity. Preliminary observations showed that Romaine lettuce was palatable to and supported acceptable growth of the snails, but it's likely not the diet that produces the highest growth rate and reproductive output. Experiments will be performed to determine the ideal diet to provide maximum snail output in captivity. Another factor that may contribute to low reproductive output and low hatch rates is density-dependent reproduction. It is possible that snails may be constrained in their mating habits or limited from laying healthy eggs due to stress from overcrowding. Future experiments will consider the effect of broodstock density on reproductive output. Finally, wild snails reproduce between February and June with peak reproduction occurring during the months of March and April. Physiologically, snails may require an overwintering period to stimulate production. Experiments will be conducted to determine if exposure to outdoor conditions during the winter improves spring reproductive output.

FISH

Lake-wide electrofishing was not conducted during fall 2007 due to extreme low-water conditions in Lake Okeechobee. Lake-wide trawl sampling was conducted at 18 of the 27 nearshore and pelagic sites sampled during the 1988–1991 trawling events. Trawl sampling resulted in the capture of 1,172 fish with a combined biomass of 177.5 kg. Twenty fish species were represented in the catch. Five species collectively comprised 78 percent of the catch by number and were, in order of abundance: bluegill (*Lepomis macrochirus*), white catfish (*Ameiurus catus*), threadfin shad (*Dorosoma petenense*), black crappie (*Pomoxis nigromaculatus*), and Florida gar (*Lepisosteus platyrhincus*). Five species collectively comprised 87 percent of the catch by weight and were, in order of biomass: Florida gar, Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*), white catfish, black crappie, and bluegill.

Comparison of lake-wide trawl sampling data for selected dominant species from 2007, 2006, 2005, and 1988–1991 show noticeable trends in relative abundances. Orinoco sailfin catfish were not present in Lake Okeechobee during the 1988–1991 period, therefore, have quickly become a significant component of the lake's fish community. The systematic decline in the relative abundance of black crappie and the increase in the relative abundance of bluegill are also notable. The decline in black crappie relative abundance is due to extremely poor recruitment since 2002 and the short-lived nature of the species. The recovery of this species in Lake Okeechobee will require a rebound in the abundance of threadfin shad, which adult black crappie feed on almost exclusively. Threadfin shad abundances have increased since 2005 but remain well below levels observed during 1988–1991, a period when black crappie abundances were high. The 2004 and 2005 tropical seasons degraded water quality within the lake, directly impacting the phytoplankton and zooplankton that are consumed by the shad. Continued improvements in lake conditions should lead to an increase in shad abundance. The drought and associated low water levels in Lake Okeechobee have allowed for some recovery of littoral vegetation communities to initiate recovery, which may in turn be increasing secondary production and the availability of prey for bluegill.

IN-LAKE MANAGEMENT

REVISED LAKE OKEECHOBEE OPERATING SCHEDULE

At the end of April 2008, the USACE approved a new Regulation schedule (LORS2008) for Lake Okeechobee to replace the Water Supply and Environment (WSE) regulation schedule that had been in effect since 2000. This revision, which is expected to be fully implemented in WY2009, attempts to optimize operations within existing structural constraints to meet the diverse requirements of the lake, its receiving waters, and its users.

LORS2008 was evaluated based on overall systemwide performance measure benefits including estuaries, Lake Okeechobee, Water Quality Everglades/Water Conservation Areas, and Water Supply Lake Okeechobee Service Area, Lower East Coast Service Area, Everglades snail kite habitat, Herbert Hoover Dike integrity, and navigation impacts. This schedule will result in lower average lake levels than those under WSE. As part of the revised schedule, temporary forward pumps have been deployed at some structures to allow for deliveries of irrigation water in the event of extreme low lake stages [< 10 ft (< 3.1 m) NGVD] similar to those that occurred during the 2000–2001 drought and the more recent drought. The successful operation of these temporary pumps during the 2006–2008 drought indicates that this component of LORS2008 has been useful.

The temporary LORS2008 is projected to result in lake levels that may potentially result in an exceedance and/or violation of the District's Lake Okeechobee MFL rule, depending upon actual rainfall received during the implementation timeframe of this regulation schedule. The District has revised its water shortage management plan to mitigate the severity and frequency of low lake levels caused by LORS2008 on water supply and lake ecology.

This interim schedule is anticipated to be in effect until either the risk of dike failure is reduced with the required improvements to Reaches 1, 2, and 3 of the Herbert Hoover Dike, or until CERP Band 1 projects are implemented, whichever comes first. Implementation of an alternative schedule will eventually be required to address prolonged low lake levels and the associated impacts on the lake's ecology and water supply.

WATERWAY MAINTENANCE

The District provided funding to the City of Belle Glade to conduct mechanical maintenance dredging of the finger canals of the Belle Glade Marina, in conjunction with boat ramp and campground restoration efforts that are under way with grant funds from Palm Beach County. These efforts were started in 2007 and completed during 2008.

VEGETATION MANAGEMENT

Aerial and ground treatments of exotic and invasive emergent vegetation continued in 2007–2008. Approximately 5,000 ac (2,023 ha) of torpedograss were treated in the Moore Haven and Indian Prairie regions of the marsh. This brings the total acreage treated in Lake Okeechobee since 2000 to nearly 30,000 ac (12,145 ha) of torpedograss and 7,398 ac (2,995 ha) of cattail. While torpedograss treatment efficacy has varied, a generally high level of control has been achieved. In some areas of the Moore Haven Marsh, torpedograss has been controlled for more than four years following a single treatment. Native vegetation including spikerush and fragrant water lily has become established in many of the treatment sites. Treatment efficacy of cattail also has been high. Cattail treatments have been confined to interior marsh locations to preserve the remaining cattail wall that helps prevent nutrient-rich pelagic water from entering the interior marsh. Many cattail treatment sites are now open and fires have eliminated much of the dead vegetation. Changes in the marsh community continue to be monitored and quantified through the use of GIS-based vegetation maps.

HABITAT RESTORATION

Pond apple tree (*Annona glabra*) planting continued during WY2008. Due to ongoing construction at the EAA Reservoir in western Palm Beach County, several thousand mature pond apple trees in a canal were to be flooded. In April 2008, the District transplanted 1,500 of these trees as part of ongoing habitat restoration work on Torry Island in Lake Okeechobee. The project took advantage of the availability of trees as tall as 8 ft that would most likely be completely submerged when the EAA Reservoir was completed and provided a unique opportunity to enhance environmental restoration efforts in Lake Okeechobee. Pond apple trees provide desirable habitat for other native species, including the endangered snail kite, endangered Okeechobee gourd (*Cucurbita okeechobeensis*), and wading birds. Future plantings of cypress (*Taxodium* spp.) are planned along the Rim Canal spoil islands near Moore Haven.

Approximately 5,000 discarded tires located on Kreamer Island in Lake Okeechobee have been mechanically removed in an effort to enhance the wetland habitat and take advantage of the low lake stage. The tires were transported to a tire recycling facility for shredding.

SEDIMENT MANAGEMENT

Continued low water levels on Lake Okeechobee provided additional opportunities for the District, in conjunction with the FWC, to cost-effectively remove muck sediments from nearshore regions of the lake. Once these muck sediments are removed and water levels return to normal, the anticipated environmental benefits in these areas will include improved water clarity, increased coverage of desirable emergent and submerged plants, and improved fish-spawning and wildlife-foraging habitat. Three areas were selected for sediment removal during 2008: (1) Northwest Marsh, (2) Worm Cove, and (3) Horse Island (**Figure 10-28**). Total project costs of \$1.4 million were funded through state appropriations, the FWC and the SFWMD for FY2008. An estimated 314 ac (127 ha) were scraped to remove an estimated 348,000 cubic yards (y³) (or 266,065 m³) of muck including materials with different characteristics and origins. Permanent disposal of the entire 2 million cubic yards of muck sediments removed from the lake in 2007 was also completed this year.

TILLING DEMONSTRATION PROJECT

The drought-related low water levels in Lake Okeechobee provided the opportunity to test new management practices within the lake to help sequester sediment nutrients, improve soil substrates, and to enhance desirable wetland vegetation. A demonstration project was conducted to determine whether soil tilling is a technically feasible and economically attractive approach for dealing with enriched organic materials (plants and/or sediments) that have accumulated across portions of the lake's littoral zone. Where present in excess, this organic layer provides an unwanted source of phosphorus upon reflooding and can inhibit germination of the native seed bank in the sand soils underneath. Conventional methods for removal of this organic layer involve scraping and hauling of the material to an approved disposal site. Tilling this material into the underlying soil offers a lower-cost option for treating these areas because no hauling or disposal of the material is required. Results from a previous demonstration of this process in STA-1W in 2007 indicated that this method could be effective at burying surficial high-phosphorus sediments and reducing internal phosphorus loading. Tilling effects on the wetland seed bank and the vegetation that establish in the treated area have not been previously considered.

The demonstration project was conducted in May 2008 on a 40-acre site located adjacent to Indian Prairie Canal in the northwest littoral zone (**Figure 10-28**). The site was divided into eight five-acre plots to allow for two replicate plots to be treated using each of four methods. Plots were mechanically tilled using two different plow types to either flip or disk the overlying muck layer into the underlying sand substrate to two different depths. The first tilling method employed a moldboard plow to bury the surface organic layer to depths of either 22.5 or 30 cm by flipping the soil. The second method used a Baker plow to mix the organic layer into the underlying sand to a depth of either 30 or 37.5 cm. Soil samples were collected from each plot just prior to and just following treatment in order to quantify the effects of each treatment on the resident seed bank and soil phosphorus concentration and flux rates. Conditions in the treated plots were compared to an adjacent untreated site (control) and a second adjacent site where the organic layer had been removed by scraping the previous year. Surface soils (0–2.5 cm depth) were collected from each plot, combined into a single sample, and then spread across sterile sand soil in plastic trays and maintained under saturated and flooded conditions for one month to determine the abundance and species composition of the seed bank. Soil cores were collected and separated into 0–15, 15–30, and 30–60 cm depth fractions and assayed for total and extractable phosphorus. Additional 30-cm cores were flooded and incubated for 28 days to measure phosphorus flux. These experiments were still under way at the time this report was written.

Dominant vegetation in each plot was determined just prior to treatment and again approximately one month afterwards. A final survey will be conducted after more normal lake levels have returned and the area has reflooded.

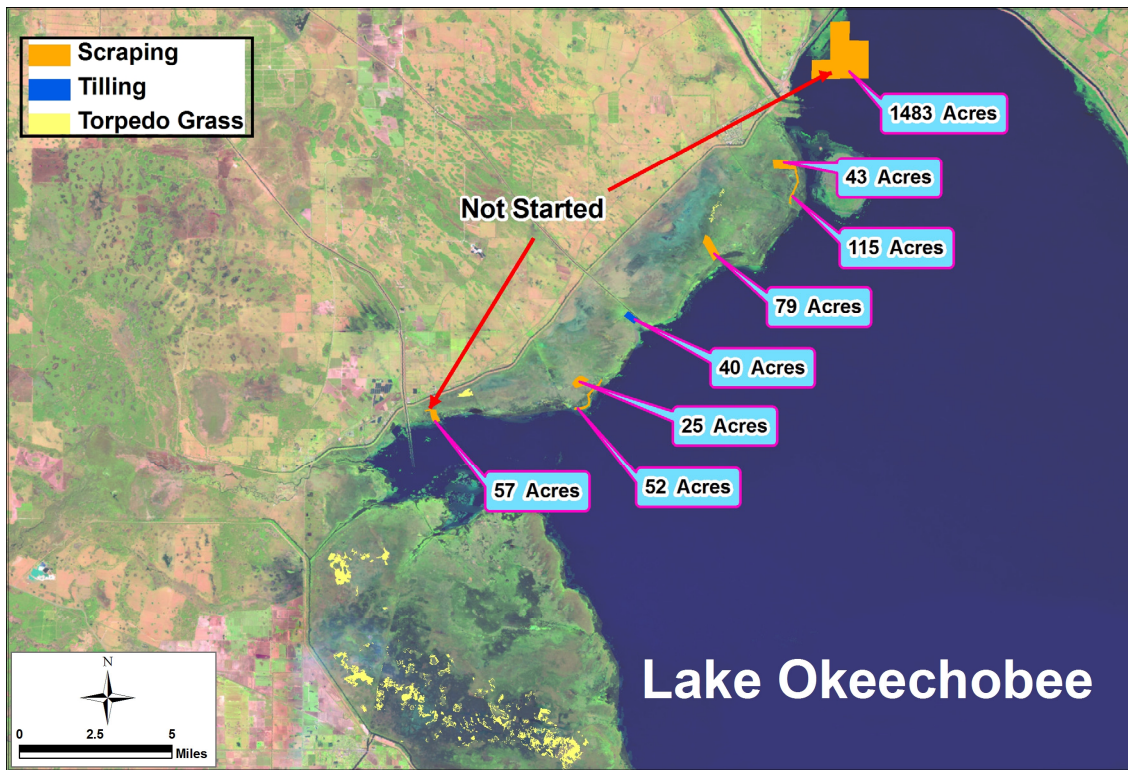


Figure 10-28. Location of muck scraping and tilling projects performed in Lake Okeechobee during CY2008.

CONCLUSIONS

Under NEEPP, a comprehensive array of state and federal projects has been undertaken within the watershed and in Lake Okeechobee to address the key issues of excessive phosphorus loading, harmful high water levels, and exotic plants. Considerable progress has been made to control the spread of exotic plants in the lake and projects have been implemented to reduce phosphorus transport from the watershed and capture runoff during high rainfall periods. The interim lake regulation schedule (LORS2008) focuses on public health and general welfare considerations associated with the safety of the Herbert Hoover Dike. Because of the complex nature and long history of problems associated with the lake, full implementation of NEEPP will require more than a decade, and improvements in lake water quality are expected to be slowed by internal nutrient recycling.

Ongoing watershed research and assessment has assisted in the development of implementation strategies for reducing watershed phosphorus loads. In particular, analysis of available information indicates that there is sufficient legacy phosphorus in the watershed to maintain elevated phosphorus loads to Lake Okeechobee for many years. Effective load-reduction strategies will need to consider methods for reducing the mobility of this legacy phosphorus in addition to controlling future inputs of phosphorus to the watershed.

As BMPs and other load-reduction strategies are applied, monitoring has shown improvement of water quality at some BMP implementation locations. Analysis of water-quality trends revealed a significant decreasing trend for mean monthly TP concentrations for dairy operations that had at least one or more TP load reduction projects incorporating BATs. These types of load reduction projects are the most comprehensive form of BMP implementation and involve intensive measures such as edge-of-farm stormwater chemical treatment and on-site water retention and reuse. Watershed monitoring efforts will continue to determine the long-term effectiveness of these and other load-reduction practices.

Ongoing research in the lake provides guidance for adaptive management of aquatic vegetation, water levels, and exotic plants. Conditions in Lake Okeechobee are strongly influenced by extreme weather events, as illustrated by environmental responses to recent hurricanes and droughts. Hydrologic variation is the rule rather than the exception in the lake's watershed, with a very wet period (WY2005–WY2006) quickly followed by extreme drought conditions (WY2007–WY2008). These hydrologic fluctuations affect the extent and abundance of aquatic vegetation and fish within the lake. The fluctuations also affect water-quality conditions in the lake and its watershed. Phosphorus loads were exceptionally high during 2005–2006 and extremely low during 2006–2007 as a result of large differences in tributary flows. Sediment resuspension caused by the 2004–2005 hurricanes continued to contribute to higher than normal in-lake TP and turbidity during the 2008 water year. These strong linkages between weather patterns and in-lake conditions complicate efforts to relate trends in lake water quality to watershed phosphorus management programs.

Despite an ongoing drought, monitoring results indicated that 2008 was the first year of significant post-hurricane recovery in the lake. Turbidity and TP levels in the nearshore region declined, resulting in an improved underwater light environment, the appearance of nascent vascular SAV beds, and a continued absence of severe algal blooms. A return to more normal lake stages should promote the recovery of emergent vegetation in the littoral zone as well. While much of the recovery from these weather events is expected to occur naturally, some intervention may be required to aid the recovery of certain drought-sensitive species such as the Florida apple snail.

APPROPRIATIONS/EXPENDITURES

The FY2001–FY2008 summary of state of Florida funding appropriations and expenditures for the Lake Okeechobee Protection Program is presented in **Table 10-20**. FY2008 values reflect preliminary financial information as of September 30, 2008. Final values are expected to be received in early 2009. There were no appropriations from the state in FY2004, and the FDACS received no state appropriations during FY2006.

Table 10-20. State funding appropriations and expenditures for the Lake Okeechobee Watershed Protection Program (FY2001–FY2008).

Note: FY2008 financial data is preliminary as of September 30, 2008.

Appropriation Year	SFWMD Appropriation	Expended to Date	Available
FY01 SFW11 (1519G)	8,500,000	8,500,000	0
FY01 SFW12 (1591G)	15,000,000	14,999,999	1
FY01 SFWMD Total	\$23,500,000	\$23,499,999	\$1
FY02 SFSWP1 (1748)	10,000,000	10,000,000	0
FY02 SFWMD Total	\$10,000,000	\$10,000,000	\$0
FY03 DEP TMDL Implementation Funds	850,000	811,860	38,140
FY03 SFW31 (1769) grant 42	7,500,000	7,410,425	89,575
FY03 SFWMD Total	\$8,350,000	\$8,222,285	\$127,715
FY05 SFW51 - Nubbin Slough	4,300,000	1,045,122	3,254,878
FY05 SFW61 grant 46	5,000,000	780,436	4,219,564
FY05 - DEP Nubbin Slough	3,300,000	0	3,300,000
FY05 - Hydromentia	1,800,000	1,800,000	0
FY05 SFWMD Total	\$14,400,000	\$3,625,558	\$10,774,442
Fast Track Projects - Reimbursable Expenditures	25,000,000	19,628,613	5,371,387
FY06 Sub Basin Monitoring Network	225,000	225,000	0
FY06 SFWMD Total	\$25,225,000	\$19,853,613	\$5,371,387
FY07 Hydromentia - Algae Turf Scrubber - FDEP	750,000	750,000	0
FY07 Hydromentia - Algae Turf Scrubber- FDACS	221,610	221,610	0
Fast Track Projects - Reimbursable Expenditures	24,925,000	24,925,000	0
Community Budget Issue Requests(CBIR) - Taylor Creek PL566 & Alternative Storage/Disposal of Excess Water	6,200,000	1,578,834	4,621,166
FY07 Cody's Cove & Eagle Bay Grant	2,478,548	2,478,548	0
Indiantown Citrus Growers Association	287,808	267,853	19,955
Raulerson & Sons Ranch Stormwater Reuse AWS	330,000	330,000	0
FY07 SFWMD Total	\$35,192,966	\$30,551,845	\$4,641,121
FY08 Sub Basin Monitoring Network	225,000	225,000	0
FY08 SFWMD Total	\$225,000	\$225,000	\$0
Grand Total - SFWMD State Appropriation - 221	\$116,892,966	\$95,978,299	\$20,914,667
FY01 FDACS Appropriation	15,000,000	15,000,000	0
FY05 FDACS Appropriation	5,000,000	5,000,000	0
FY05 FDEP Pahokee WWTP	700,000	700,000	0
FY07 FDACS Appropriation	24,628,051	24,628,051	0
FY08 FDACS Appropriation	3,000,000	1,491,000	1,509,000
Total Outside Agency State Appropriation	\$48,328,051	\$46,819,051	\$1,509,000
Save Our Everglades Trust Fund - Specific Appropriation 1741			
FY08 LOFT - Grant 59	43,100,000	0	43,100,000
FY08 NE Water Storage Disposal Projects - Grant 59	4,200,000	0	4,200,000
FY08 Technical Plan - Grant 59	1,700,000	844,326	855,674
FY08 Bio Wetland & Chem/Hybrid - Grant 62	3,000,000	3,000,000	0
FY08 Taylor Creek Alga Turf Scrubber Nutrient Recovery Facility (Hydromentia) -Grant 62 - 412000 Funds	300,000	150,000	150,000
FY08 Alga Turf Scrubber Mobile Pilot Unit and Design of a Full-Scale Alga Turf Scrubber System in the EAA - Grant 62 -412000 Funds	495,000	90,000	405,000
FY08 Powel Creek Alga Turf Scrubber	1,205,000	0	1,205,000
Total - Save Our Everglades Trust Fund - 412	\$54,000,000	\$4,084,326	\$49,915,674
Total - Lake Okeechobee	\$219,221,017	\$146,881,676	\$72,339,341

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