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

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## SUMMARY

Lake Okeechobee is the largest lake in the southeastern United States. The lake is shallow, turbid, eutrophic, and it is a central component of the hydrology and environment of South Florida. Lake Okeechobee supplies water for nearby towns, agriculture, and downstream ecosystems and provides flood control for the surrounding areas. The lake is home to migratory water fowl, wading birds, and the federally endangered Everglade Snail Kite (*Rostrhamus sociabilis*). It is also a multimillion-dollar recreational and commercial fishery. This chapter provides the Water Year 2006 (WY2006) (May 1,2005–April 30, 2006) 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 Lake Okeechobee Protection Program (LOPP) and the Lake Okeechobee and Estuary Recovery (LOER) Plan.

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. In addition, the lake was directly impacted by three hurricanes (Frances, Jeanne, and Wilma) and indirectly affected by two additional hurricanes (Charley and Ivan) in WY2005 and WY2006.

The impacts of hurricanes Frances and Jeanne, which struck the lake in September 2004, and hurricane Wilma, which struck in October 2005, include increased suspended solids, total and

soluble phosphorus, total and inorganic nitrogen, and significant reductions in water column transparency and submerged aquatic vegetation (SAV).

Excessive loads of phosphorus to the lake originate from agricultural and urban activities that dominate land use in the watershed. Total phosphorus (TP) loads were 714 metric tons per year (mt/yr) averaged over WY2002–WY2006. These loads are more than five times higher than the Total Maximum Daily Load (TMDL) of 140 mt/yr (five-year average) considered necessary to achieve the in-lake target of 40 parts per billion (ppb) of TP. The loads from WY2006 were 795 mt of TP, with 237 mt originating from the Kissimmee River. This amount is lower than the TP load in WY2005 (960 mt), which experienced strong impacts from hurricanes Charley, Frances, and Jeanne. However, the total flow to the lake was greater in WY2006 than WY2005. This is attributed to the wetter spring and summer season in WY2006 compared to WY2005, which offset the flows from the September 2004 hurricanes. The lower TP load in WY2006 is a consequence of lower TP inflow concentration.

To offset the large flow of water to Lake Okeechobee in WY2006 [3,721,648 acre-feet (ac-ft) or 459,058 hectare meters (ha-m)], over 3,905,991 ac-ft (481,796 ha-m) of water was discharged. A majority of this flow was released to the St. Lucie and Caloosahatchee rivers, 908,352 and 2,175,732 ac-ft (112,043 and 268,372 ha-m), respectively. This discharge included 824 mt of TP, with 250 mt and 362 mt being discharged to the St. Lucie and Caloosahatchee rivers, respectively.

Lake stage was at 14.85 ft [4.5 m, National Geodetic Vertical Datum (NGVD) 1929] on May 1, 2005, and increased to a height of 17.12 ft (5.2 m, NGVD) on November 8, 2005. The lake stage steadily declined to 13.55 ft on April 30, 2006. The high water levels and high suspended sediments early in WY2006 reduced light availability within the lake's nearshore and littoral zones, resulting in a significant decline of SAV from 54,900 acres (22,217 ha) in August 2004 (before the hurricanes) to 10,872 acres (4,400 ha) in August 2005. Monthly transect monitoring indicated that the SAV declined even further due to poor light conditions caused by high suspended-solids and water levels. The low water levels since May 2006 may allow light penetration to the lake bottom and possibly improve conditions for SAV coverage.

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 last decade. 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. As a result, the Florida legislature passed the Lake Okeechobee Protection Act (LOPA) (Section 373.4595, Florida Statutes) in 2000, mandating that the TMDL be met by 2015 and that the SFWMD, FDEP, and FDACS work together to implement an aggressive program to address the issues of excessive phosphorus loading and exotic species expansion.

In January 2004, the SFWMD, FDEP, and FDACS submitted the LOPP to the Florida legislature. The LOPA requires that the LOPP be reevaluated every three years to determine if further phosphorus load reductions are needed to achieve the TMDL. The reevaluation is in progress and due in January 2007. The LOPP contains a phased, watershed-based, comprehensive approach to reduce phosphorus loading to the lake. Because the legislature has provided substantial funding for the implementation of the LOPA since 2000, the cooperating agencies have been able to implement a large number of phosphorus reduction projects. These projects include phosphorus source control grant programs for agricultural landowners, Dairy Best Available Technology pilot projects, soil amendment projects, isolated wetland restoration, remediation of former dairies, and regional public/private partnerships. In addition, the LOPP contains elements of research and monitoring, as specified by the LOPA. A comprehensive monitoring program for water quality in the lake and watershed and ecological indicators in the lake has been implemented. The SFWMD conducts the monitoring program for water quality at the project and sub-basin levels in the watershed, which extends beyond the historical network of flow/load monitoring stations at basin outlet structures. Ongoing research and model applications continue to provide the predictive understanding necessary to evaluate the effectiveness of water management alternatives on phosphorus load reductions.

In addition to the LOPP, the SFWMD and USACE are implementing the Lake Okeechobee Watershed Project (LOWP), which is a part of the Comprehensive Everglades Restoration Plan (CERP). The LOWP will in part address phosphorus loads to the lake and also provide alternative storage locations so that water levels in the lake can be regulated for greater environmental benefits while still serving water supply and other water resource functions. The LOWP is intended to reduce the TP load approximately 60 mt/yr and store approximately 273,000 ac-ft (33,674 ha-m) of water. The load reduction will help to meet the restoration and TMDL goals for Lake Okeechobee. The offsite storage will help reduce high lake stage and reduce flood control discharges to the estuaries. The draft Lake Okeechobee Project Implementation Report for the LOWP is scheduled for completion in late 2007. Similar to the LOPP, both CERP and LOWP are adaptive programs; therefore, if responses are not occurring as expected, or if research and demonstration illuminate other applicable findings, the restoration programs can be modified to optimize their effectiveness.

In October 2005, the state announced the LOER Plan to help restore the ecological health of Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. The plan consists of a combination of capital projects and numerous interagency initiatives designed to provide measurable and meaningful improvements to water quality and quantity in Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. Key state agencies charged with carrying out the plan include SFWMD, FDEP, FDACS, and Florida Department of Community Affairs (FDCA).

Conditions in Lake Okeechobee are reported as five-year averages for consistency with the phosphorus TMDL and to reduce the variability that can be attributed to climate and hydrology. For WY2002–WY2006, the averages for TP, total nitrogen (TN), soluble reactive phosphorus (SRP), and dissolved inorganic nitrogen (DIN) are 158 ppb, 1.68 ppm, 48 ppb, and 287 ppb, respectively. The WY2006 averages for these nutrients are higher than these five-year averages, reflecting the impacts of hurricane events and constant sediment resuspension during the water year. The five-year lake TP concentration is over three times higher than the goal of 40 ppb that was used to establish the TMDL. The five-year average ratio of total nitrogen to total phosphorus (TN:TP) at 10.6, and dissolved inorganic nitrogen to soluble reactive phosphorus (DIN:SRP) at 6.0, favor dominance of blue-green algae that accounts for most of the algal biomass in the lake. The goal for water clarity in shoreline areas (100 percent light visibility to the lake bed from May to September) was attained approximately 25 percent of the time in the past five years, and the goal for algal bloom frequency (five percent of all samples exceeding 40 ppb of chlorophyll *a*) was exceeded in 14.9 percent of all samples taken in the past five years.

A Geographic Information Systems (GIS) map developed from aerial photography taken in 2003 shows a number of changes in the littoral landscape during WY2006: cattail coverage was 23,840 acres (9,648 ha), a reduction from 25,000 acres (10,117 ha) in 1996; torpedograss (*Panicum repens*) coverage increased from 13,000 acres (5,261 ha) in 1996 to more than 17,000 acres (6,880 ha); fragrant water lily (*Nymphaea odorata*) increased from 8,000 acres (3,237 ha) to nearly 11,000 acres (4,452 ha) over the same time period; and bulrush (*Scirpus californicus*) coverage was 168 acres (68 ha).

During WY2006, coordinated efforts continued for revising the regulation schedule for Lake Okeechobee to improve system-wide benefits. In addition to the lake, other areas considered include the estuaries, the Water Conservation Areas, water supply for the Lake Okeechobee Service Area and Lower East Coast Service Area, snail kite habitat, integrity of the Herbert

Hoover Dike that surrounds the lake, and navigation. In June 2006, the USACE identified a Tentatively Selected Plan that attempts to balance the performance measure criteria established for plan evaluation.

Aerial and ground treatments of exotic and invasive emergent vegetation continued in WY2006. Approximately 5,000 acres (2,023 ha) of torpedograss (*Panicum repens*) and 3,000 acres (1,214 ha) of cattail (*Typha* spp.) were treated in the Moore Haven and Indian Prairie regions of the marsh. This brings the total acres treated in Lake Okeechobee since 2000, to nearly 25,000 acres (10,117 ha) of torpedograss and 7,400 acres (2,995 ha) of cattail.

Planting efforts for pond apple (*Annona glabra*) and cypress (*Taxodium* spp.) also were initiated during WY2006 on the restored shoreline of Ritta Island in the southern end of Lake Okeechobee. Approximately 100 plants of the Okeechobee gourd (*Cucurbita okeechobeensis* ssp. *okeechobeensis*), an endangered species, were removed from the Hurricane Wilma debris piles and transported to adjacent spoil islands by the USACE and SFWMD. Although few transplants survived, the Okeechobee gourd was found to be thriving on spoil islands that were created by the Florida Fish and Wildlife Conservation Commission with materials derived from the removal of an organic berm along the northwestern marsh of the lake during the 2001 drought.

# INTRODUCTION

Lake Okeechobee (located at 27$^o$ N latitude and 81$^o$ 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 in excess of 427,500 acres (ac) (1,730 square kilometers [$km^2$]), and it 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 ($mi^2$) (14,000 $km^2$) watershed that includes the Upper Kissimmee Chain of Lakes, the Kissimmee River, Lake Istokpoga, Fisheating Creek, and other sub-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, as it provides water supply to urban areas, agriculture, and downstream 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 Everglade snail kite (Aumen, 1995). The lake also is used for flood control during the wet season. The lake faces three major environmental challenges: (1) excessive TP loads, (2) unnaturally high and low water levels, and (3) rapid spread of exotic and nuisance plants. In addition, the lake has been directly impacted by three hurricanes in WY2005 and WY2006 (Frances, Jeanne, and Wilma) that have affected water levels and water quality in the lake.

This chapter updates the discussion of lake and watershed conditions presented in Chapter 10 of the *2006 South Florida Environmental Report – Volume I* (2006 SFER – Volume I), focusing on water quality, water levels, and aquatic vegetation. Results of recently completed research projects are presented, as well as status on ongoing watershed and in-lake management projects. Project timelines, information about Fiscal Year 2006 (FY2006) (October 1, 2005—September 30, 2006) funding sources, and other aspects of project planning are also included. Information regarding exotic plant control programs, and associated research projects to optimize those programs, are presented in Chapter 9 of this volume.

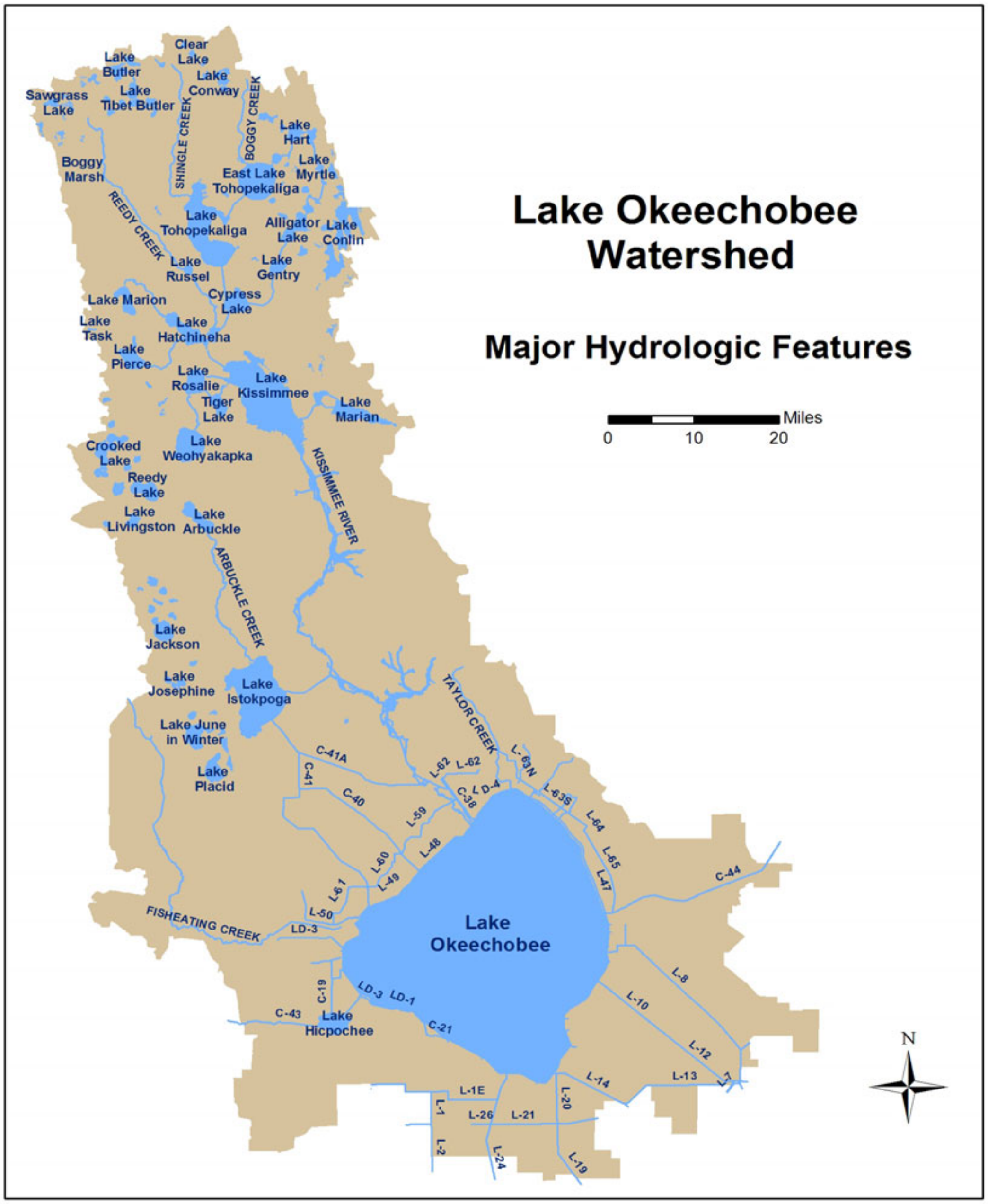


**Figure 10-1.** Major hydrologic features of the Lake Okeechobee watershed (L = levee, C = canal).

# OVERVIEW OF LAKE OKEECHOBEE PROGRAMS

## LAKE OKEECHOBEE PROTECTION PROGRAM

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 will be accomplished by achieving and maintaining compliance with water quality standards in the lake and its tributary waters. The approach is a watershed-based, phased, comprehensive, and innovative protection program designed to reduce phosphorus loads and implement long-term solutions based upon the Lake Okeechobee Total Maximum Daily Load (TMDL) of total phosphorus (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. FDEP (2001) defined atmospheric loading for the lake as follows:

> Wet deposition phosphorus loading rates average around 10 mgP/m$^2$/yr, while dry deposition phosphorus loading rates range from 10 mgP/m$^2$/yr to 20 mgP/m$^2$/yr (Pollman, 2000). Based on data presented by Curtis Pollman, the Lake Okeechobee Technical Advisory Committee (2000) recommended that 18 mgP/m$^2$/yr is an appropriate atmospheric loading of phosphorus over the open lake.

The 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.

Elements of the program include the (1) Lake Okeechobee Protection Plan (LOPP), (2) Lake Okeechobee Construction Project, (3) Watershed Phosphorus Control Program, (4) Research and Water Quality Monitoring Program, (5) Internal Phosphorus Management Program, (6) Exotic Species Control Plan, and (7) Annual Progress Report. The South Florida Water Management District (District or SFWMD), in cooperation with the FDEP and the Florida Department of Agriculture and Consumer Services (FDACS), developed the LOPP on January 1, 2004 (SFWMD et al., 2004). The protection plan is currently being reevaluated and is due to the Florida legislature on January 1, 2007.

The Watershed Phosphorus Control Program uses a multifaceted approach to reduce phosphorus loads through continued implementation of existing regulations and Best Management Practices (BMPs), development and implementation of edge of farm treatment systems, improvement and restoration of the hydrologic functions of the natural and managed systems, and use of alternative technologies for nutrient reduction. Alternative technologies for phosphorus reduction already implemented include chemical treatment at dairy outflows and an algal turf scrubber (ATS™) treating water from Taylor Creek. ATS™ is a proprietary technology that uses algae to remove excess nutrients (e.g. nitrogen, phosphorus) from water. The Lake Okeechobee Construction Project is being implemented in two phases: two pilot Stormwater Treatment Areas (STAs) in the Taylor Creek/Nubbin Slough (S-191) basin, and the Lake Okeechobee Watershed Project (LOWP) of the Comprehensive Everglades Restoration Plan (CERP) in the northern Lake Okeechobee basins.

## LAKE OKEECHOBEE AND ESTUARY RECOVERY PROGRAM

In October 2005, Governor Bush announced the Lake Okeechobee and Estuary Recovery (LOER) Plan to improve the ecological health of Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. The plan consists of a combination of capital projects and numerous interagency initiatives designed to provide measurable and meaningful improvements to water quality and water quantity in Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. Key state agencies charged with carrying out the plan include SFWMD, FDEP, FDACS, and Florida Department of Community Affairs (FDCA).

Initial funding has been provided for five LOER construction projects north of Lake Okeechobee identified as Lake Okeechobee Fast-Track (LOFT) projects (**Figure 10-2)**. These LOFT projects are specifically designed to provide water quality improvements and include a 500-ac [202-hectare (ha)] expansion of the Nubbin Slough Stormwater Treatment Area (STA), a 30,000 acre-feet (ac-ft) [3,701 hectares-meters (ha-m)] reservoir in association with the Taylor Creek STA, a 2,700-ac (1,093 ha) STA at Lakeside Ranch, and the re-routing of flows from the S-133 and S-154 basins to the Lakeside Ranch STA in the S-135 basin.

Additional components of the LOER Plan include revisions to the Lake Okeechobee Regulation Schedule, establishment of TMDLs for Lake Okeechobee tributaries, implementation of mandatory fertilizer BMPs, revisions to Environmental Resource Permitting (ERP) criteria for new development, evaluation of options for storage and/or disposal of excess surface water, implementation of growth management plans to encourage innovative land use planning, elimination of land application of residuals, and full implementation of the LOPP and LOWP. All LOER components are under way; once implemented, they are expected to improve water quality, expand water storage, facilitate land acquisition, and enhance lake and estuary health.

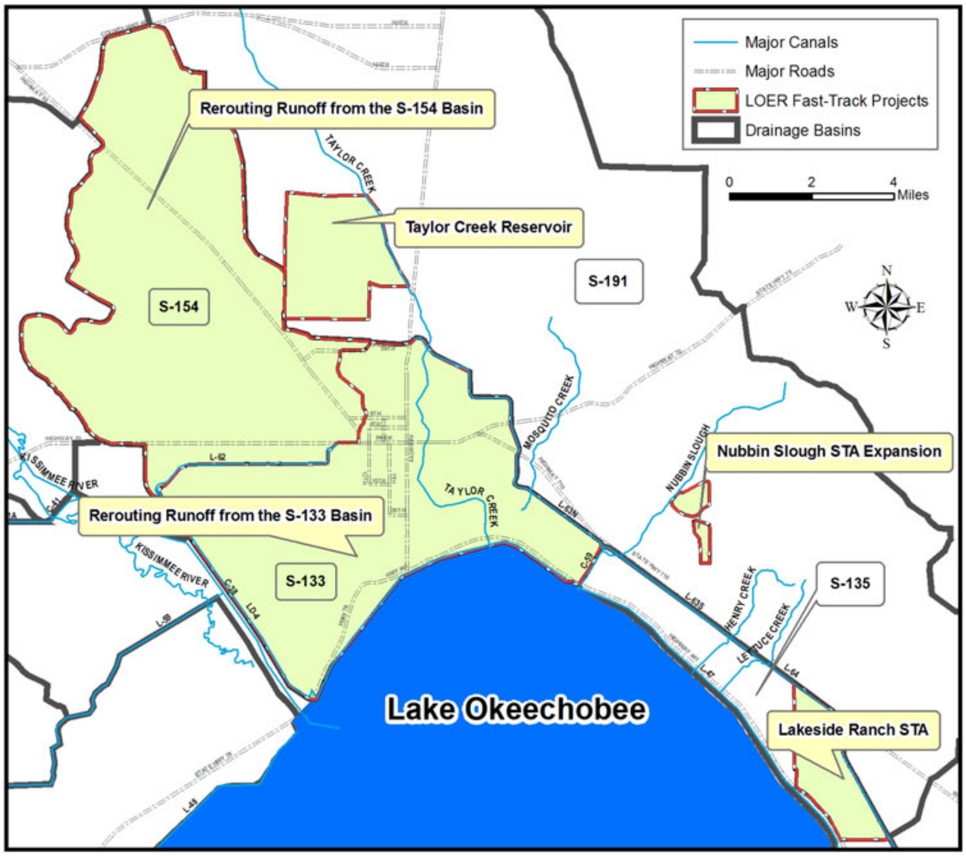


**Figure 10-2.** Lake Okeechobee Fast-Track (LOFT) projects under the Lake Okeechobee and Estuary Recovery (LOER) Plan.

# WATERSHED STATUS AND MANAGEMENT

## WATERSHED STATUS

The Lake Okeechobee watershed spans from just south of Orlando to areas bordering the lake on the south, east, and west. This watershed, known as the LOPP area, includes 61 drainage basins and six regions with a drainage area of 5,400 $mi^2$ [13,859 $km^2$] (**Figure 10-3**). The continuous urban and agricultural development in South Florida and consequent rapid land use changes in the watershed require periodic land use updates to support District planning and management activities. The most recent land use data were updated in May 2006 as part of the LOPP reevaluation and includes two major land use changes (SFWMD et al., in prep.) (**Figure 10-4**). The first is an increase of urban areas that have occurred throughout the watershed (**Table 10-1**). The second is in the Lake Istokpoga drainage basins, where many areas previously listed as “other” have been changed to the “citrus” category.

Nutrient levels in surface runoff are directly related to local land use and land management practices (Hiscock et al., 2003; Zhang et al., 2002). The major land use in the northern Lake Okeechobee basins is improved pasture for beef cattle grazing, while the major land uses in the Upper Kissimmee basins are natural areas and urban. The major land use in the southern basins is sugarcane production. Natural areas and citrus groves represent the majority of land use in the eastern basins and the Lake Istokpoga basins. Although dairy farms in the northern basins only cover one percent of the land use area, they represent a considerable source of phosphorus to some tributaries and up to 5 percent of the total external loading to the lake (Bottcher, 2006).

Surface water discharges and phosphorus loading rates from major tributary basins were calculated for WY2006 (**Table 10-2**). Data are based on continuous flow monitoring stations (**Figure 10-5**) and TP samples collected on a weekly basis. Among the major tributary basins, the largest surface water inflow comes from the Upper Kissimmee basins, followed by the S-65A through S65-E basins, Lake Istokpoga, Fisheating Creek, and Taylor Creek/Nubbin Slough. Discharge from the Upper Kissimmee Basin contributed the largest TP loads to Lake Okeechobee, followed by Taylor Creek/Nubbin Slough, C-41, Fisheating Creek, and Lake Istokpoga basins. The TP load to the lake in WY2006 from all tributary basins and atmospheric deposition was 795 mt. The five-year rolling average TP load from WY2002 through WY2006 was 714 mt, which is more than five times higher than the 140 mt/yr TMDL for TP.

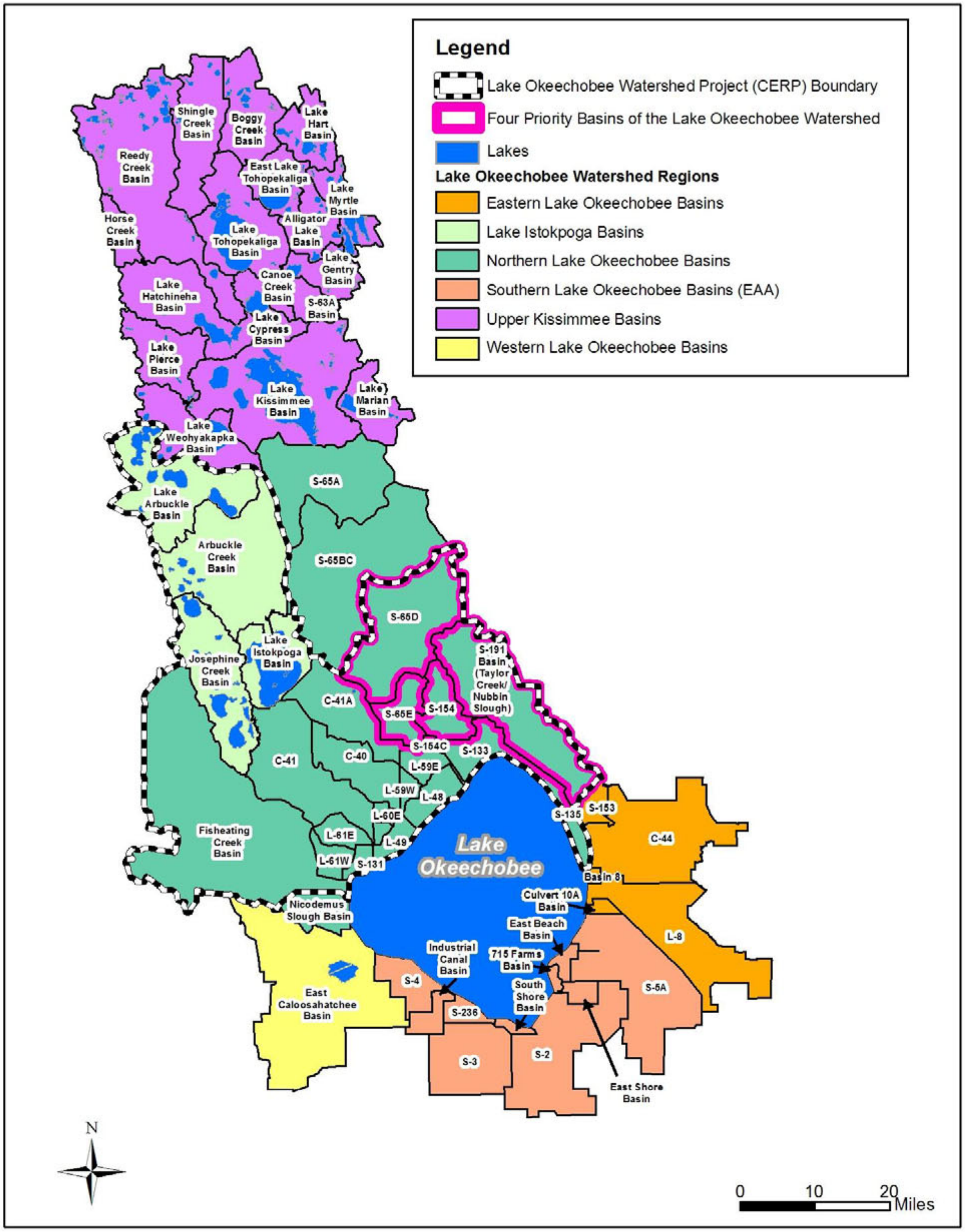


**Figure 10-3.** Lake Okeechobee watershed basins, regions, and priority basins (WY2006).

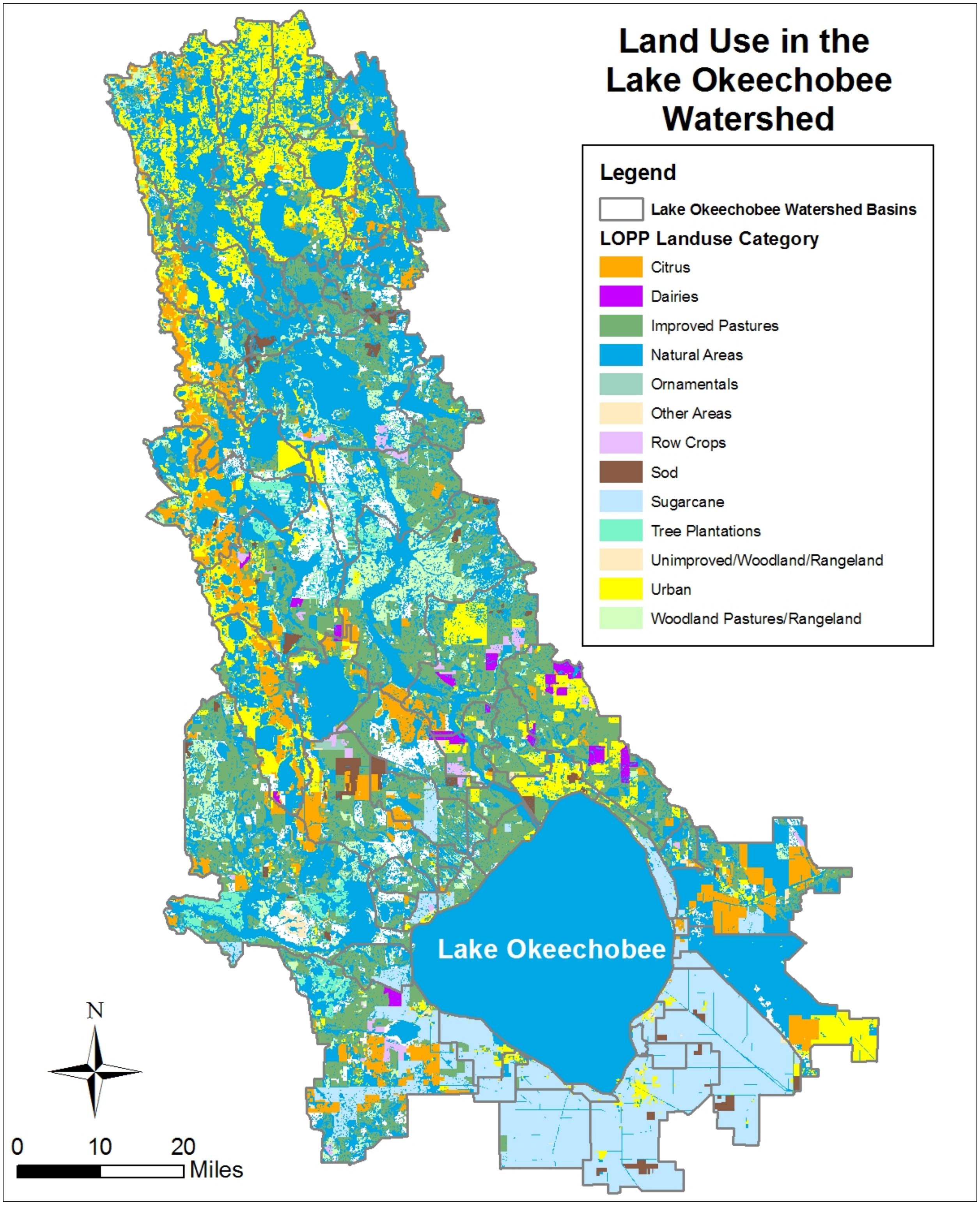


**Figure 10-4.** Land use map for the Lake Okeechobee watershed (WY2006).

**Table 10-1.** Land use data for the Lake Okeechobee Protection Plan (LOPP) area.

| Land Use | Area (acre) | | Change |
|---|---|---|---|
| | 2006 | 2003 | |
| Citrus | 234,629 | 209,961 | 12% |
| Dairies | 22,432 | 28,121 | -20% |
| Improved Pastures | 674,356 | 693,480 | -3% |
| Natural Areas | 1,282,267 | 1,308,438 | -2% |
| Ornamentals | 4,687 | 4,687 | 0% |
| Other Areas | 27,567 | 95,994 | -73% |
| Row Crops | 23,157 | 22,881 | 1% |
| Sod | 39,081 | 32,867 | 19% |
| Sugarcane | 399,710 | 400,318 | 0% |
| Tree Plantations | 49,687 | 52,001 | -4% |
| Unimproved Pastures/Rangeland | 324,630 | 339,967 | -5% |
| Urban | 368,884 | 262,371 | 41% |
| **LOPP Total Acreage** | **3,451,086** | **3,451,086** | -- |

Note: Ornamentals were included in "Other Areas" in 2003.

**Table 10-2.** WY2006 Surface water inflows and total TP concentrations and loading rates for the major tributary basins 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) | 56 | 7 | 3,302 | 88 | 0.0 |
| C-40 Basin (S-72) – S68 | 11,613 | 1,433 | 43,964 | 1,062 | 15.2 |
| C-41 Basin (S-71) – S68 | 69,363 | 8,556 | 94,654 | 864 | 73.9 |
| S-84 Basin (C-41A) – S68 | 85,267 | 10,518 | 58,487 | 316 | 33.2 |
| S-308C (St. Lucie – C-44) | 14,493 | 1,788 | 129,429 | 293 | 5.2 |
| East Beach DD (Culv 10) | 230 | 28 | 6,624 | 114 | 0.0 |
| East Shore DD (Culv 12) | 3,486 | 430 | 8,416 | 155 | 0.7 |
| Fisheating Creek | 305,442 | 37,677 | 289,366 | 180 | 67.9 |
| Industrial Canal | 17,126 | 2,113 | 13,024 | 152 | 3.2 |
| L-48 Basin (S-127 total) | 29,984 | 3,699 | 20,774 | 192 | 7.1 |
| L-49 Basin (S-129 total) | 23,960 | 2,956 | 12,093 | 72 | 2.1 |
| L-59E | 39,058 | 4,818 | 14,409 | 245 | 11.8 |
| L-59W | 39,535 | 4,877 | 6,440 | 314 | 15.3 |
| L-60E | 25,029 | 3,087 | 5,038 | 211 | 6.5 |
| L-60W | 5,486 | 677 | 3,271 | 135 | 0.9 |
| L-61E | 7,011 | 865 | 14,286 | 0 | 0.0 |
| L-61W | 10,669 | 1,316 | 13,567 | 0 | 0.0 |
| Taylor Creek/Nubbin Slough (S-191) | 187,793 | 23,165 | 120,754 | 618 | 143.2 |
| S-131 Basin | 25,556 | 3,152 | 7,164 | 138 | 4.3 |
| S-133 Basin | 46,253 | 5,705 | 25,660 | 313 | 17.8 |
| S-135 Basin (S-135 total) | 42,392 | 5,229 | 18,088 | 167 | 8.7 |
| S-154 Basin | 49,214 | 6,071 | 33,798 | 595 | 36.1 |
| S-2 | 10,335 | 1,275 | 106,371 | 181 | 2.3 |
| S-3 | 1,988 | 245 | 62,946 | 231 | 0.6 |
| S-4 | 22,238 | 2,743 | 26,389 | 218 | 6.0 |
| S65 A through E Basins | 637,563 | 78,645 | 429,283 | 32 | 25.1 |
| South FL Conservancy DD (S-236) | 13,106 | 1,617 | 11,028 | 126 | 2.0 |
| South Shore/South Bay DD (Culv 4A) | 413 | 51 | 4,134 | Not Available | 0.0 |
| Nicodemus Slough (Culv 5) | 3,344 | 412 | 25,641 | Not Available | 0.0 |
| Upper Kissimmee basins at S-65 | 1,474,473 | 181,880 | 1,021,674 | 117 | 211.9 |
| Lake Istokpoga (S-68) | 527,974 | 65,127 | 392,147 | 87 | 56.7 |
| S-5A Basin (S-352 WPB Canal) | 0 | 0 | 119,475 | 0 | 0.0 |
| East Caloosahatchee (S-77) | 0 | 0 | 200,993 | 0 | 0.0 |
| L-8 Basin (Culv 10A) | 12,093 | 1,492 | 108,402 | 154 | 2.3 |
| Rainfall | | | | | 35.0 |
| **Totals** | **3,742,543** | **461,652** | **3,451,087** | **172** | **795.4** |

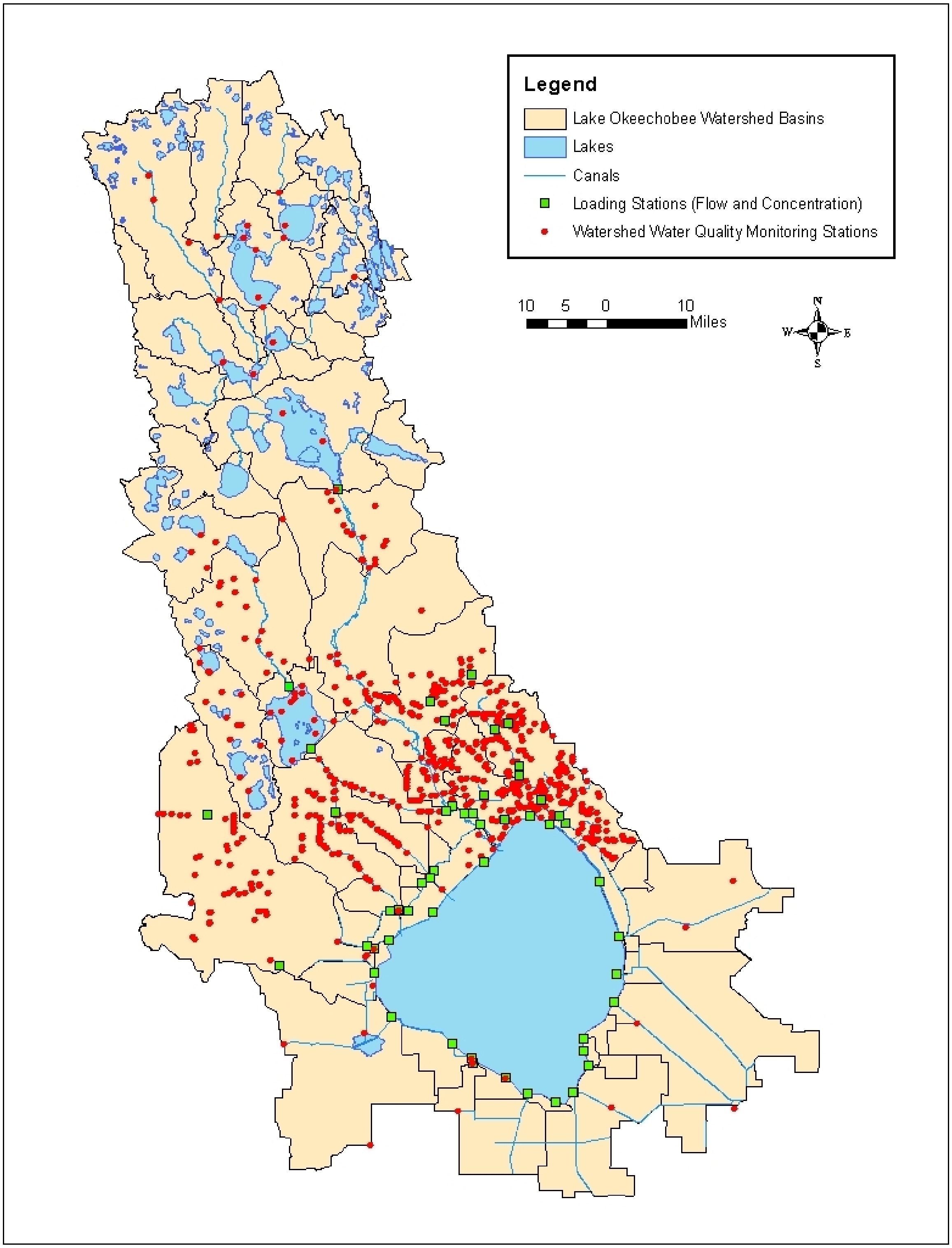


**Figure 10-5.** Locations of WY2006 sampling stations where TP loads were determined from tributary basins that drain into Lake Okeechobee (green squares). Other watershed water quality sampling stations also are shown (red dots).

## WATERSHED PHOSPHORUS CONTROL PROGRAMS

The Lake Okeechobee Watershed Phosphorus Control Program 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 the programs and coordinate with existing regulatory programs, including 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 the LOPA (Section 373.4595, F.S.), the FDACS is charged with implementing a voluntary BMP program (Rule 5M-3) on all agricultural lands within the Lake Okeechobee watershed. In general, farmers are eligible to receive between 75 percent and 87.5 percent cost share, either through the FDACS or a combination of the FDACS and the 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 phosphorus reduction projects and large-scale regional projects, research and monitoring, existing regulations, and exotic plant control.

### FDACS Agricultural Programs

Considerable efforts have been made since 2002 on the implementation of agricultural BMPs and water-quality improvement projects to immediately reduce the discharge of phosphorus from the watersheds to the lake. The FDACS BMP program consisted of two phases. The first was implementation of interim BMPs based on assessments contained in existing cow/calf and citrus water-quality BMP manuals. The second involved development of more detailed conservation and nutrient management plans. Based on current information, it is more efficient to proceed to the conservation and nutrient management planning stage; therefore, the interim assessments are no longer being performed.

The FDACS and NRCS have executed an interagency Memorandum of Agreement (MOA) that commits the available resources within the two agencies to expedite delivery and implementation of nutrient and conservation management planning to agricultural landowners in the watershed. To accelerate the development of conservation plans, the FDACS contracted with the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), in conjunction with NRCS, to provide training for third-parties that wish to participate in the development of nutrient management and/or conservation plans. The FDACS and NRCS have also executed an agreement to expedite the development, engineering/design, and implementation of Comprehensive Nutrient Management Plans (CNMP) on all of the Concentrated Animal Feeding Operations (such as dairies and chicken production facilities) within the Lake Okeechobee watershed.

Cow/calf production is the largest agricultural land use in the Lake Okeechobee watershed, and it is anticipated that the implementation of BMPs identified in conservation plans will substantially improve water quality in the watershed. Conservation plans developed by the NRCS have been completed on 80,089 ac (32,410 ha). In a cooperative effort, the FDACS and the NRCS have obtained, to date, a federal appropriation of $950,000 to expedite conservation planning in the Lake Okeechobee watershed. The funds have been used to identify and train technical service providers and conservation planners who are willing to work in the Lake Okeechobee watershed to develop conservation plans for cow/calf, citrus, row crop, and other agricultural operations. This creative endeavor has resulted in an additional 166,911 ac (67,545 ha) of conservation plans in various stages of development.

The Agricultural Nutrient Management Plans (AgNMPs) for all active dairies in the four priority basins (S-191, S-154, S-65D, and S-65E) were completed in 2002, representing over 31,000 ac (12,545 ha). The two goals of the AgNMPs were whole-farm nutrient balance and an edge-of-farm phosphorus discharge concentration of 150 ppb. While the dairies shared common phosphorus sources, each also had unique circumstances. The AgNMPs indicated that it would cost a total of $140 million to achieve both of these goals for all dairies in the watershed. The interagency team directed funds to be expended on the surface water management component aimed at lowering phosphorus at the edge-of-farm discharge point. The planning, engineering, and design for the initial four dairies will be completed by June 2007. A total of 22 dairies are expected to participate in the program. All projects are expected to be completed by FY2010. The AgNMPs will get the majority of dairies to the 150 ppb target, but some may need chemical treatment.

Collectively, the CNMPs, AgNMPs, and conservation planning activities cover 278,000 ac (112,500 ha) in the watershed. An additional 634,000 ac (256,564 ha) of agriculture operations in the watershed also have been agreed upon for participation either in the BMP process or in the development of a whole farm treatment project based on modeling. One of the challenges to implement this program is attrition of participation due to the pressure from development and purchases of land for other uses. Approximately 13,046 ac (5,280 ha) of land that either had or were developing BMP plans have dropped the effort due to land sales in the past year alone.

The TP loading reduction to Lake Okeechobee from typical BMPs implemented/planned through June 30, 2007, is 18.5 mt (**Table 10-3)**. This reduction reflects special BMP projects (**Figure 10-6**) in the FDACS' typical cost-share BMP program and does not include the phosphorus load reduction from either owner-implemented or typical cost-share BMPs implemented on cow/calf operations throughout the watershed.

The FDACS has completed adoption of an amendment to administrative Rule 5M-3 that expands the effective area of the rule from the four priority basins to include the entire Lake Okeechobee watershed. The rule adopts BMP manuals for citrus producers and cow/calf operations, conservation plans for vegetable and row crop producers, and AgNMPs for dairy operations, and discusses the process for implementing these BMPs. Through this rule, the implementation of appropriate BMPs — accompanied with the submission of a Notice of Intent to implement a BMP plan — provides the landowner with a presumption of compliance with Florida water-quality criteria. Landowners who choose not to participate in the FDACS BMP program will be required to monitor the quality of water leaving their properties through the LOWOD (Chapter 40E-61, F.A.C.) permitting program and to demonstrate compliance with existing and future phosphorus targets and requirements set forth in the Surface Water Improvement and Management (SWIM) plan or an established tributary TMDL.

**Table 10-3.** TP load reduction projects that implemented/planned by Florida Department of Agriculture and Consumer Services (FDACS) under typical cost-share Best Management Practice (BMP) program.

| Basin | Project Category | Project Site | Annual Phosphorus Reduction to the Lake (mt) | Completion Date |
|---|---|---|---|---|
| S-154 | Dairy Hurricane Upgrade | Milking R | 0.63 | 7-31-06 |
| S-191 | Dairy Composting Project | McArthur 1 and 3 | 2.74 | 12-31-06 |
| | Dairy Hurricane Upgrade | Larson 5 | 0.93 | 12-31-05 |
| | Dairy Hurricane Upgrade | McArthur 1 and 3 | 0.40 | 12-31-05 |
| | Dairy Stormwater Management System | Larson 5 and 6 | 1.58 | 6-30-07 |
| | Dairy Stormwater Management System | Larson 7 and 8 | 1.84 | 6-30-07 |
| | Florida Ranchlands Environmental Services Project | Williamson Cattle Company | 0.09 | 10-01-06 |
| S-65D and S-65E | Tailwater Recovery Project | Joe Hall | 0.36 | 5-01-06 |
| | Dairy Composting Project | Butler Oaks | 1.91 | 5-01-06 |
| | Dairy Hurricane Upgrade | Butler Oaks | 0.28 | 2-28-06 |
| | Dairy Stormwater Management System | B-4 | 3.08 | 6-30-07 |
| | Dairy Stormwater Management System | Butler Oaks | 4.45 | 6-30-07 |
| C-41A | Citrus Variable Rate Fertilizer Technology | Lykes Brothers | 0.20 | 12-30-05 |
| Arbuckle Creek | Dairy Hurricane Upgrade project | Wabasso Dairy | TBD | 02-30-06 |
| Josephine Creek | Dairy CNMP Implementation | Sumerset Dairy | TBD | 6-30-07 |
| **Total** | | | **18.49** | |

TBD To Be Determined

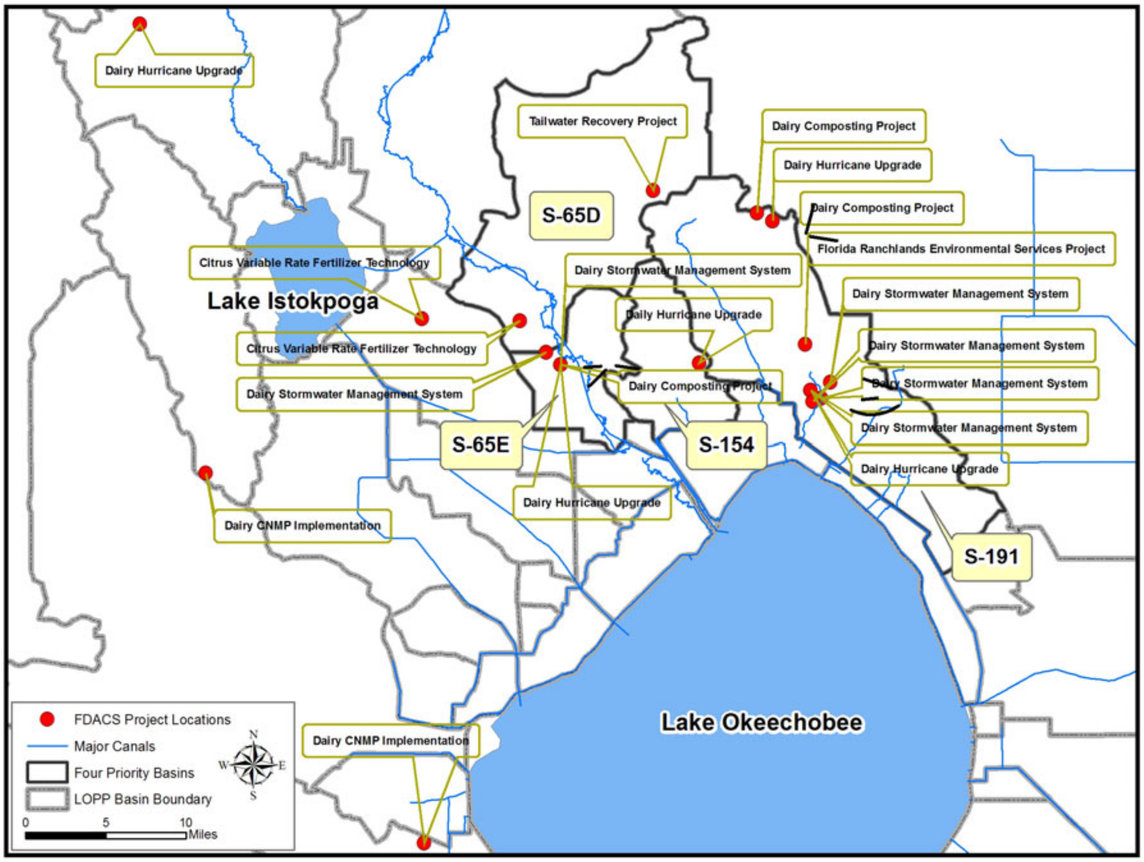


**Figure 10-6.** FDACS special project locations under cost-share BMP programs.

## FDEP Non-Agricultural Programs

A phased approach is used to reduce phosphorus loadings to Lake Okeechobee from non-agricultural areas in the Lake Okeechobee watershed. The largest contributors of phosphorus loading from non-agricultural areas to Lake Okeechobee are animal feed and fertilizer distributors, golf courses, and failing wastewater systems (septic tanks and package plants). Efforts since the inception of the LOPA include implementation of BMPs, master planning for stormwater and wastewater, implementation of stormwater retrofits, the designing of larger urban stormwater projects, and public education.

Interim measures in the first phase include BMPs identified in the Florida Land Development Manual, UF/IFAS lawn fertilization rates, and UF/IFAS turfgrass BMPs. These nonstructural BMPs primarily target homeowners and businesses. UF/IFAS extension agents are working with homeowners, as well as lawn maintenance companies, on better lawn management. The implementation of these BMPs follows a non-regulatory incentive-based approach.

The next phase is to develop more detailed plans for addressing phosphorus loading to Lake Okeechobee from stormwater and wastewater sources in the watershed's urbanized areas. Stormwater master plans have been developed for two of the urban areas surrounding Lake Okeechobee – the City of Okeechobee/Okeechobee County and the City of Moore Haven/Glades County. The SFWMD's Okeechobee Service Center is working cooperatively with Okeechobee

County to expand the plans. Stormwater master plans are being developed for other urban areas within the Lake Okeechobee watershed. Because a majority of the urban areas were developed prior to the adoption of state stormwater regulations, the existing infrastructure is typically inadequate to properly deal with stormwater. Stormwater retrofits, such as detention/retention facilities and swales, are needed to improve the water quality of urban stormwater runoff.

Public education offers a means to promote measures for reducing phosphorus entering stormwater in the urbanized areas. The UF/IFAS, through the Florida Yards and Neighborhoods Program, provides weekly articles in the 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 BMPs when applying such chemicals. This brochure is available at retail stores in the city of Okeechobee where fertilizers are sold. UF/IFAS monitors the number of people requesting assistance information regarding this program.

Under the LOER initiative announced by Governor Bush in 2005, agencies are working with the fertilizer industry to produce and distribute low- or no-phosphorus fertilizers state-wide. Additionally, the SFWMD and FDEP will be working with the municipalities to implement appropriate lawn fertilization BMPs. This initiative is planed for completion in 2008.

## SFWMD Phosphorus Control Programs

An extensive effort was expended in WY2006 on BMP implementation in the LOPP area to reduce phosphorus loads to the lake. The SFWMD, in coordination with the FDACS and FDEP, has developed and implemented more that 30 phosphorus reduction projects (**Figure 10-7**). These projects have been implemented under programs such as the Phosphorus Source Control Grants, Isolated Wetland Restoration, Dairy Best Available Technologies (BATs), Public/Private Partnerships, and Former Dairy Remediation (**Table 10-4**). TP load reduction from these phosphorus reduction projects is estimated at 30.6 mt of the load reductions necessary to meet the lake's TMDL. All of 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 (PSCG) program is to fund the early implementation of projects that have the potential for reducing phosphorus exports to Lake Okeechobee from the watershed. The program consists of 13 projects (**Table 10-4**) with a total cost of $7.5 million. An interagency team evaluated the projects and ranked them using established evaluation criteria. The funded projects range in size and complexity, and grant recipients consist of landowners, public facilities, and private corporations.

All PSCG projects were to be implemented by September 30, 2004, with an operational life of 10 years or more. As of June 2006, four projects were completed, seven are operational and being monitored, one constructed but not yet operational (Candler Ranch, iron humate filter), and one (Solid Waste Authority, biosolids pelletization) was under construction. Of the 13 PSCG projects, 11 are agricultural and include isolated wetland restoration, stormwater retention areas, chemical treatment of runoff, concrete cooling ponds for dairy cows, and composting of chicken manure. One urban PSCG project, to replace septic and package wastewater treatment systems with a gravity sewer system in Okeechobee, was completed in WY2005.

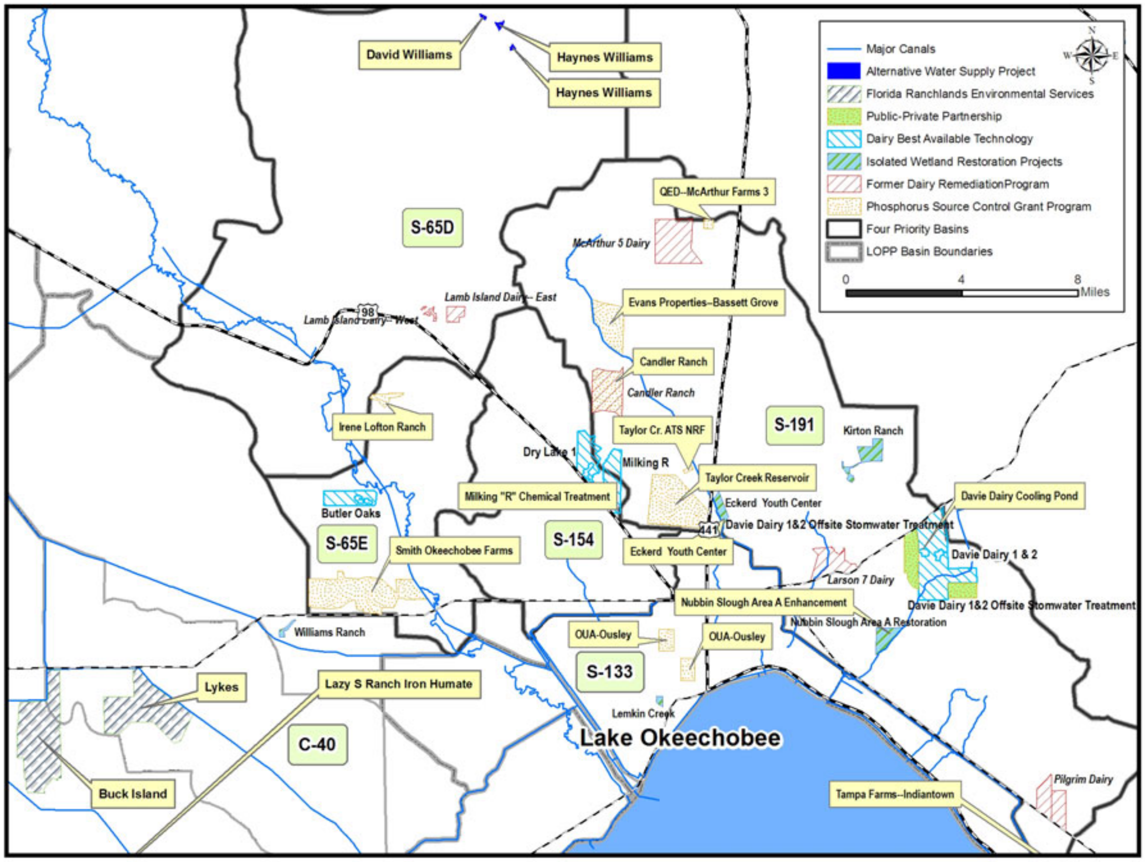


**Figure 10-7.** SFWMD project locations under Lake Okeechobee watershed phosphorus control programs.

### *DAIRY BEST AVAILABLE TECHNOLOGIES*

In October 2000, the District initiated the Dairy Best Available Technologies (BATs) 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 10-4**). These projects consist of capturing stormwater runoff (especially from all of the high-nutrient pasture areas), reusing the runoff on site in current operations if possible, and if offsite discharge is necessary, chemically treating the stormwater prior to its release. The three Dairy BATs projects are fully constructed, and performance monitoring was initiated in May 2004. TP load monitoring is a component of the project so that performance can be accurately determined. Project performance is being evaluated at various TP discharge concentration goals ranging from 150 ppb to 40 ppb. Annual TP load reductions could range from 27 to 78 percent. The FDEP provided funds from the 2002–2003 state general revenue funds designated for TMDL implementation projects to be used for the design and implementation of a fourth BAT site, the Milking "R" Dairy. This fourth site was completed in December 2005 and is in the performance monitoring phase.

**Table 10-4.** SFWMD TP load reduction projects that implemented/planned under the Watershed Phosphorus Control Program.

| Basin | Project Category | Project Site | Annual P Reduction to Lake (mt) | Status |
|---|---|---|---|---|
| S-154 | P Source Control Grant Program | Tampa Farms – Indiantown | 1.11 | Complete |
| | | Milking "R" Chemical Treatment | 0.00 | Became part of Dairy BAT |
| | Dairy Best Available Technology (BAT) | Dry Lake 1 | 1.48 | Complete |
| | | Milking R | 0.69 | Complete |
| S-191 | P Source Control Grant Program | QED – McArthur Farms 3 | 6.02 | Ongoing |
| | | Candler Ranch | 0.00 | Non-Operational |
| | | Davie-Dairy Cooling Pond | 0.39 | Ongoing |
| | | Evans Properties – Bassett Grove | 0.13 | Complete |
| | | Tampa Farms – Indiantown | 2.15 | Ongoing |
| | | Solid Waste Authority | 1.16 | In Design |
| | | Taylor Creek ATS NRF | 1.81 | Dec-06 |
| | Dairy BAT | Davie Dairy 1 and 2 | 0.68 | Complete |
| | Isolated Wetland Restoration Project | Kirton Ranch | 0.81 | Complete |
| | | Nubbin Slough Area A Restoration | TBD | Ongoing |
| | | Eckerd Youth Center | 0.40 | Apr-07 |
| | Former Dairy Remediation | Mattson | 0.54 | Complete |
| | | McAuthur 5 | 0.30 | Complete |
| | | Candler | 0.03 | Complete |
| | | Larson Dairy 7 | 0.29 | Jul-07 |
| | | Pilgrim | 0.29 | Jul-07 |
| | Public-Private Partnership | Davie Dairy 1 and 2 offsite stormwater treatment | 0.54 | Complete |
| S-133 | P Source Control Grant Program | OUA-Ousley | 0.22 | Complete |
| | Isolated Wetland Restoration Project | Lemkin Creek | 0.12 | Ongoing |
| S-65D and S-65E | P Source Control Grant | Tampa Farms-Indiantown | 3.26 | Ongoing |
| | | Smith Okeechobee Farms | 0.59 | Ongoing |
| | | Lofton Ranch | 0.04 | Ongoing |
| | | Solid Waste Authority | 1.16 | In Design |
| | Dairy BAT | Butler Oaks | 3.41 | Complete |
| | Former Dairy Remediation | Lamb Island Dairy – East | 1.85 | Complete |
| | | Lamb Island Dairy – West | 0.11 | Complete |
| | Alternative Water Supply Project * | Haynes Williams | 0.16 | Complete |
| | | David Williams | 0.16 | Complete |
| C-40 | Florida Ranchlands Environmental Services Project | Lykes Brothers | 0.20 | Complete |
| C-41 | Florida Ranchlands Environmental Services Project * | Buck Island Ranch | 0.37 | Complete |
| Fisheating Creek | P Source Control Grant Program | Lazy S Ranch Iron Humate | 0.11 | Ongoing |
| **Total for Watershed P Control Programs** | | | **30.58** | |

* Cost-share with FDACS
TBD To Be Determined

### ISOLATED WETLAND RESTORATION

The Lake Okeechobee Isolated Wetland Restoration Program (LOIWRP) is designed to enhance and restore wetlands, reduce phosphorus 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 multiagency 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, completed in March 2004; (2) Lemkin Creek, a state-owned property in the design phase; (3) Eckerd Youth Center, a state-owned property in planning phase; and (4) Nubbin Slough Area A restoration (**Table 10-4**). The TP load reductions from the first three projects are estimated as 1.33 mt.

### FORMER DAIRY REMEDIATION

The Lamb Island Dairy Remediation Project has been constructed and performance monitoring was conducted from November 2004 through November 2005. The annual TP load reduction for the property was estimated to be 1.96 mt due to the site improvements implemented.

Five former dairy remediation projects are in various stages of implementation for the privately owned former dairies that are now cow/calf operations. Planned remediation practices include retaining runoff from old high intensity areas, rehydrating onsite wetlands, amending high-phosphorus soils, and reducing the flow of storm water offsite. Design and construction were completed on three farms, and the construction for the remaining two will be completed by July 2007. Water-quality monitoring for phosphorus concentration reductions during flow events will be conducted for one year following construction completion.

### REGIONAL PROJECTS/PUBLIC-PRIVATE PARTNERSHIP PROGRAM

Davie Dairy is the participant in the Public-Private Partnership Program; the load reduction from the pilot program is shown in **Table 10-4**.

### ALTERNATE WATER STORAGE AND TREATMENT

In October 2005, the District, in cooperation with Alderman-DeLoney Ranch, Buck Island Ranch (McArthur Agro-Ecology Research Center), Lykes Bros. Inc., Williamson Cattle Company, World Wildlife Fund, NRCS, FDACS, and FDEP, started a three-year pilot project titled “Florida Ranchlands Environmental Services” under the LOER program. The purpose of the pilot project is to design, field test and evaluate a market-based program to pay for environmental services on ranchlands, specifically water storage, phosphorus retention, and wetland habitat enhancement. This will result in environmental benefits for South Florida and greater Everglades ecosystem. The goal of the program is to produce measurable benefits to the environment, be profitable for ranchers, cost-effective for tax payers, easily administered, and replicable in other regions and watersheds. Additional project sites are being considered utilizing

State funds. The phosphorus reduction total from these additional project sites is under investigation.

### *OTHER REGIONAL PROJECTS*

Through a coordinated effort by the FDEP, Okeechobee County, and the District, the Lemkin Creek urban STA project is designed to treat urban stormwater runoff from southwest Okeechobee County and reduce phosphorus loading to the lake. Phase I of the project includes water storage and wetland re-hydration. Phase II consists of land acquisition for approximately 330 ac of agricultural lands. It is expected that approximately 50 percent of the urban runoff from the city of Okeechobee would be captured and treated by the STA.

The expansion of the Nubbin Slough STA will provide an additional 500 ac of STA that will be coordinated with the 809 ac of Critical Project STA currently under construction by the USACE. The expansion design is complete, and release of the project for bid is pending state and federal permits. The LOER fast track projects include a 30,000 ac-ft (3,701 ha-m) reservoir in association with the Taylor Creek STA, a 2,700-acre (1,093 hectare) STA at Lakeside Ranch, and the re-routing of flows from the S-133 and S-154 basins to the Lakeside Ranch STA in the S-135 basin.

The Brighton Seminole Reservation reservoir is another regional project. The main objective of project is to design and construct a shallow reservoir for storing and treating excess water in the Indian Prairie Basin. In WY2006, the project was in the planning and design phase.

## Regulatory

While amendments to the LOWOD permitting program (Chapter 40E-61, F.A.C.) remain under review with SFWMD staff, the program is being administered to support voluntary BMP implementation throughout the watershed. The District evaluates permit applications from those operations that are not participating in a BMP program and new urban developments within the watershed. In addition, revisions are being proposed through the ERP criteria that deal specifically with land use changes occurring throughout the Lake Okeechobee watershed. The LOPA requires that “prior to authorizing a discharge into Works of the District, the District shall require responsible parties to demonstrate that proposed changes in land use will not result in increased phosphorus loading over that of existing land uses.” These revisions target a zero net increase in phosphorus loads to the watershed through land use changes and require the implementation of BMPs and stormwater management systems for further reductions in phosphorus loads in new developments.

The U.S. Environmental Protection Agency (USEPA) and FDEP are accelerating the development of TMDLs for tributaries in the Lake Okeechobee watershed. Tributary TMDLs will support both the proposed LOWOD amendments and the revisions to the ERP criteria proposed in LOER. The USEPA Region 4 proposed TMDLs for the Lake Okeechobee tributaries in September 2006. The effort is currently under review and is expected to be completed in 2007.

## LAKE OKEECHOBEE CONSTRUCTION PROJECT

The Lake Okeechobee Construction Project is being implemented in two phases. Phase I projects in the four priority basins include two pilot STAs, a stormwater detention pond as part of the Lake Okeechobee Critical Projects (a joint program between the SFWMD and USACE), a sediment removal pilot project, and design work on a large-scale STA in the S-191 basin. Phase II, known as the CERP LOWP, is to provide approximately 60 mt of TP load reduction needed to meet the TMDL target of 140 mt/yr.

### Phase I of the Lake Okeechobee Construction Project

Phase I of the Lake Okeechobee Construction Project is intended to bring immediate TP load reductions to Lake Okeechobee, consistent with the recommendations of the South Florida Ecosystem Restoration Working Group's Lake Okeechobee Action Plan (Harvey and Havens, 1999).

Lake Okeechobee Critical Projects activity included completion of plans and specifications for the Taylor Creek (Grassy Island Ranch) STA in December 2002 and for the Nubbin Slough (New Palm/Newcomer Dairy) STA in June 2003. Construction contracts were awarded for both STAs, and a combined groundbreaking ceremony was held on June 30, 2004. Subsequently, a ribbon-cutting ceremony was held for each facility on April 27, 2006.

The reduction of TP loads to Lake Okeechobee is estimated as 2.08 mt/yr for the Taylor Creek STA and 8.6 mt/yr for the Nubbin Slough STA after the Nubbin expansion project is completed. These estimates are based on model simulations using the Dynamic Model for Stormwater Treatment Areas model (Walker and Kadlec, 2004) with lower inflow concentrations after BMPs are implemented.

### Phase II of the Lake Okeechobee Construction Project

The objectives of the LOWP are to reduce phosphorus loading to Lake Okeechobee, attenuate peak flows from the watershed, provide more natural water level fluctuations in the lake, and restore wetland habitat. These goals will be accomplished by constructing reservoir storage approaching 273,000 ac-ft (33,674 ha-m) in volume and constructing stormwater treatment facilities capable of removing approximately 60 mt of phosphorus from the tributary flows prior to release to Lake Okeechobee. Although this project was originally expected to provide 130 mt of phosphorus removal, no acceptable component was found for the Fisheating Creek Basin, for which the initial phosphorus removal goal was 50 mt. The LOER fast-track projects were part of the original LOWP, which provide about 14 mt TP load reduction. About 6 mt of phosphorus removal was lost when no practical means of connecting the C-41A basin reservoir with the STA in the C-41 basin. Thus, the revised phosphorus removal contribution of the LOWP is about 60 mt. The project will also select about 3,500 ac (1,416 ha) of watershed land for wetland and habitat restoration. The LOWP has developed three final alternatives and is performing a detailed evaluation of these alternatives to determine the probable environmental and other societal benefits that will accrue from each alternative. The draft Lake Okeechobee Project Implementation Report is scheduled for completion in December 2007. Detailed information about LOWP is available on the CERP web site at www.evergladesplan.org/pm/projects/proj_01_lake_o_watershed.cfm.

# WATERSHED RESEARCH, ASSESSMENT, AND MONITORING

## RESEARCH AND STUDIES

The SFWMD, in cooperation with the FDEP and FDACS, has implemented a comprehensive research and water quality monitoring program for the lake and watershed. Several other agencies and interested parties participate in the monthly interagency team meetings and various project teams. Watershed research and assessment studies are reviewed and prioritized each year by the interagency team to ensure that information needs are addressed and watershed projects have been designed and implemented successfully. The data obtained will fill information gaps that have been identified by the interagency participants, assist in focusing on areas of concern, and determine performance of watershed management efforts.

A number of research and demonstration projects were started, continued, or completed in 2006 (**Table 10-5)**. The LOPA required that on-farm and tributary water management practices be assessed. The Watershed Assessment Model (SWET, 2002) was applied to Buck Island Ranch, location of the MacArthur Agro-ecology Research Center, near Lake Placid, Florida (Zhang et al., 2006). This is a 10,378 acre (4,200 ha) cattle ranch and is operated at full commercial scale allowing researchers to investigate ecological interactions under the economic realities of a working agricultural operation. A physically-based Watershed Assessment Model (WAM) is used for hydrological and water quality analyses. WAM simulates surface and groundwater quality based on land use, soil, weather, and land management practices. The model uses Geographic Information System (GIS) functions to overlay land use, soils, and rain zones to create a list of unique combinations to estimate the nutrient concentrations in the surface and groundwater flow leaving each source cell. The objective of this study was to determine the potential phosphorus load reduction under various water management alternatives for the most intensively managed portion of the ranch, where 39 proposed structures for onsite water detention are located. The average base load from the ranch is 1.87 mt/yr. A detention depth ranging from 0.25 to 0.5 inch runoff for pastures is recommended to achieve a ranch-level phosphorus load reduction of 20 percent.

## ASSESSMENT OF BMP EFFECTIVENESS

In accordance with the LOPA, a two-phased approach was used to determine the BMP effectiveness. 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 to develop the initial BMP performance estimates for all land uses. 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 District 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. 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 10-5)**.

**Table 10-5.** Status of Lake Okeechobee watershed research, demonstration, and assessment projects during WY2006.

| Project Name (Investigator) | Major Objectives/Conclusions | Status |
|---|---|---|
| Modeling Phosphorus Load Reductions of Agricultural Water Management Practices on a Beef Cattle Ranch (SFWMD) | The average base load from the ranch is 1.87 mt per year. Scenario One included a water detention depth of 0.25 inch for unimproved and woodland pastures. An estimated 4% load reduction could be obtained. Scenario Two increased water detention depth of 0.5 inch to these two pastures and an estimated 7% load reduction would be achieved. Scenario Three changed water detention depth to 0.25 inch for all three pasture types and an estimated 16% load reduction would be achieved. An estimated 19% load reduction would be achieved with a detention depth of 0.25 inch for beef pastures, 0.5 inch for unimproved and woodland pastures under Scenario Four. It is recommended that a detention depth ranging from 0.25 to 0.5 inch should be used to achieve a ranch-level phosphorus load reduction of 20%. | Complete |
| SFWMD and City of Okeechobee Cooperative Agreement –Sediment Trap Installation project (City of Okeechobee) | To develop a cooperative agreement with the city of Okeechobee for the installation of two sediment removal technologies. These technologies include a Continuous Deflective Separation (CDS) unit and a Tributary Sediment Trap (TST). These two units were previously studied under a demonstration project by Environmental Research and Design, Inc.; it was determined these technologies were more suited to urban environments where particulate sizes would likely be larger. Installation of these two technologies will not only support the SFWMD's efforts to support the LOPP, but will also enhance the city of Okeechobee's Storm Water Master Plan. | Complete |
| Data Review and Evaluation for Upgrading the Phosphorus Assimilation Algorithm (Soil and Water Engineering Technology, Inc.) | The project was completed in September 2006. The consultant recommended to obtain additional data needed to properly parameterize the phosphorus assimilation algorithm (PAA). Fifteen additional monitoring stations were proposed based on the PAA data needs: ten additional flow and water quality sites and five water quality only sites. These sites were proposed in four different sub-basins to obtain PAA parameterization data for the four major stream types found in the Lake Okeechobee watershed. Because monitoring alone will not be able to fully describe all the conditions that will be needed to complete the PAA assessments, it is recommended that hydrologic/water quality modeling be used to support the PAA assessment. | Complete |
| Cow/Calf Water Quality BMP Demonstration (UF/IFAS) | To evaluate the effectiveness of cow/calf production BMPs with regard to reducing phosphorus loadings. Specific objectives include (i) identify selected cow/calf BMPs and design hydrologic monitoring network for evaluating BMPs' effectiveness at watershed-scale for reducing phosphorus discharges; (ii) 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; (iii) use the monitoring data to test and modify selected hydrologic simulation models for their effectiveness in simulating the effectiveness of BMPs; and (iv) 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 will be completed in June 2007. | Ongoing |
| Wetland BMP Research (UF/IFAS) | The study objectives are (i) to demonstrate and determine the efficacy of isolated wetlands located in land areas used for dairy and cow/calf operations, on phosphorus assimilation and storage; (ii) to design and optimize on farm or edge-of-the-field treatment wetlands to maximize phosphorus removal performance (both mass removal per unit area basis, and effluent concentration basis) land areas used for cow/calf operation; (iii) review current hydrologic and phosphorus models for adaptation to the Okeechobee Basin wetland systems and to predict phosphorus assimilation capacity of the basin; (iv) to develop phosphorus assimilation coefficients/algorithms for use in water quality models to demonstrate the effectiveness of isolated and constructed wetlands to store phosphorus; and (v) to 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. | Ongoing |
| Taylor Creek Pilot STA Baseline Characterization (UF/IFAS) | The overall objective of the study is to document the existing soil and vegetative conditions in the Taylor Creek Pilot STA following construction but prior to operation. This work effort will allow evaluation of changes in the physical, chemical, and biological functions of the STA over time. The project started in April 2005 and will be completed in January 2007. | Ongoing |
| Dairy Lagoon Seepage Characterization and Remediation Processes (to be determined) | An extensive monitoring well system has been established to determine the movement of nutrients in groundwater resulting from lagoon leakage. Preliminary results indicate very little movement of phosphorus. Study to continue through a full dry/wet cycle to determine the effect on phosphorus movement. The modeling and monitoring will be completed in June 2008. | Ongoing |

**Table 10-5.** Continued.

| Project Name (Investigator) | Major Objectives/Conclusions | Status |
|---|---|---|
| Water Quality Best Management Practice (BMP) for Beef Cattle Ranch Demonstration (Archbold Expeditions) | The study objectives are (i) to develop an understanding of the relationship between beef cattle operational practices and water quality and (ii) to provide recommendations for the development of environmentally and economically sustainable cow/calf practices in the Lake Okeechobee watershed. Cattle stocking rates evaluated in this study have no measurable effect on nutrient loads from the pastures, which may be related to high concentrations of phosphorus in the soil from past fertilization practices in improved pastures. The current project evaluates 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 project started in May 2004 and will be completed in December 2008. | Ongoing |
| Taylor Creek Tributary Dredging (Okeechobee County) | To remove accumulated sediment material in finger canals that are tributary to the lower section of Taylor Creek in the S-133 basin. Sediments in these canals are detrimental to the quality of water in Taylor Creek, which ultimately flows into Lake Okeechobee. The removal of this sediment will not only remove phosphorus from the system but improve flood protection and navigation in specific reaches. The soil analysis for dredging material has turned up no constituents of concern so it will not be necessary to truck the material to the landfill. The material will be land applied on near by agricultural operations as a soil amendment. The project will be completed in March 2007. | Ongoing |
| Lake Istokpoga Canal Maintenance Dredging and Sediment Removal (Highlands County) | This project is an evaluation of 15 to 20 residential access canals around the periphery of Lake Istokpoga for dredging and other canal maintenance options. These waterways provide considerable navigational and other benefits to Highlands County. This project will include (i) canal bottom evaluations to determine canal depth and extent of sediment accumulation; and (ii) collection and analysis of sediments in the canals. Information will be used to design an implementation plan, subsequent permitting, and prioritization of canals for maintenance dredging within the project area. Canals deemed eligible for maintenance dredging under the FDEP's rules will then be prioritized and placed in the second phase of this project. Canals where maintenance dredging is not an option will be placed in the third phase of this project if necessary. The sediment characterization will establish the levels of the contaminants in the sediment, which will be used to identify the proper disposal method for the dredged material. The project was begun in August 2005 and completed in August 2006. | Ongoing |
| 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 phosphorus exports from phosphorus impacted soils. This project will extend existing on-farm demonstration studies monitoring the effects of soil phosphorus values on forage productivity, diagnostic tissue values and phosphorus mining capacity. | Ongoing |
| Rapid Soil and Tissue Analysis Techniques Using Near Infrared Reflectance Spectroscopy (UF/IFAS) | This project is evaluating 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. Thus, providing the ability to interpret analytical results of soil, tissue and water tests for in the field recommendations for nutrient needs/applications and timing of crop harvesting to maximize production and environmental benefits. | 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 water table in the uplands soils may release absorbed phosphorus form the soil into the groundwater. This project will develop the protocol needed to determine the potential for these releases and recommend BMPs that can be used to prevent or manage these releases. | 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 sate horticulture industry. The study will determine both environmental and production benefits from the use of cowpeat versus Florida and Canadian peat. | Ongoing |
| WAM BMP Assessment Tool and Model Upgrade (Soil and Water Engineering Technology, Inc.) | This project will 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. | Ongoing |

In July 2006, the District worked with a consultant to update the Phosphorus Reduction Performance and Implementation Costs under BMPs and Technologies in the Lake Okeechobee Protection Plan Area Report. The purpose of this re-evaluation was to (1) update the values in the previous report, (2) include one additional agricultural land use category (ornamentals) in the assessment, and (3) separate range/woodland pastures from unimproved pastures. To complete these tasks, a workshop was held in May 2006 with leading agricultural experts with specific knowledge of BMP implementation practices and effectiveness. The workshop was invaluable to determine the latest research and management practices for the primary crops grown in the Lake Okeechobee basins. The appropriate values for existing and BMPs practices for each agricultural land use were discussed in detail, with updated values being developed by group consensus (Bottcher, 2006). It is anticipated that the implementation of owner and typical cost-share BMPs in the urban and agricultural sectors will provide approximately a 25 percent reduction in phosphorus loads into the tributaries within the Lake Okeechobee watershed. Additional reductions could be achieved by a more aggressive BMP implementation program within the basin. The reductions shown are for a “typical” BMP implementation level under a moderately aggressive program that assumes a limited amount of cost share support will be available for agricultural landowners.

## WATER QUALITY MONITORING IN THE WATERSHED

Water quality monitoring is conducted through the LOWP, the LOWA micro-basin monitoring, and through the District’s ambient water quality monitoring program. Through the LOWP, the USGS monitors 16 sub-basin sites within the LOWP boundary north of Lake Okeechobee for stream flow, phosphorus, nitrogen, and total suspended solids. Continuous flow and weekly water quality samplings are collected at these stations. Additional information can be found on the CERP web site. Basin water quality data for WY2006 are presented in the *Watershed Status* section of this chapter.

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 the coordinating agencies, specifically 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, the LOWP monitoring network, and the Lake Okeechobee inflow sites, are used by LOWA staff to evaluate changes in phosphorus 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 phosphorus source areas are detected and phosphorus discharges within a basin do not improve, then the coordinating agencies can require the implementation of additional BMPs or regional projects.

For the past three years, data has been collected at established LOWA micro-basin monitoring sites (**Figure 10-5).** During WY2006, the LOWA staff also began collecting samples in five additional basins: S-65A, S-65BC, Josephine Creek, Arbuckle Creek, and Lake Arbuckle. LOWA monitored 14 basins in WY2006; 11 were monitored at structure outlets. Nine monitoring stations had average TP concentrations in the watershed greater than those at the basin discharge outlet to the lake (**Table 10-6**). Eight basins had TP concentrations at the structure outlet that were above the target concentration (SWIM plan target) (SFWMD, 1981). A detailed data analysis of each basin is provided to the coordinating agencies to help direct BMP implementation.

**Table 10-6.** WY2006 TP concentration data collected at micro-basin sampling sites in the Lake Okeechobee watershed.

| Basin | Watershed Sampling Sites | | | | | Structure Outlet | | | | Basin SWIM Plan Concentration Target |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean (ppb) | Median (ppb) | Std Dev | Number of Samples | Number of Monitoring Sites | Mean (ppb) | Median (ppb) | Std Dev | Number of Samples | |
| Taylor Creek/Nubbin Slough S-191 | 877 | 564 | 1,119 | 361 | 36 | 451 | 427 | 163 | 71 | 180 |
| S-133 | 172 | 126 | 132 | 79 | 5 | 206 | 182 | 87 | 14 | 180 |
| S-154[a] | 919 | 632 | 917 | 222 | 14 | 639 | 769 | 377 | 3 | 180 |
| S-154C | --- | --- | --- | --- | --- | 283 | 227 | 191 | 20 | 180 |
| S-65A[b] | 135 | 99 | 128 | 68 | 12 | 79 | 80 | 18 | 23 | 70 |
| S-65BC[c, d] | 84 | 65 | 95 | 213 | 14 | 67 | 66 | 9 | 26 | N/A |
| S-65E[e] | 423 | 268 | 456 | 342 | 24 | 82 | 69 | 31 | 30 | 180 |
| S-65D | 373 | 152 | 429 | 299 | 15 | 73 | 65 | 23 | 24 | 180 |
| Slough Ditch S-84 (C-41A) | 354 | 154 | 441 | 101 | 8 | 102 | 93 | 36 | 12 | 100 |
| Harney Pond Canal S-71 (C-41) | 240 | 138 | 255 | 384 | 24 | 198 | 143 | 138 | 56 | 180 |
| Indian Prairie S-72 (C-40) | 165 | 138 | 102 | 110 | 7 | 235 | 221 | 100 | 38 | 180 |
| Josephine Creek | 498 | 69 | 184 | 197 | 16 | N/A | N/A | N/A | N/A | N/A |
| Fisheating Creek | 318 | 527 | 265 | 404 | 21 | 116 | 87 | 64 | 17 | 180 |
| Arbuckle Creek | 511 | 97 | 861 | 255 | 11 | N/A | N/A | N/A | N/A | N/A |
| Lake Arbuckle | 115 | 74 | 107 | 97 | 4 | N/A | N/A | N/A | N/A | N/A |

a Basin's data are incomplete; seven samples each (collected between January and April) for two LOWA sites are not included and one USGS site has data only through September 2006.

b Basin was sampled from January 9, 2006, through April 30, 2006.

c Basin data are incomplete; seven samples collected between January and April for one LOWA site was not available.

d S-65B and C basins had target TP concentrations of 60 and 130 ppb, respectively.

e Data for basin are based on 23 of 24 sites; no WY2006 data (five samples collected between February and April) are available for one site.

N/A Not Available

## CHALLENGES AND UNRESOLVED ISSUES

- Land values have leveled off, but the most recent increases in the watershed continue to make it more attractive for agricultural operators to divide their landholdings into smaller parcels for development. As a result, land use in the watershed is moving toward single-family ranchettes and subdivisions. The challenge is to assure that these land use changes will not increase phosphorus loads to the lake. This issue should be addressed in the new ERP criteria mandated under the LOER initiative.
- Long-term phosphorus loading in the watershed has created residual phosphorus in the soils. The increase in residual phosphorus has reduced the phosphorus assimilative capacity of soils and wetlands in the watershed, resulting in more phosphorus discharge to the lake. Methods are needed to manage and capture phosphorus stored in the watershed before it gets to the lake. The District is soliciting landowners to develop opportunities to store water on their farms and is developing ongoing water storage projects within the watershed.
- The ability to quantify phosphorus loads at sub-basins and to identify high-phosphorus source areas within a sub-basin is critical to determining the effectiveness of BMPs already implemented and redirecting resources to problem areas. This warrants maintenance of and continued funding for the USGS monitoring network for sub-basin loads and the District's biweekly monitoring to determine high phosphorus source areas.
- The development and implementation of urban BMPs continues to be a challenge as the number of developments increase throughout the watershed. Under the LOER initiative, agencies are working with the fertilizer industry to produce and distribute low- or no-phosphorus fertilizer statewide. Additionally, the SFWMD and FDEP work with the municipalities to implement lawn fertilization BMPs.

# LAKE STATUS

## STATUS OF LAKE PERFORMANCE MEASURES IN WY2006

This section discusses the status of the lake based on measurements of water quality, chlorophyll, phytoplankton, submerged aquatic vegetation (SAV), and water levels. A subset of the measurements was adopted as quantitative performance measures for the LOPA (SFWMD et al., 2004). Collectively, these measures describe the status of the ecosystem and its responses to implemented restoration programs. Measures are provided as five-year averages to ensure consistency with TMDL reporting, reduce the effect of year-to-year variation attributed to climate and hydrology, and help reveal underlying trends. These values are compared to quantitative restoration goals (**Table 10-7**). The phosphorus 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 WY2006 averaged observations are reported and document the water quality and lake level conditions of this year.

Of the 11 performance measures that can be compared to five-year (WY2002–WY2006) averages, none have reached their goal (**Table 10-7**). These include phosphorus loads, pelagic and nearshore TP, nutrient limitation, algal bloom frequency, water clarity, and SAV density. The nearness of SAV density to meeting restoration goals and can be attributed to two years (WY2002 and WY2004) when lake conditions were conducive to a very large spatial distribution of plants. The WY2006 values for these 11 performance measures are further from the target with the exception of SRP:DIN ratio and algal blooms. The WY2006 conditions of the lake are explored further in the *Post-2004 and 2005 Hurricane Assessment* section of this chapter. Of the three stage related goals, two were achieved during this water year. Water levels did not fall below 10 ft in the past water year and a spring recession was achieved with lake levels receding from 15.7 ft in January 2006 to 12.01 ft in June 2006.

## PHOSPHORUS BUDGET

TP loads to the lake from tributaries and atmospheric deposition (estimated as 35 mt/yr; FDEP, 2001) in WY2006 totaled 795 mt (**Table 10-8**; **Figure 10-8, Panel A**). The large loads in WY2006 are attributed primarily to the large flow of water into the lake (3,721,648 ac-ft or 459,058 ha-m). A large part of this load in WY2006 came from the Upper and Lower Kissimmee Rivers that contributed 237 mt of TP (30 percent) and 2,112,110 ac-ft (260,525 ha-m, 57 percent) of water. The percent contribution from the Kissimmee in WY2006 is consistent with the contribution in the past 10 years that has averaged 180 mt (40 percent) of phosphorus per year and 1,337,642 ac-ft (164,996 ha-m, 50 percent) of the total flow to the lake.

To offset the WY2006 inflow, over 3,905,991 ac-ft (481,796 ha-m) of water was released from Lake Okeechobee. A majority of this outflow was discharged to the St. Lucie and Caloosahatchee rivers, 908,352 and 2,175,732 ac-ft (112,043 and 268,372 ha-m), respectively. This discharge included 824 mt of phosphorus, with 250 mt and 362 mt being discharged to the St. Lucie and Caloosahatchee rivers, respectively. For the 10-year period from WY1993 through WY2003, Lake Okeechobee contributed 28 and 90 percent of the TP load and 50 and 85 percent of the hydraulic load to the Caloosahatchee and St. Lucie rivers, respectively (Crean and Iricanin, 2005). This equated to 65 and 83 mt of phosphorus and 783,000 and 400,000 ac-ft (96,581 and 49,339 ha-m) of water per year, respectively.

**Table 10-7.** Summary of Lake Okeechobee rehabilitation performance measures, rehabilitation program goals, and lake conditions. Unless otherwise indicated, conditions are five-year averages (WY2002–WY2006), as specified in the Restoration Assessment Plan of the LOPP.

| Performance Measure | Goal | Five-Year Average | WY2006 Average |
|---|---|---|---|
| Total Phosphorus (TP) load | 140 mt/yr (to be met by WY2015) | 714 mt/yr | 795 mt/yr |
| Total Nitrogen Load | N/A | 1,626 mt/yr | 1,876 mt/yr |
| Inorganic Nitrogen Load | N/A | 931 mt/yr | 834 mt/yr |
| Pelagic TP | 40 ppb | 158 ppb | 214 ppb |
| Pelagic TN | N/A | 1.68 ppm | 1.80 ppm |
| Pelagic SRP | N/A | 48 ppb | 73 ppb |
| Pelagic DIN | N/A | 287 ppb | 445 ppb |
| Pelagic TN:TP | > 22:1 | 10.6:1 | 8.5:1 |
| Pelagic DIN:SRP | > 10:1 | 6.0:1 | 6.3:1 |
| Plankton nutrient limitation | Phosphorus > Nitrogen | Nitrogen >>> Phosphorus | Nitrogen >>> Phosphorus |
| Diatoms:cyanobacteria[a] | > 1.5 | 0.63 | N/A |
| Algal bloom frequency | < 5% of pelagic chlorophyll *a* exceeding 40 µg/L | 14.9% | N/A |
| Water clarity | Secchi disk visible on lake bottom at all nearshore SAV sampling locations from May through September | 25% | 0% |
| Nearshore TP | Below 40 ppb | 135 ppb | 165 ppb |
| Submerged aquatic vegetation (SAV)[b] | Total SAV > 40,000 acres<br>Vascular SAV > 20,000 acres | 34,973 acres total<br>17,032 acres vascular | 10,872 acres total<br>10,625 acres vascular |
| 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 | Goals not attained |
| Spring recession (January to June 2006) | Stage recession from near 15.5 ft in January to near 12.5 ft in June | N/A | Goal attained |

[a] Mean (WY2001–WY2005)

[b] Mean yearly acreages (from 2001–2005 maps)

N/A Not Applicable

**Table 10-8.** 10-year (WY1993—WY2003) phosphorus budget for Lake Okeechobee (in mt).

| May-April Water Year | Mean Lake P Mass | Net Change in Lake Content[a] | Load In[b] | Load Out | Net Load[c] | Sediment Accumulation[d] | Net Sedimentation Coefficient ($\sigma_y$) |
|---|---|---|---|---|---|---|---|
| 1997 | 481 | -266 | 167 | 161 | 6 | 272 | 0.57 |
| 1998 | 610 | 510 | 913 | 594 | 319 | -191 | -0.31 |
| 1999 | 532 | -543 | 312 | 241 | 70 | 613 | 1.15 |
| 2000 | 735 | 106 | 685 | 322 | 363 | 257 | 0.35 |
| 2001 | 383 | -320 | 134 | 209 | -75 | 245 | 0.64 |
| 2002 | 430 | 264 | 624 | 87 | 536 | 273 | 0.63 |
| 2003 | 594 | 143 | 639 | 328 | 311 | 168 | 0.28 |
| 2004 | 578 | 113 | 553 | 310 | 244 | 130 | 0.23 |
| 2005 | 1,108 | 270 | 960 | 605 | 355 | 85 | 0.08 |
| 2006 | 1,104 | -194 | 795 | 824 | -329 | 165 | 0.15 |
| **Average** | **651** | **20** | **584** | **367** | **218** | **198** | **0.37** |

[a] Net change from beginning of water year (May 1) to beginning of next water year (May 1)
[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 phosphorus budget for the lake (James et al., 1995a; the 2006 SFER – Volume I) has been updated. The average lake phosphorus mass was calculated as 1,104 mt. The load, discharge, and mass values are much larger than the 10-year historical averages of input, output, and mass (584 mt/yr, 367 mt/yr, and 651 mt, respectively). The phosphorus load to the lake in WY2006 (795 mt) was lower than WY2005 (960 mt) despite the higher flow in WY2006 (**Figure 10-8, Panel A**), because TP concentration in the inflowing water was lower (**Figure 10-8, Panel B**). Two independent hypotheses could account for this reduction: (1) the 2004 hurricanes flushed the most mobile phosphorus out of the watersheds leaving less mobile phosphorus behind and (2) increased BMP effectiveness.

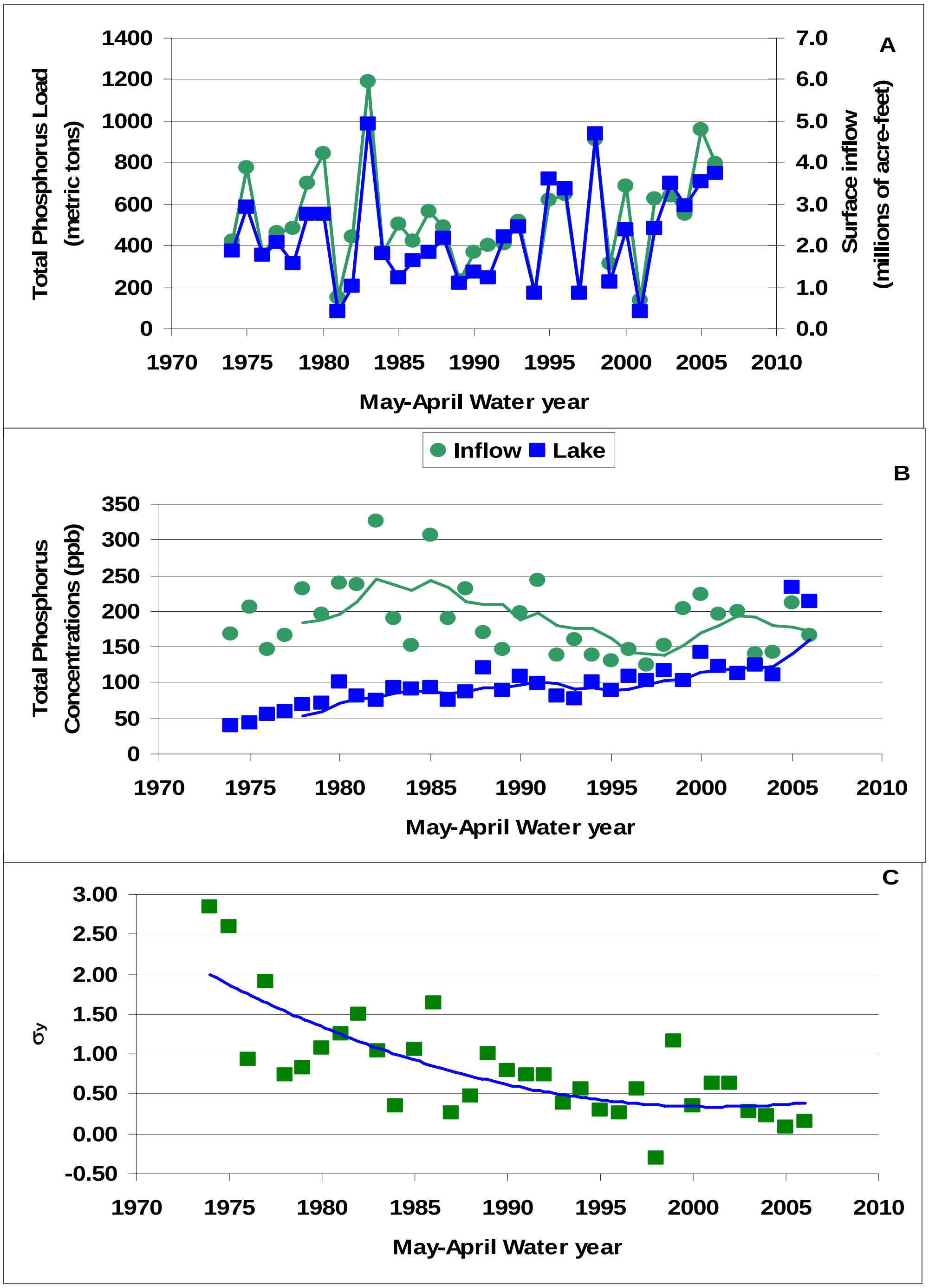


**Figure 10-8.** Timelines of (A) water year phosphorus load and inflow entering Lake Okeechobee from its tributaries, (B) inflow and lake average TP concentrations (five-year moving average trendlines), and (C) net sedimentation coefficient [σy] calculated from the WY2006 phosphorus budget of Lake Okeechobee. (Trendline is a second-order polynomial.)

The five-year rolling average of inflow TP concentration (**Figure 10-8, Panel B**) shows an increase of inflow TP concentration from the 1970s through the mid 1980s, followed by a decline through the 1990s. The decline in inflow phosphorus coincides with declines of TP loads from tributaries that included the Lower Kissimmee River (S65A through S65E basins), Taylor Creek Nubbin Slough, and the Everglades Agricultural Area (**Figure 10-3**; Flaig and Havens, 1995). TP concentrations increased to approximately 200 ppb between WY1999 and WY2001. A slight decline in the five-year rolling average followed, despite the high concentration in WY2005, attributed to the impacts of hurricanes Frances and Jeanne.

TP concentrations of lake water (averaged from stations L001 through L008) have increased from approximately 40 ppb in the 1970s to over 200 in the last two water years (**Figure 10-8, Panel B**). The highest yearly average TP concentration occurred in WY2005 (233 ppb) followed by a slight decline in WY2006 (214 ppb). These high values changed the slope of the five-year moving average. These water years are the only time when the in-lake concentration exceeds the inflow concentrations. This indicates that internal loadings (between sediments and the water column) may contribute significantly to the TP concentration in Lake Okeechobee.

To quantify the effects of sediment water interactions, the phosphorus budget can be used. The decline of the net sedimentation coefficient, $\sigma_y$ (per yr), which is the amount of phosphorus that accumulates in the sediment per year divided by the average phosphorus lake mass, is an indication of the increased importance of these sediment water interactions (**Figure 10-8, Panel C**). A low net sedimentation coefficient indicates that the lake is unable to absorb excess phosphorus loads from the watershed. For WY2006, the value was 0.15, which is substantially lower than the 10-year average of 0.37 (**Table 10-9**). The low net sedimentation coefficient is a result, in part, of the large mass of phosphorus in the water column that can be attributed to the large loads and resuspension of phosphorus from sediments. The coefficient is also a result of the small accumulation of phosphorus in the sediments that is the difference between settling and resuspension of phosphorus to and from the sediment. This overall decline of $\sigma_y$ has continued since the 1970s (**Figure 10-8, Panel C**; James et al., 1995a; Janus et al., 1990).

The reduction in the net sedimentation coefficient may be due to saturation of phosphorus-binding sites on lake sediment particles (Fisher et al., 2001) or a reduction of water-column calcium (James et al., 1995b; see *Other Water Quality Concerns* section of this chapter), an element that plays a key role in sequestration of phosphorus 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).

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 has been shown to be ineffective in precipitating phosphorus under conditions similar to those that prevail in the open water region of the lake. However, the District intends to investigate calcium as well as a number of other chemical compounds as potential methods for sequestering phosphorus.

## ALGAL BIOMASS AND TOXINS

The ratio of total nitrogen to total phosphorus (TN:TP) averages 10.6:1, and the ratio of dissolved inorganic nitrogen to soluble reactive phosphorus (DIN:SRP) averages 6:1 for the five-year average of WY2002–WY2006 (**Table 10-7**). These values favor dominance of blue-green algae, which presently account for most of the algal biomass in the lake and include some toxic species. Increased eutrophication of Lake Okeechobee and other water bodies in South Florida has led to an increased frequency of blue-green algal (cyanobacteria) blooms and their associated toxins. Since May 2004, the District has routinely monitored bloom formations and associated blue-green toxins in Lake Okeechobee. Water samples from six shoreline stations where blooms often form were analyzed on a monthly basis for the presence of microcystin, a cyanobacteria toxin. This program was expanded in August 2005 to include 41 stations throughout the northern watershed from the Kissimmee Chain of Lakes (KCOL), the Kissimmee River, Lake Istokpoga, Lake Okeechobee, the Caloosahatchee and St. Lucie rivers and estuaries, and in various canals that drain from Lake Okeechobee toward the West Palm Beach area (**Figure 10-9**).

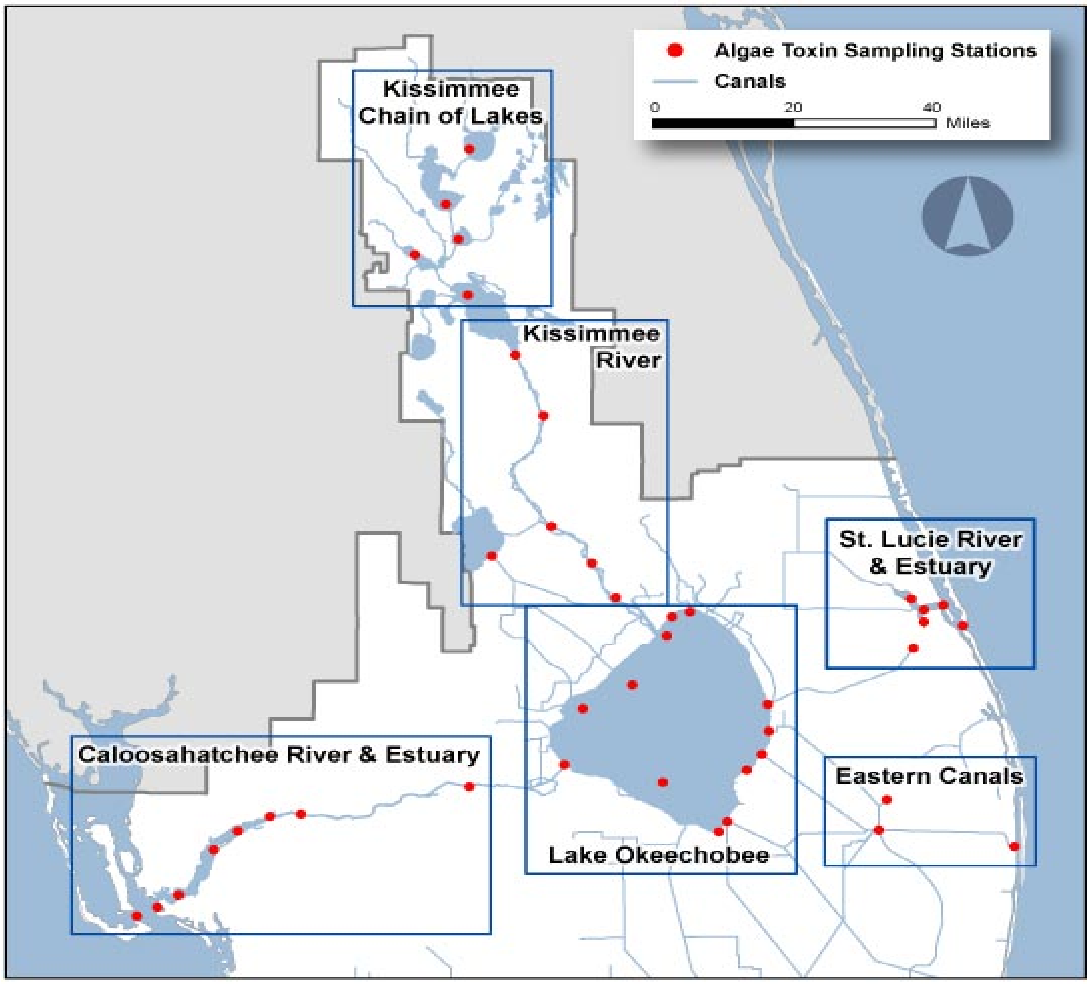


**Figure 10-9**. Monitoring sites for the District-wide assessment of the blue-green algal toxin microcystin.

Prior to June 2005, cyanobacterial toxin concentrations in Lake Okeechobee were quite low (**Figure 10-10**). However, during the summer 2005, many lakes and canals (from the KCOL south to Lake Okeechobee, and from Lake Okeechobee to the east and west coast estuaries) experienced prolific cyanobacteria blooms, and elevated levels of microcystin in samples from Lake Okeechobee and the St. Lucie Estuary were reported. Under this relatively new monitoring effort, however, it is unclear whether prior instances of elevated toxin levels were similar to those in the summer 2005. District-wide toxin surveys conducted after August 2005 indicated that toxin concentrations were lowest in the KCOL and the Kissimmee River and highest in the eastern canals. Concentrations in the east and west coast estuaries were similar to those found in Lake Okeechobee.

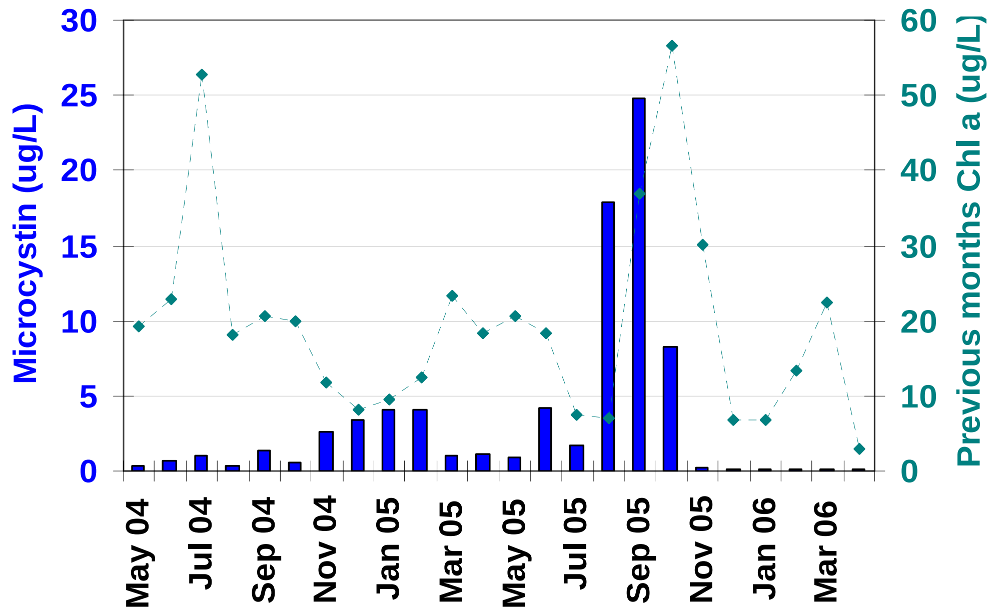


**Figure 10-10.** Average microcystin (bars) and chlorophyll *a* (from the previous month-line graph) levels in Lake Okeechobee (May 2004–April 2006).

## OTHER WATER QUALITY CONCERNS

The District maintains a pesticide monitoring program that measures organic toxins in sediments and water samples on a quarterly basis at locations throughout South Florida. Additional information on this 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 S65E, S191, Fisheating Creek, S2, S3, and S4. In the latest report (December 2005), where water was flowing into the lake (S65E and Fisheating Creek), no pesticides were reported (Pfueffer, 2006).

Pesticides are not used on the lake as part of any control program by the SFWMD. However, herbicides are used to control exotic and invasive species. The District has not studied direct effects of herbicides on lake fauna. Some negative effects have been observed on buttonbush 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 from the spraying of water hyacinth in bulrush stands. 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 *Vegetation Management* section of this chapter and Chapter 9 of this volume).

James et al. (1995b) noted a declining trend of calcium in Lake Okeechobee and hypothesized that this could be attributed to reduced loading credited to reduced back pumping into the lake from the Everglades Agricultural Area. 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 10-11**).

Sulfate is known to impact eutrophication (Lamers et al., 2002) and is recognized to impact mercury cycling in the Everglades (Marvin-Dipasquale and Oremland, 1998). However, as with other ions in the lake, sulfate has declined from over 60 parts per million (ppm) in the early 1970s to under 30 ppm in the 2000s. No sulfate research has been conducted on Lake Okeechobee to date. Although mercury is a concern in Florida waters, especially for fish consumption, Lake Okeechobee limits are among the least restrictive of all advisories in the state (for information on individual lakes and water bodies see http://www.doh.state.fl.us/environment/community/fishconsumptionadvisories/FreshfishSearch.html).

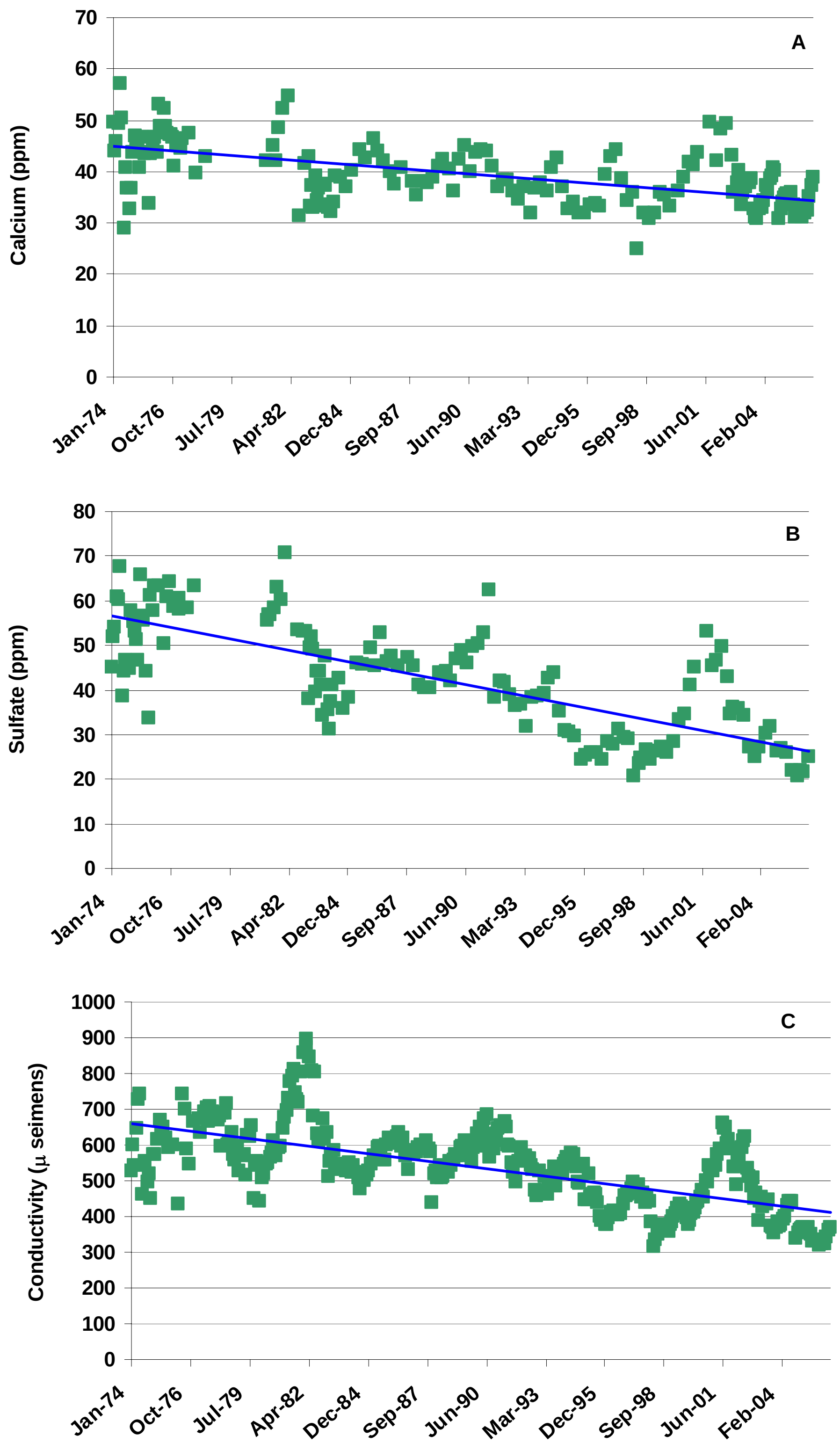


**Figure 10-11**. Monthly Average Values of (A) calcium, (B) sulfate, and (C) conductivity at the eight long-term monitoring stations (L001 through L008). The blue line represents a regression of the average values over time.

## POST-2004 AND 2005 HURRICANE ASSESSMENT

The Lake Okeechobee monitoring program (**Figure 10-12**) allows assessment of the longer-term impacts of hurricanes Frances (September 5, 2004) and Jeanne (September 26, 2004) along with the short-term impacts of Hurricane Wilma (October 24, 2005) on water quality in the lake. The assessment of the 2004 hurricane season compared selected water quality parameters from one year before the hurricanes (September 1, 2003–September 1, 2004) to one year after the hurricanes (October 1, 2004–October 1, 2005). This comparison was done for the three major regions of the lake (**Figure 10-13**): (1) the open water pelagic region, which is deep (8.2–16.4 ft or 2.5–5.0 m), turbid, and light-limited, has high TP concentrations (> 100 ppb) and no rooted plants or attached algae (Havens et al., 1995); (2) the nearshore region, which is shallow (< 1.6–3.3 ft or < 0.5–1.0 m), with moderate TP concentrations (30–60 ppb) and submerged and wave-tolerant emergent plants; and (3) a littoral region along the west and south shoreline, which is shallow (0–3.3 ft, or 0–1 m), with low TP concentrations (5–20 ppb) and a diverse plant community (Havens et al., 1999 and 2004; Hwang et al., 1998). The impacts of Hurricane Wilma are determined graphically for selected water quality measures.

The high inflows, TP loads, and lake levels in WY2005 had a large influence on the lake (see the 2006 SFER – Volume I, Chapter 10). For example, chloride declined significantly after the 2004 hurricanes, most likely a result of dilution from the increased water volume (**Table 10-9**). In addition, alkalinity declined in the littoral region, calcium declined in the offshore region, and sulfate declined in the nearshore and offshore regions, also most likely as a result of dilution.

The increase in concentrations of TP, total suspended solids (TSS), soluble reactive phosphorus (SRP), and total nitrogen (TN), and reduced Secchi Disk depth and transparency (defined as the ratio of Secchi Disk depth to total depth at a given location) that have persisted in the nearshore and offshore regions (**Table 10-9**) could all be attributed to resuspension of sediment from an increased layer of unconsolidated sediments. Although impacts on water quality from Hurricane Wilma were much less pronounced from the previous hurricanes, TSS and DIN did increase in the month after the hurricane in the offshore and nearshore region, and TP and SRP increased in the littoral region (**Figure 10-15**).

Three lines of evidence suggest that hurricanes caused an increase in the unconsolidated layer of sediment. The first is a comparison of sediment cores taken before (spring 2003) and after (spring 2005) the 2004 hurricane season. Based on lead isotope ($^{210}Pb$) analysis (**Figure 10-16**; Pollman and Engstrom, 2005), two cores showed that between 9 and 12 cm of surface sediment were mixed after the hurricanes. The second line of evidence is the maximum shear stress calculated for each of the past four hurricanes that directly impacted Lake Okeechobee (**Table 10-10**). The strong and prolonged shear stress generated from Hurricane Frances (**Figure 10-14, Panel A**) most likely resulted in an increase of the unconsolidated mud sediment layer. The shear stress produced by Hurricane Frances was greater than the shear stress produced by the stronger Hurricane Wilma (**Table 10-10**; **Figure 10-14, Panel B**), because Hurricane Frances moved much slower and impacted the lake for a longer period, creating the greatest shearing stress out of all four hurricanes. The third line of evidence is a comparison of water quality and 15-minute wind frequencies before and after the 2004 hurricanes. The 15-minute wind values were slightly (but significantly, $p < 0.05$) higher in the pre-hurricane period (October 1, 2003–August 1, 2004) than in the post-hurricane period (October 1, 2004–August 1, 2005, **Figure 10-17**). However, the post-hurricane period, with the slightly weaker winds, had higher TSS, TP, TN, SRP, and shallower Secchi Disk depth than the pre-hurricane period (**Table 10-10**), an indication that sediments are more easily resuspended after the hurricanes than before.

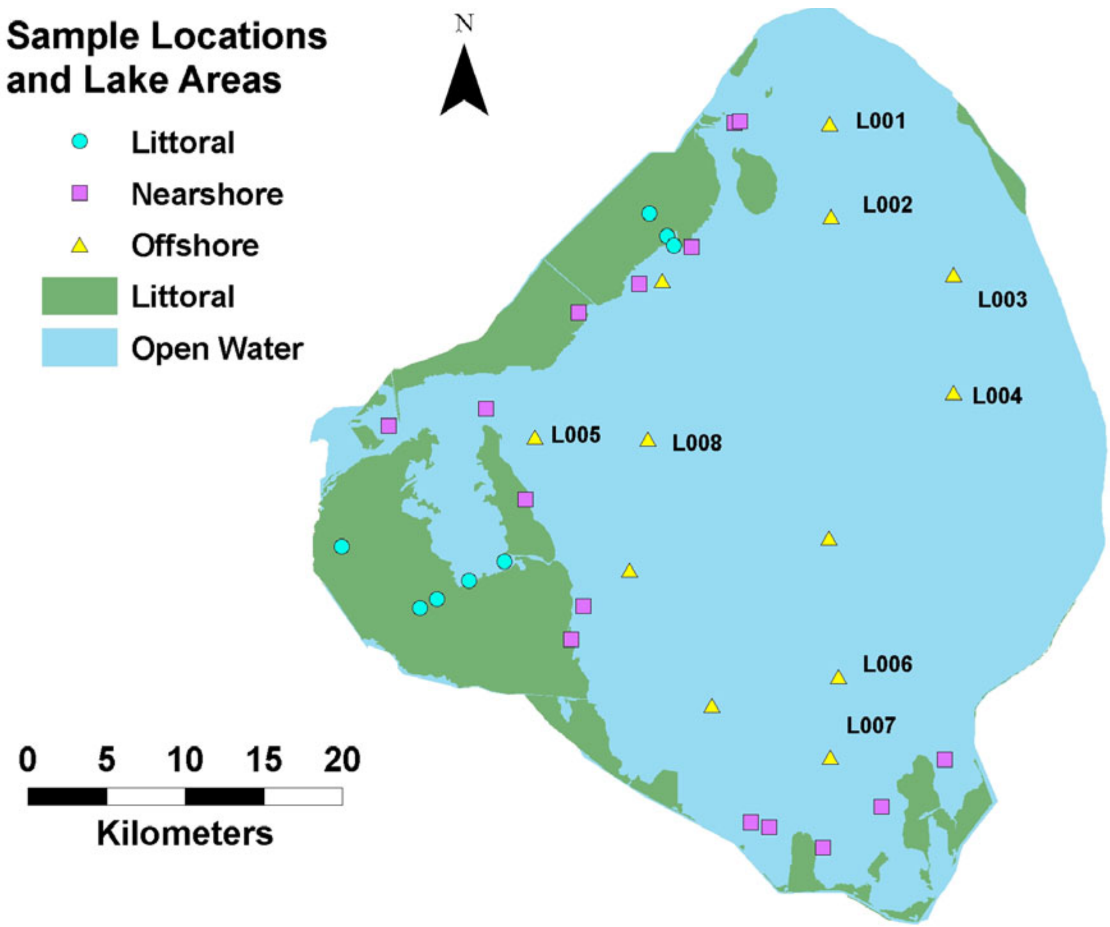


**Figure 10-12.** Locations of sampling stations in the Lake Okeechobee network (WY2006). L001 through L008 are long-term monitoring stations.

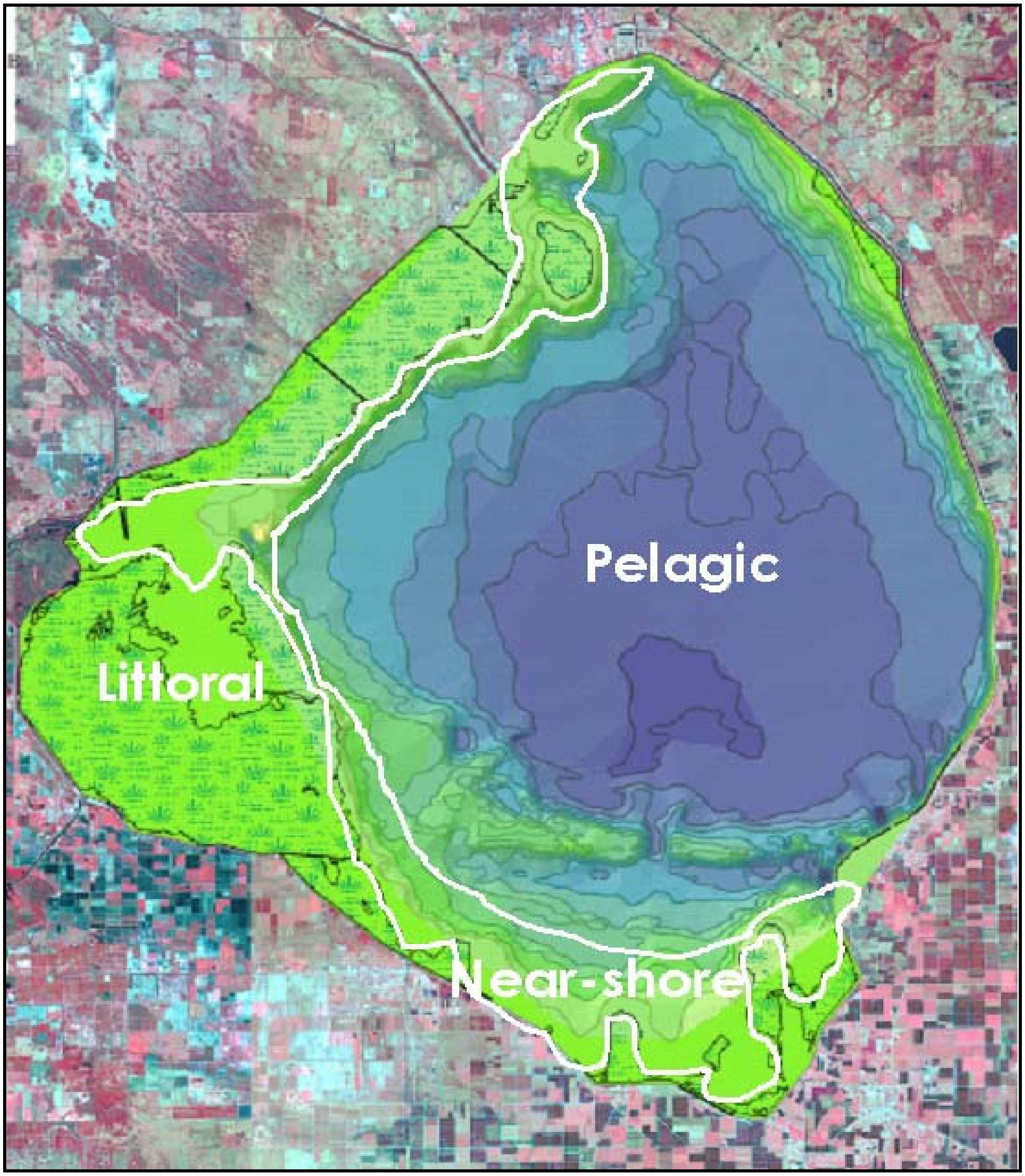


**Figure 10-13.** Three major habitat zones in Lake Okeechobee shown as an overlay on a 2002 lake bathymetric map. These zones are based on dominant primary producers (Havens, 2003).

**Table 10-9.** Selected water quality measurements for the three regions of Lake Okeechobee before (September 1, 2003–September 1, 2004) and after (October 1, 2004–October 1, 2005) the impacts of hurricanes Frances and Jeanne. Significant before and after differences determined with an SAS Mixed Model (Littell et al., 1996). Shading only = $p < 0.001$; Shaded box = $p < 0.05$. N/D = no data

| Parameter | Statistic | Littoral | | Nearshore | | Offshore | |
|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After |
| **Chloride (mg/L)** | Mean | 62.5 | 42.8 | 47.7 | 38.8 | 47.6 | 38.3 |
| | Stdev | 29.1 | 10.3 | 9.8 | 9.4 | 6.6 | 6.5 |
| | N | 103 | 101 | 152 | 154 | 151 | 156 |
| **Alkalinity (mg $CaCO_3$/L)** | Mean | 108.5 | 99.4 | 89.5 | 92.7 | 92.4 | 98.7 |
| | Stdev | 34.4 | 25.3 | 19.6 | 25.0 | 14.5 | 24.8 |
| | N | 103 | 101 | 152 | 154 | 151 | 156 |
| **Calcium (mg/L)** | Mean | 37.0 | 35.1 | 33.4 | 33.6 | 35.2 | 33.5 |
| | Stdev | 9.6 | 6.6 | 8.2 | 6.6 | 4.9 | 4.3 |
| | N | 103 | 101 | 61 | 60 | 127 | 131 |
| **Sulfate (mg/L)** | Mean | N/D | N/D | 28.5 | 25.2 | 27.9 | 24.9 |
| | Stdev | | | 8.2 | 6.3 | 4.4 | 4.9 |
| | N | | | 48 | 48 | 49 | 52 |
| **Secchi Disk Depth (m)** | Mean | 0.74 | 0.54 | 0.58 | 0.22 | 0.35 | 0.15 |
| | Stdev | 0.32 | 0.32 | 0.36 | 0.18 | 0.26 | 0.08 |
| | N | 75 | 101 | 148 | 154 | 151 | 156 |
| **Transparency ratio Secchi Disk Depth/Total Depth** | Mean | 0.79 | 0.63 | 0.35 | 0.12 | 0.13 | 0.5 |
| | Stdev | 0.26 | 0.35 | 0.30 | 0.10 | 0.14 | 0.4 |
| | N | 64 | 99 | 147 | 150 | 151 | 148 |
| **Total Suspended Solids (mg/L)** | Mean | 6.3 | 12.6 | 11.6 | 46.5 | 23.8 | 74.2 |
| | Stdev | 7.7 | 19.8 | 10.0 | 42.5 | 19.1 | 70.6 |
| | N | 103 | 101 | 152 | 154 | 150 | 156 |
| **Total Phosphorus (mg P/L)** | Mean | 0.038 | 0.099 | 0.075 | 0.202 | 0.120 | 0.244 |
| | Stdev | 0.038 | 0.081 | 0.034 | 0.073 | 0.045 | 0.095 |
| | N | 103 | 99 | 152 | 154 | 151 | 154 |
| **Soluble Reactive Phosphorus (mg P/L)** | Mean | 0.011 | 0.042 | 0.018 | 0.072 | 0.036 | 0.076 |
| | Stdev | 0.027 | 0.040 | 0.017 | 0.018 | 0.021 | 0.016 |
| | N | 103 | 101 | 152 | 154 | 151 | 156 |
| **Total Nitrogen (mg N/L)** | Mean | 1.41 | 1.45 | 1.24 | 1.93 | 1.35 | 2.12 |
| | Stdev | 0.52 | 0.56 | 0.31 | 0.65 | 0.33 | 0.66 |
| | N | 103 | 99 | 152 | 154 | 151 | 154 |
| **Dissolved Inorganic Nitrogen (mg N/L)** | Mean | 0.029 | 0.147 | 0.063 | 0.470 | 0.163 | 0.589 |
| | Stdev | 0.040 | 0.256 | 0.090 | 0.281 | 0.128 | 0.262 |
| | N | 103 | 101 | 151 | 154 | 151 | 156 |
| **Chlorophyll *a* (µg/L)** | Mean | 24.6 | 28.1 | 28.9 | 22.5 | 24.9 | 12.8 |
| | Stdev | 50.2 | 51.9 | 19.7 | 33.0 | 16.3 | 8.0 |
| | N | 102 | 100 | 152 | 153 | 151 | 155 |

**Table 10-10.** Comparison of hurricane forces on Lake Okeechobee.

| Hurricane | Peak date and time | Average Hourly Maximum (and Maximum 15-minute) Wind Speed (mi/hr) | Persistent Time (days wind > 18 mi/hr) | Maximum Bottom Current (m/s)* | Maximum Bottom Shear Stress ($N/m^2$)* |
|---|---|---|---|---|---|
| **Irene** | 10/15/99 9:00 PM | 50 (52) | 2.3 | 0.10 | 8.2 |
| **Frances** | 9/5/04 2:00 AM | 66 (67) | 4.7 | 0.18 | 16.0 |
| **Jeanne** | 9/26/04 1:00 AM | 70 (74) | 2.5 | 0.11 | 13.2 |
| **Wilma** | 10/24/05 11:00 AM | 78 (91) | 1.5 | 0.12 | 13.4 |

* Calculated from the Lake Okeechobee Environment Model

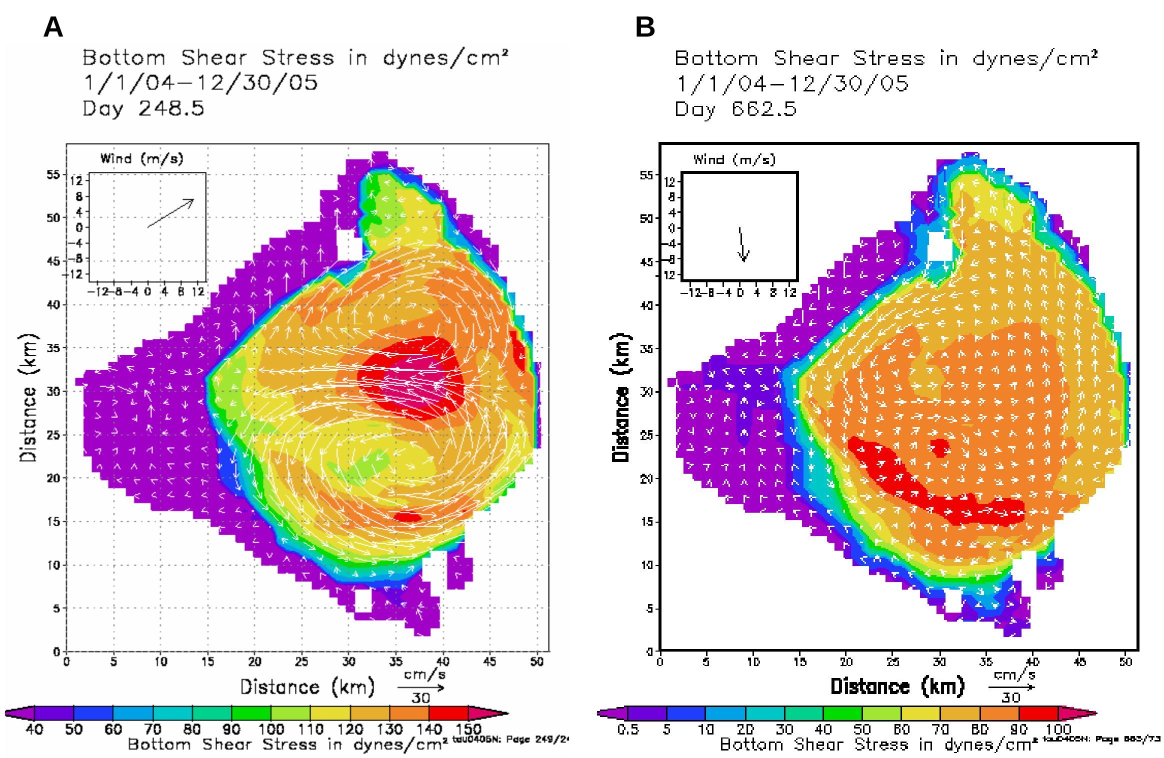


**Figure 10-14.** Shear stress from major hurricanes: (A) bottom stress distribution generated by Hurricane Frances (September 5, 2004) and (B) bottom stress distribution generated by Hurricane Wilma (October 24, 2005).

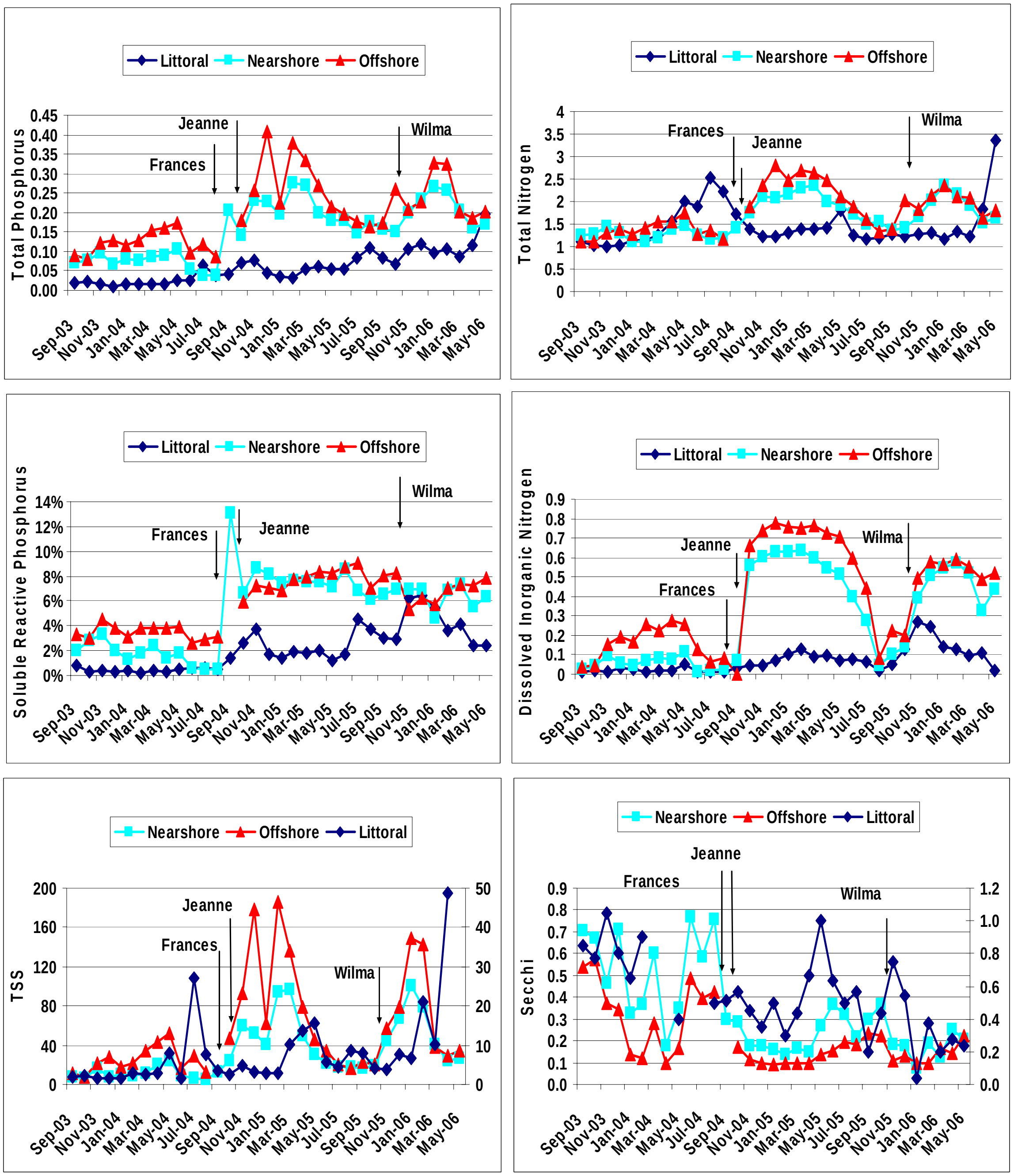


**Figure 10-15.** Monthly average values for various in-lake parameters by region (September 2003–May 2006). Arrows indicate hurricane dates.

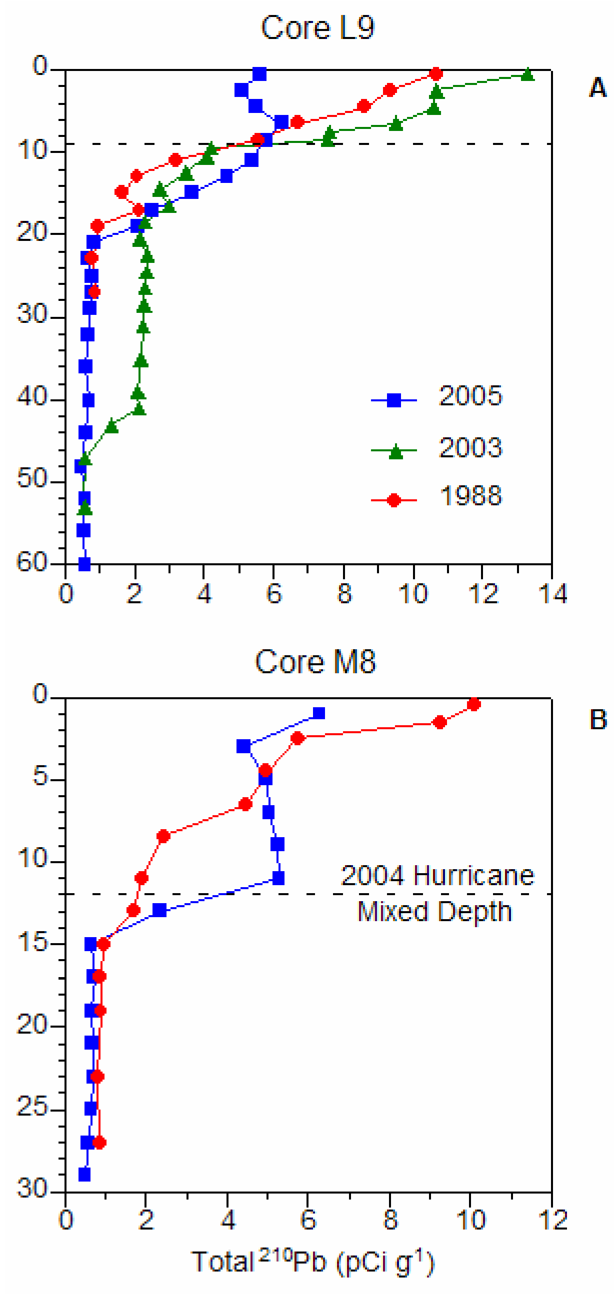


**Figure 10-16.** Comparison of lead isotope ($^{210}$Pb) vertical profiles in cores (A) L9 and (B) M8. Measured in April 2005 with previously measured profiles; 1988 data from Brezonik and Engstrom (1998) and 2003 data from Schottler and Engstrom (submitted 2005).

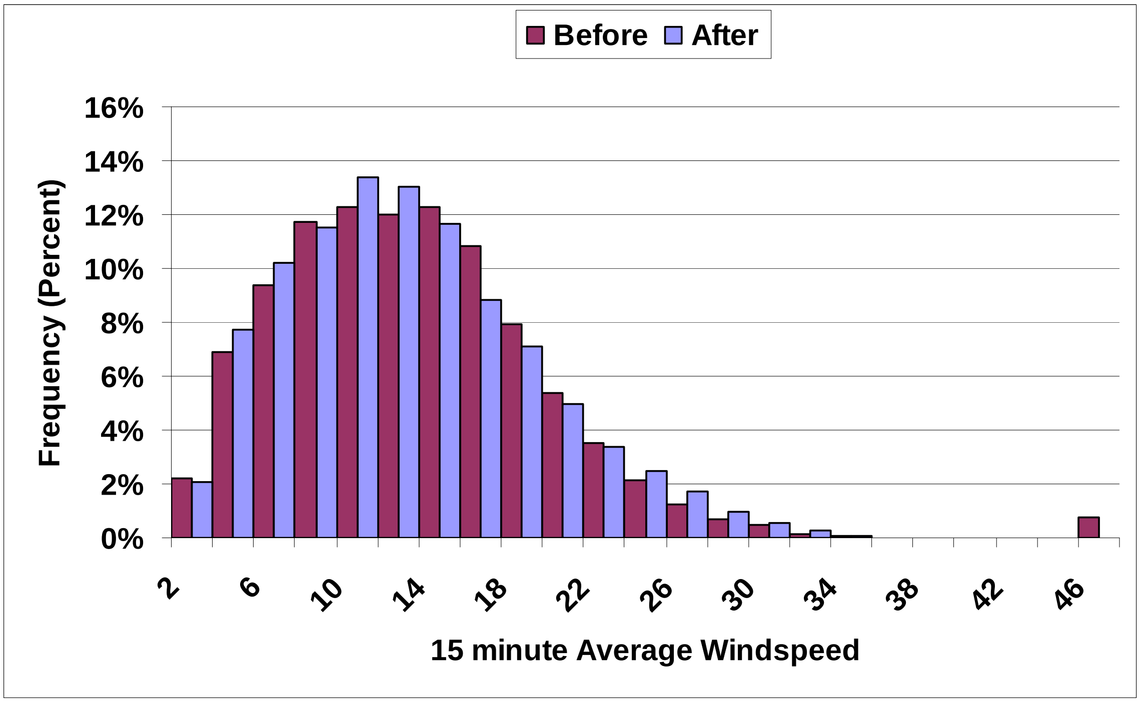


**Figure 10-17** Histogram of 15-minute wind speeds in the 10 months before (October 2003–July 2004) and 10 months after (October 2004–July 2005) the 2004 hurricanes.

The high suspended solids and resulting low light penetrations that persisted throughout the winter of WY2004 (**Figure 10-15**) contributed to the continued declines in SAV. Between July 2004 (before the hurricanes) and October 2004 (after the hurricanes), average SAV biomass, as measured at quarterly monitoring sites, declined from 32.32 grams per square meters ($g/m^2$) dry weight to 4.65 $g/m^2$ dry weight, probably as a result of direct wind, wave, seiche, and lake stage impacts (**Figure 10-18**). Indications from monthly transect sampling through WY2006 showed that the SAV community had been severely affected. A reduction in lake-wide SAV coverage from 54,875 ac in late summer 2004 to 10,872 ac in late summer 2005 was revealed during the 2005 annual SAV mapping survey (**Figure 10-19**). Similarly, the full extent of the damage caused by Hurricane Wilma will not be known until the results of the 2006 annual mapping survey are completed. However, monthly transect data suggest that there has been no recovery of SAV since the 2005 annual mapping exercise and additional losses of SAV may have occurred as a result of the influence of Hurricane Wilma.

Light availability for SAV growth is dependent on a combination of water transparency and lake stage. A transparency ratio of 0.5 or greater is desirable because it signifies that sunlight can penetrate to the lake bottom and stimulate SAV growth. This metric is typically applied on a site specific basis since bathymetry and water transparency vary spatially throughout the lake. A transparency ratio greater than 0.5 was found in only three percent of the nearshore samples in WY2006.

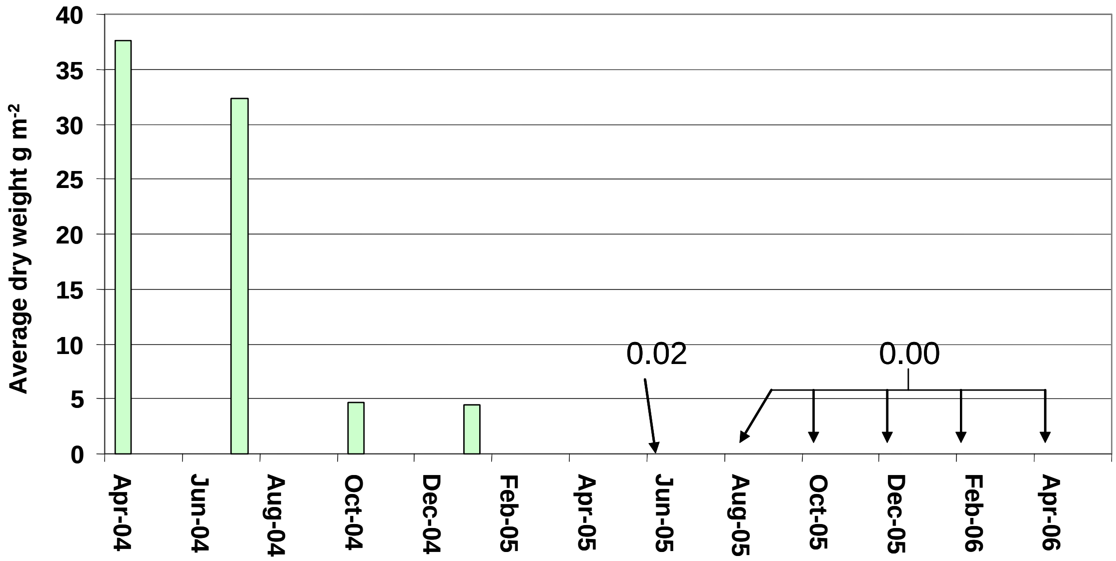


**Figure 10-18.** Results of monthly submerged aquatic vegetation (SAV) transect sampling (April 2004–May 2006).

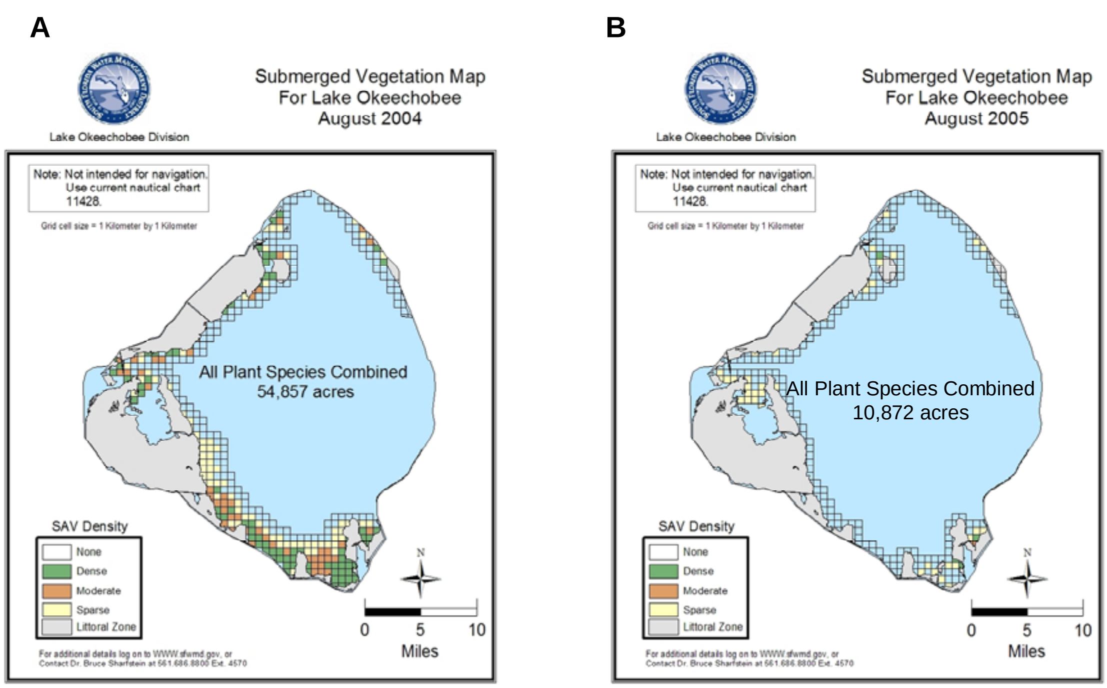


**Figure 10-19.** Annual SAV mapping results for (A) 2004 before hurricanes Frances and Jeanne, and (B) 2005 before Hurricane Wilma.

## EFFECTS ON EMERGENT VEGETATION, VEGETATION RESTORATION PROGRAMS, AND IN-LAKE INFRASTRUCTURE

After Hurricane Wilma's eye passed to the southeast of the lake, the wind shifted to the northwest, and most of the cattail (*Typha* spp.) in the southeastern portion of South Bay was uprooted and transported to Torry and Kreamer islands and the rim canal to the east of these islands (**Figure 10-20**). The USACE facilitated the removal of approximately 117,000 cubic yards of dead vegetation (mostly cattail) that contained over 7.5 mt of phosphorus. The cattail rack was dense enough to clog approximately 2 to 3 miles of the Rim Canal, making navigation through that stretch of the canal impossible for several months thereafter (**Figure 10-21**). Additionally, the Torry Island Campground and Marina suffered extensive damage (**Figure 10-22**).

**Figure 10-20.** Cattail wrack piled up on Torry Island (photo by SFWMD).

**Figure 10-21.** Dead vegetation in the Rim Canal being removed by an aquatic weed harvester (photo by SFWMD).

**Figure 10-22.** Damage to the Torry Island Campground (photo by SFWMD).

# LAKE RESEARCH AND BIOMONITORING

## SUBMERGED AQUATIC VEGETATION

The lake research/modeling program continues to focus on (1) developing a predictive understanding of how SAV responds to variations in underwater irradiance; (2) quantifying the role of SAV in the nearshore phosphorus cycle; and (3) enhancing an existing hydrodynamic and water quality model of the lake to provide spatially explicit predictions regarding lake-wide water quality and nearshore SAV dynamics. As previously noted, there is also an ongoing research program aimed at optimizing methods for the control of torpedograss and other exotic and nuisance plants. Chapter 9 of this volume provides further information on exotic species and on biomonitoring of invertebrates, fish, and emergent aquatic vegetation.

### Light Influence on SAV Growth and Germination

Current investigations continue to evaluate the effects of light intensity on growth and germination of the four major species of SAV in Lake Okeechobee: eelgrass (*Vallisneria* sp.), musk grass (*Chara* sp.), hydrilla (*Hydrilla verticillata*) and peppergrass (*Potemogeton* sp.). This work is being done to aid the development of an evaluation tool to predict the effect of alternative lake management strategies on environmental conditions in Lake Okeechobee.

By the end of WY2006, the light requirements for growth of eelgrass, musk grass, and hydrilla have been determined. An experiment to determine the light requirements of peppergrass was conducted during summer 2006.

Results indicated that eelgrass has the highest light requirement for growth, followed by musk grass and hydrilla. Similarly, for the same light levels, hydrilla has the most rapid growth rate, followed by musk grass and eelgrass. These studies also indicated that light is required for seed germination of eelgrass and peppergrass. (Musk grass germination experiments were under way early in WY2007.)

### Current Velocities Inside SAV Beds in Lake Okeechobee

Large SAV beds in the nearshore region of Lake Okeechobee may alter local flow patterns, reducing confidence in the reliability of model predictions of lake-wide circulation. In addition, reduction of current velocity in beds of dense SAV encourage the settling of particulate material, the uptake of nutrients into plant tissue and bottom sediments, leading to improved conditions conducive for plant bed expansion.

Acoustic Doppler current profilers (ADCPs) were deployed in two relatively large SAV beds to generate profiles of current movement across each bed under varying flow conditions. Both the Hydrilla-dominated and nearly monotypic eelgrass beds used in this study were moderately low in biomass (as measured by dry weight) for Lake Okeechobee. The experimental beds were located on the west side of King's Bar Island and approximately 3 km south of the mouth of the Kissimmee River. Three ADCP units in each bed were oriented in a north-south transect, with one unit each being positioned at the outside edge, halfway to the center, and at a central location in each bed. Flow data were collected in discrete 20 cm vertical segments of the approximately 2 m deep water column for 17 to 21 days. During periods of high flow and/or wind speed, current flow was in the same direction near the surface and in the bottom portion of the water column. Water transport rates during these periods were approximately 1.5 km/day. Kissimmee River outflow appeared to considerably influence flow direction and transport rates during high flow periods. When wind was light (e.g., less than 5 m/sec), flow patterns in the deeper portions of the water column were not the same as those in the surficial layers, and transport rates were low (e.g., 350 $m^2$/day at the central hydrilla site). Flow was less variable and most prominently reduced at the inner eelgrass bed site relative to its corresponding outer site, where a 60 percent and 44 percent flow reduction was recorded in the lower and upper layers, respectively. Flow reduction in the hydrilla-dominated bed was approximately 15 percent in both the upper and lower layers of the water column. Based on these data, the "meadow forming" eelgrass bed had a larger effect on transport rates and flow pattern alteration than the "canopy forming" hydrilla-dominated bed. Plant, sediment, and water column nutrient data are in the process of being analyzed to identify the effects of SAV bed flow dynamics on these parameters.

## EMERGENT AQUATIC VEGETATION

### Bulrush

Giant bulrush (*Scirpus californicus*) stands, located in Lake Okeechobee at lake-bed elevations of 10 to 10.5 ft (3 to 3.2 m) NGVD, appeared to suffer damage when exposed to prolonged periods of deep flooding. These bulrush stands provide important fish and wildlife habitat. They also dampen wave energy and stabilize bottom sediments, thus, reducing turbidity and protecting desirable submerged vegetation behind the bulrush barrier. The concern is that excessive inundation of these stands due to prolonged occurrence of high stage levels might cause their failure. Loss of the protective bulrush stands might cause a cascade of events leading to loss of other native vegetation and degradation of water quality and wildlife habitat.

An evaluation of the influence of water depth on the persistence of giant bulrush was conducted to support prudent management of the lake and minimized adverse effects of stage level manipulation. The results of this study indicate that undisturbed bulrush can persist at a water depth of three ft or less (lake stage of 13–13.5 ft, or 3.9–4.1 m NGVD); however, prolonged periods of water depths greater than 3 ft (0.9 m) may cause bulrush stands to fail. Disturbances such as herbivory or strong winds appear to reduce the ability of giant bulrush to persist at the 3 ft (0.9 m) inundation. Based on data collected from this study, inundation of bulrush stands should be maintained at less than 3 ft (0.9 m) to minimize adverse effects of stage level manipulation on the persistence of giant bulrush.

### 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 GIS map was developed in 2005 using color infrared aerial photography collected in 2003 (**Figure 10-23**). Analysis of these maps indicates that there have been a number of changes in the littoral landscape.

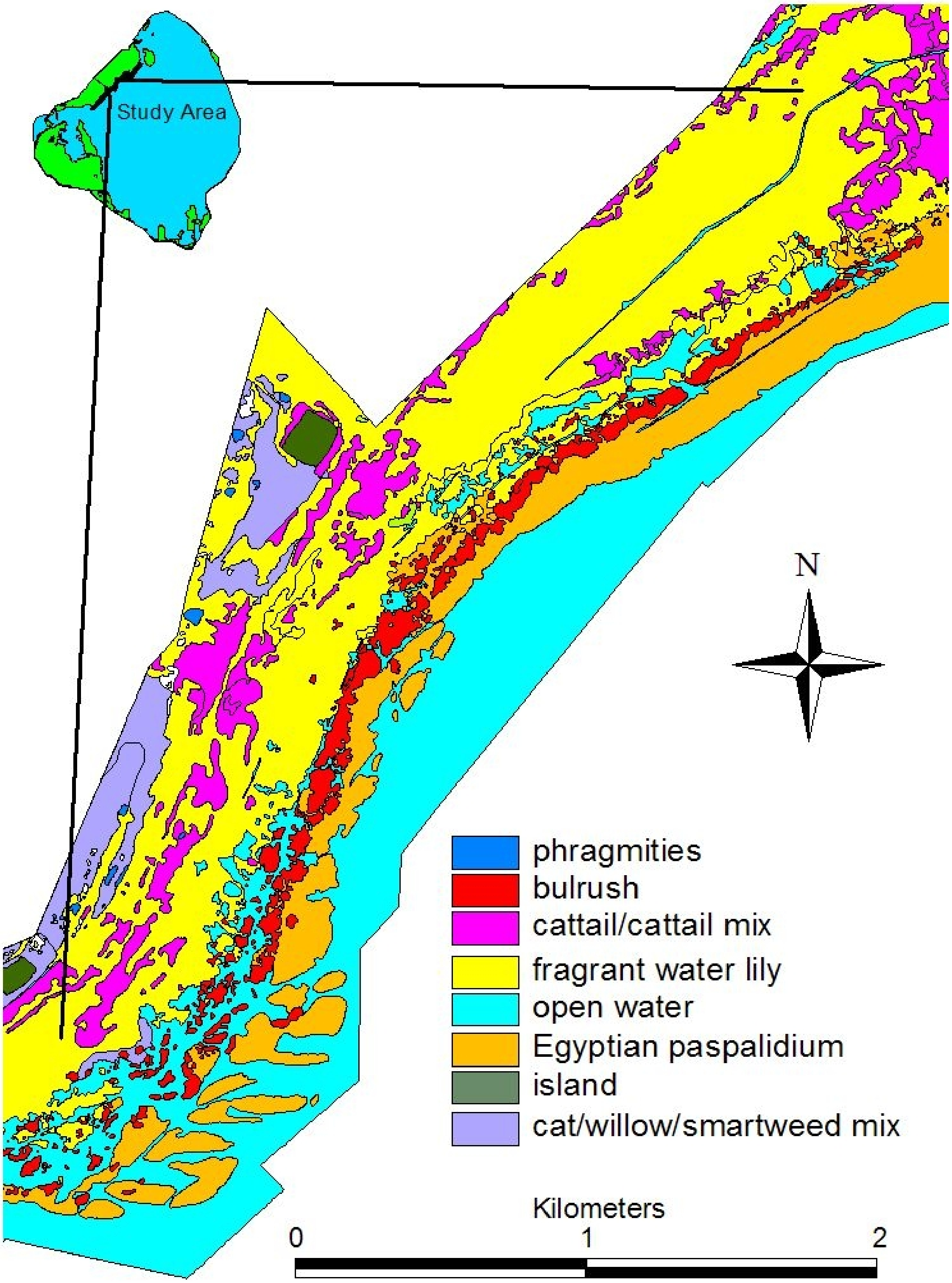


**Figure 10-23.** Emergent vegetation along the northwest edge of the marsh in Lake Okeechobee (2003).

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 baldwinii*), 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 (with a shorter hydroperiod), 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). This reduction is attributed to large-scale fires and the record drought of 2001 and 2002. Although the total acreage of cattails decreased, the distribution of cattail increased 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 with herbicide in 2000 to 2002. The distribution of fragrant water lily increased to nearly 11,000 ac (4,452 ha). Although fragrant water lily is a native, excessive growth of this plant may not be desirable because large amounts of detrital material can accumulate in dense lily beds.

The distribution of bulrush along the northwest marsh edge has been monitored closely since 1999 (**Figure 10-24).** Bulrush coverage varied from 194 ac (78 ha) in 1999, 266 ac (108 ha) in 2001, 193 ac (78 ha) in 2002, 167 ac (68 ha) in 2003, to 285 ac (116 ha) in 2005. The increase in bulrush coverage in 2001 occurred in conjunction with a large reduction in lake stage during the drought. The reductions in bulrush coverage that occurred after 2001 occurred in conjunction with prolonged exposure to extreme dry conditions (sediments exposed greater than 4 months) followed by exposure to excessive flooding depths that exceeded 2 m.

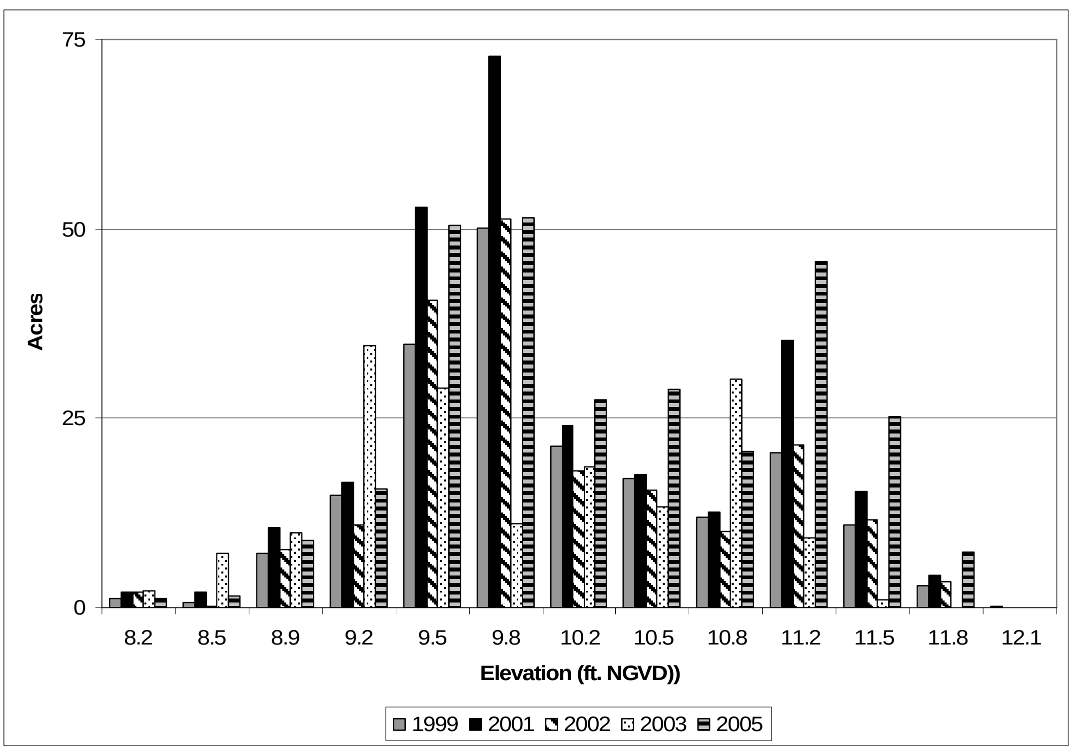


**Figure 10-24.** Aerial coverage (hectares) and distribution of bulrush by calendar year (1995–2005) and elevation along the lakeward edge of Lake Okeechobee's northwest marsh.

## EXOTIC SPECIES

The District has not tracked exotic animals on the lake, and exotic plant tracking is limited to torpedograss and melaleuca. Melaleuca is now totally controlled on the lake; annual treatments are now aimed primarily at seedling control. The torpedograss population on the lake currently stands at approximately 16,000 ac. Five-thousand ac were treated in both 2004 and in 2005. Torpedograss control is keeping up with, and may be gaining on, its rate of spread (see *Vegetation Management* section of this chapter). The hurricanes of 2004 and 2005 appear to have had minimal impact on either melaleuca or torpedograss.

## LAKE MACROINVERTEBRATE STATUS – IMPLEMENTATION OF A THREE-YEAR BASELINE MONITORING STUDY

The first year of a three-year baseline assessment of the lake's sublittoral macroinvertebrate community was completed in WY2006 (**Table 10-11**). Triplicate samples were collected in August 2005 and February 2006 from the same eighteen pelagic sites sampled by Warren et al. (1995). Six sites each were located in the three dominant sediment types (mud, peat, and sand); and within-sediment site locations were determined by water column depth. A total of 48 taxa were collected, representing 20 major taxonomic groups. Oligochaetes (segmented worms) accounted for 64 percent of the total number of organisms in the pelagic zone, and they dominated the mud and sand zone assemblages. Acarina (water mites) were the most abundant taxa in the peat zone, followed by the exotic Asian clam (*Corbicula fluminea*). Chironomids (midge fly larvae), which comprised 26 percent of pelagic benthos abundance from 1987 to 1991, accounted for only 3 percent of the abundance during 2005. Gastropods, amphipods, and chironomids, which were common in past years, had either very low abundances or were absent from the 2005 samples. Overall, the assemblage continued to reflect poor, and possibly deteriorating, water quality conditions, as has been reported in previous studies.

**Table 10-11.** Macroinvertebrate densities and diversity indices for different areas of Lake Okeechobee (derived from Warren et al., 2006).

| | **Habitat** | | |
|---|---|---|---|
| **Statistic** | **Mud no. m$^{-2}$ (c.v.)*** | **Sand no. m$^{-2}$ (c.v.)*** | **Peat no. m$^{-2}$ (c.v.)*** |
| Total Taxa | 14 | 33 | 30 |
| Mean Total Organisms | 1,521 (0.72) | 5,841 (0.98) | 2,652 (1.55) |
| Mean Taxa Richness | 3.31 (0.31) | 7.44 (0.36) | 6.33 (0.67) |
| Mean Diversity | 1.15 (0.28) | 1.79 (0.32) | 1.67 (0.44) |
| Mean Evenness | 0.71 (0.25) | 0.65 (0.28) | 0.71 (0.36) |

* Coefficient of variation expressed as proportion (not percent).

# FISH

## Population Structure

The District's Lake Okeechobee Division through the Restoration Coordination and Verification (RECOVER) Program is supporting a three-year study being conducted by the Florida Fish and Wildlife Conservation Commission (FWC) to evaluate the status of the Lake Okeechobee fishery. This work is a continuation and expansion of the study, for which results were presented in the 2006 SFER – Volume I, Chapter 10.

### *ELECTROFISHING*

Lake-wide electrofishing was conducted in late September and early October 2005. Twenty-two predetermined sites located in the interior marsh and along the lakeward edge of the western marsh were sampled. At each site, three 15-minute periods of electrofishing were conducted for a total of 990 minutes. The electrofishing caught 1,629 fish with a combined biomass of 492,393 grams. Twenty-three fish species were represented in the catch. The seven most numerically abundant species, which comprised 86 percent of the catch, were white catfish (*Ameiurus catus*), Florida gar (*Lepisosteus platyrhincus*), threadfin shad (*Dorosoma petenense*), gizzard shad (*Dorosoma cepedianum*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*). The seven species most abundant by weight were Florida gar, largemouth bass, white catfish, Orinoco sailfin catfish, bluegill, bowfin (*Amia calva*), and gizzard shad, which comprised 82 percent of the catch.

The largemouth bass population in Lake Okeechobee has been monitored with the standardized lake-wide electrofishing protocol since fall 1992. Largemouth bass recruitment was poor from 1999 to 2001, improving somewhat in 2002 and 2003 in response to the resurgence of the SAV community after the managed recession and drought of 2000 and 2001. Extremely high lake stages commencing in 2003 began to impact habitat, resulting in decreased recruitment of largemouth bass. Hurricanes Frances and Jeanne in 2004 further reduced the areal coverage of aquatic plant communities, resulting in very poor recruitment of young-of-the-year largemouth bass in 2005 (**Figure 10-25**). Also, the catch rate, based on catch-per-unit effort (CPUE) for largemouth during fall 2005 (0.16 fish/minute), was the second lowest observed catch rate since the standardized sampling program was initiated. Without substantial largemouth bass recruitment in 2006 and 2007, the sustained viability of a quality largemouth bass fishery in Lake Okeechobee is in question.

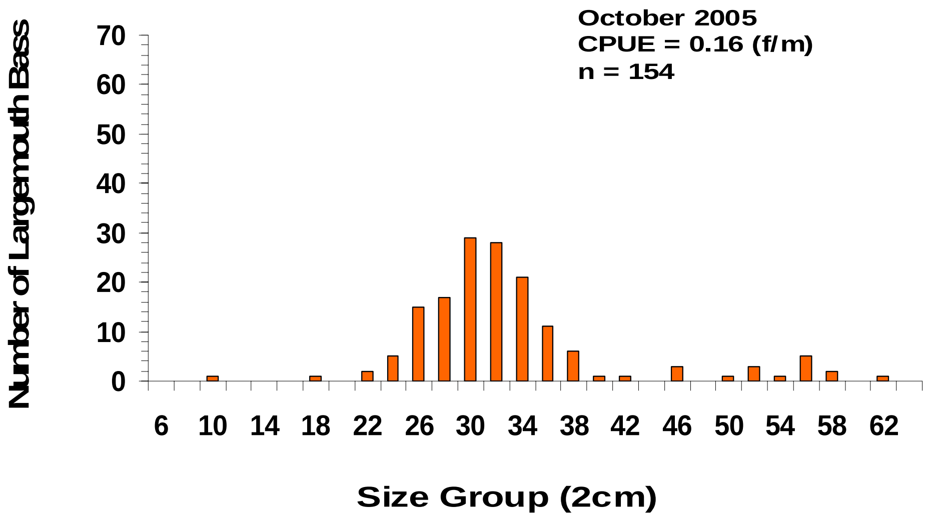


**Figure 10-25.** Length frequency plot of largemouth bass collected through electrofishing from Lake Okeechobee (fall 2005). Annual sampling effort was 990 minutes (three 15-minute repetitions at each of 22 sites).

***TRAWL***

Lake-wide trawl sampling was conducted in mid-December 2005. Sampling occurred at 27 pre-determined sites (1988–1991 lake-wide trawl sampling sites) located in the nearshore and open water areas of Lake Okeechobee. Two 10-minute replicate trawls were conducted at each site for a total of 540 minutes of trawling. Lake-wide trawl sampling resulted in the capture of 1,145 fish for a combined biomass of 85,644 grams. Fourteen fish species were represented in the catch. The three species that collectively comprised 83 percent of the catch by abundance were white catfish, black crappie (*Pomoxis nigromaculatus*), and threadfin shad. The two species that collectively comprised 87 percent of the catch by weight and in order of biomass were white catfish and Florida gar.

Comparison of lake-wide trawl sampling data from fall 2005 and data averaged for the 1988–1991 period indicated notable variations. The fall 2005 catch of 1,145 fish resulted in a CPUE of 2.12 fish/minute, compared to an annual average catch of 6,052 fish for a CPUE of 11.21 fish/minute during the 1988–1991 period. The annual catch of adult (> 200 mm in size) black crappie in 1988–1991 was 2,037 fish, compared to a catch of only five adult black crappie in all of 2005. During fall 2005 sampling, 80 threadfin shad were collected, compared to an annual average of 2,992 threadfin shad in the 1988–1991 period. Historical food habit analysis indicate young-of-year threadfin shad and gizzard shad are almost the exclusive forage of adult black crappie in Lake Okeechobee, which may help to explain the low adult population numbers encountered in this sampling.

# MODEL RESEARCH

## Lake Okeechobee Conceptual Ecological Model

At the request of RECOVER, the District's Lake Okeechobee Division scientists developed a revised Lake Okeechobee Conceptual Ecosystem Model (LOCEM) document organized by trophic guild rather than by environmental stressor. Further details on the revised LOCEM can be found on the District's web site at www.sfwmd.gov under the *What We Do, Watershed Management, South Florida Watersheds, Okeechobee* section and the *Documents* tab**.**

# WATER QUALITY MODELING

The Lake Okeechobee Water Quality Model (LOWQM) (2006 SFER – Volume I, Chapter 10) simulates algal, nutrient, and sediment dynamics on a whole lake scale. It has been used for numerous projects in the Lake Okeechobee Phosphorus TMDL (FDEP, 2001), the sediment management feasibility study (BBL, 2003; James and Pollman, in prep), and currently with the Lake Okeechobee Watershed Project. The sediment water interactions are influenced by constant settling rates, sediment resuspension rate determined through calibration of suspended solids, and flux of dissolved inorganic nutrients. While the sedimentation coefficient can be adjusted to account for possible interactions with declining calcium and increasing sulfate, currently there is no direct mechanism that dynamically changes this coefficient over time. Future development of the LOEM may consider these interactions.

## Enhancement of the Wind-Wave and SAV Module of the Lake Okeechobee Environment Model

The wind-wave model Simulating Waves Nearshore (SWAN) for the Lake Okeechobee Environment Model (LOEM) has been updated. The model has been used to simulate wind waves in the lake from 2004 to 2005. The model more accurately predicts the large wind waves during the hurricanes. Using these wave predictions, the LOEM simulated the hydrodynamic, sediment processes, and water quality during and after hurricanes from 2004 through 2005, including Charley, Frances, and Jeanne in 2004, and Wilma in 2005. The modeling results indicated that the hurricanes have had lasting impacts on the sediment transport, sediment resuspension, and nutrient exchange between the lake bed and the water column. For instance, Hurricane Frances led to huge bottom shear stress on the lake bottom (**Table 10-9**; **Figure 10-14, Panel A**), which caused large resuspension of sediment and nutrients to the lake water column.

# IN-LAKE MANAGEMENT

## REVISION OF THE LAKE OKEECHOBEE OPERATING SCHEDULE

The current Lake Okeechobee Water Supply and Environmental (WSE) Operating Schedule can restrict water releases from the lake, which results in lake stages higher than desirable for the ecosystem. This condition has been exacerbated by recent above-average rainfall years and the passage of four hurricanes over the lake or its northern watershed in 2004 and 2005, which caused rapid increases in lake stage by more than 4.5 ft (1.4 m) during 2004 and 2.5 ft (0.8 m) during 2005.

The revision of the Lake Okeechobee's operating schedule will optimize it within existing structural constraints to meet the diverse requirements of the lake, its receiving waters, and its users. This project is led by the USACE, with Project Delivery Team (PDT) support from the SFWMD as the local sponsor, and input from the USFWS, the Florida Fish and Wildlife Conservation Commission, the city of Sanibel, and Martin and Lee counties.

The goal of this revision is to bridge the gap until implementation of the many CERP, Acceler8, and LOER Fast-Track projects begins in 2009. The project was expedited with the approval and implementation of a revised regulation schedule early in 2007. Alternative regulation schedules were evaluated against performance measures that were developed as part of RECOVER. Each alternative evaluated includes temporary forward pumps as a component in the event of extreme low lake stages [< 11 ft (< 3.4 m) NGVD], similar to conditions that arose during the 2000–2001 drought. The temporary pumps are being manufactured and will be ready for installation, if needed, at S-351, S-352, and S-354. Additional solutions are being developed for supplemental deliveries north of the lake.

Prior to the USACE modeling efforts, regional meetings were held to gather public input, which resulted in a total of 11 alternatives/sensitivity runs being initially modeled, integrating both public input and agency participation.

Each PDT member agency selected their recommended alternatives, based on the approved set of Performance Measures, to be advanced into the study's final array of alternatives for full evaluation. These recommendations were based on overall system-wide benefits including estuaries, Lake Okeechobee, Water Quality Everglades/Water Conservation Areas, and Water Supply Lake Okeechobee Service Area, Lower East Coast Service Area, snail kite habitat, Herbert Hoover Dike integrity, and navigation impacts.

In June 2006, a Tentatively Selected Plan (TSP) was identified by the USACE to balance the performance measure criteria established for plan evaluation. Substantial comments were received at the public meetings held throughout South Florida to present the TSP and the Supplemental Environmental Impact Statement (SEIS). As a result, the initial implementation date of January 2007 has been extended further into 2007 to allow sufficient time for the USACE to address concerns with the TSP and better balance the performance measures of the physiographic areas under consideration. New alternatives will be evaluated, and a revised SEIS and Water Control Plan will be developed accordingly.

## VEGETATION MANAGEMENT

Aerial and ground treatments of exotic and invasive emergent vegetation continued in 2005–2006. Approximately 5,000 ac (2,023 ha) of torpedograss and 3,000 ac (1,214 ha) of cattail 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 25,000 ac (10,117 ha) of torpedograss and 7,400 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 recent wild fires in some of the treated areas have helped reduce cattail wrack. Recently opened areas are being utilized by anglers and wading birds. Changes in the marsh community continue to be monitored and quantified through the use of GIS-based vegetation maps.

## HABITAT RESTORATION

In recent years, the Lake Okeechobee Division funded the planting of approximately 6,000 pond apple (*Anona glabra*) trees on Torry Island in the southern end of Lake Okeechobee as part of habitat restoration efforts undertaken in conjunction with the city of Belle Glade. Unfortunately, hurricanes in 2004 and 2005 destroyed nearly all of these trees. Planting efforts for pond apple and cypress (*Taxodium* spp.) are under way on the restored shoreline of Ritta Island in the southern end of Lake Okeechobee. This joint effort between the SFWMD and the FWC follows the removal of an approximate five mile length of agricultural levee in 2004 to restore the hydrologic connection between the island’s interior and the lake. Planting efforts were delayed in 2004 and 2005 due to high lake levels resulting from a combination of extremely wet rainy seasons and the hurricanes that impacted the lake.

About 100 plants of the federally listed, endangered Okeechobee gourd were discovered growing among the hurricane debris piles that were deposited along Lake Okeechobee’s shore after Hurricane Wilma uprooted significant amounts of vegetation from the lake and the southern islands. These plants were carefully removed from the debris piles and transported to adjacent spoil islands by the USACE and the SFWMD staff prior to the final removal of the debris. Although few transplants survived, the Okeechobee gourd was found thriving on spoil islands that were created by the FWC with materials derived from the removal of an organic berm along the northwestern marsh of the lake during the 2001 drought.

## SEDIMENT MANAGEMENT

As described in previous consolidated reports, the District sponsored a thorough evaluation of sediment management in Lake Okeechobee (BBL, 2003). The study considered methods to manage the sediments on a whole lake scale to reduce the internal load of phosphorus from the sediment to the water column. The three final comparisons were dredging ($3 billion, 2002 dollars), chemical treatment ($500 million), and no in-lake action. The three scenarios were compared using two separate water quality models: the Internal Loading Phosphorus Model (ILPM) and the Lake Okeechobee Water Quality Model (LOWQM) (James and Pollman, in prep). The no in-lake action, which included reaching the phosphorus TMDL, showed progressive improvements of water quality that approached the in-lake restoration goal of 40 µg/L of phosphorus within 40 years. Chemical treatment predicted this goal would be reached in 15 years. Dredging likely will leave a veneer of mud sediments and, as a result, will not produce any major improvements in water quality conditions compared to the baseline. Dredging may actually exacerbate the recovery. Of the three options only chemical treatment was anticipated to improve the lake substantially over the no in-lake action. However, external load reductions to meet the phosphorus TMDL (FDEP, 2001) would still be needed to maintain lower phosphorus conditions. The no in-lake action alternative was selected as the preferred alternative.

The models used in this study both included sediments and sediment burial, which was based on sediment accumulation estimates in Lake Okeechobee developed from $^{210}$Pb dating of mud sediments (Brezonik and Engstrom, 1994). They estimated an accumulation of 1 cm of sediment per decade. Using that result, and additional information that assumed the top 5 or 6 cm of sediments could be actively remixed, it would take approximately 30 years to remove half of the available phosphorus from the sediment. With the impacts of hurricanes Frances and Jeanne, which stirred up at least 10 cm of the sediments, this estimate of available phosphorus was low and the time to remove half of the available phosphorus from the sediment has increased.

# CONCLUSIONS

A comprehensive array of state and federal projects has been undertaken within and in the watershed of Lake Okeechobee to address the key issues of excessive phosphorus loading, harmful high water levels, and exotic plants. Projects are being implemented in a cooperative manner by the SFWMD, FDEP, and FDACS. Considerable progress has been made to control the spread of exotic plants in the lake, watershed projects have been implemented to reduce phosphorus transport from agricultural lands and capture runoff water during high rainfall periods, and modifications to the lake regulation schedule are under consideration. Because of the complex nature and long history of problems associated with the lake, full implementation of the LOPA will require more than a decade, and improvements in lake water quality are expected to be slowed by internal nutrient recycling. Ongoing research in the watershed is helping to optimize the design of phosphorus reduction/flow attenuation measures, and research in the lake is providing guidance for adaptive management of water levels and exotic plants. Restoration of water quality and ecosystem functions in Lake Okeechobee is critical to South Florida as it is an integral part of the Kissimmee-Okeechobee-Everglades ecosystem and an important component of the flood control and water supply network of South Florida.

Recent hurricanes in South Florida have resulted in the re-suspension of sediment within the lake and redistribution of this material throughout the lake including the littoral zones. These storm events also created extended periods of high water levels. As a result of suspended sediments and high lake levels in-lake, phosphorus concentrations have increased and submerged aquatic vegetation has decreased, creating a concern for the fisheries and the already fragile ecosystem in the lake. In addition, these storms were primarily responsible for the large increase in phosphorus loading to the lake from the watershed. Two years after following multiple hurricanes in 2004 and 2005, the lake still struggles to recover from the impacts of these damaging storms.

# APPROPRIATIONS/EXPENDITURES

The FY2001–FY2006 summary of state of Florida funding appropriations and expenditures for the Lake Okeechobee Protection Program is presented in **Table 10-12**. FY2006 values reflect preliminary financial information as of September 30, 2006. Final values are expected to be received in early 2007. There were no appropriations from the state in FY2004, and FDACS received no state appropriations during FY2006.

**Table 10-12.** State funding appropriations and expenditures for the Lake Okeechobee Protection Program (FY2001–FY2006).

**Note**: FY2006 financial data is preliminary as of September 30, 2006.

| Agency | Appropriation | Expended to date | Available |
|---|---|---|---|
| FY01 SFWMD Appropriation | $8,500,000 | $8,500,000 | $0 |
| FY01 SFWMD Appropriation | $15,000,000 | $15,000,000 | $0 |
| **FY01 SFWMD Total** | **$23,500,000** | **$23,500,000** | **$0** |
| FY02 SFWMD Appropriation | $10,000,000 | $8,171,438 | $1,828,562 |
| **FY02 SFWMD Total** | **$10,000,000** | **$8,171,438** | **$1,828,562** |
| FY03 DEP TMDL Implementation Funds | $850,000 | $811,860 | $38,140 |
| FY03 SFWMD Appropriation | $7,500,000 | $0 | $7,500,000 |
| **FY03 SFWMD Total** | **$8,350,000** | **$811,860** | **$7,538,140** |
| FY05 SFW51 - Nubbin Slough | $4,300,000 | $986,621 | $3,313,379 |
| FY05 SFWMD Appropriation | $5,000,000 | $0 | $5,000,000 |
| FY05 - DEP Nubbin Slough | $3,300,000 | $0 | $3,300,000 |
| FY05 - Hydromentia | $1,800,000 | $74,297 | $1,725,703 |
| **FY05 SFWMD Total** | **$14,400,000** | **$1,060,918** | **$13,339,082** |
| Fast Track Projects - Reimbursable Expenditures | $25,000,000 | $2,978,257 | $22,021,743 |
| **FY06 SFWMD Total** | **$25,000,000** | **$2,978,257** | **$22,021,743** |
| **Grand Total - SFWMD State Appropriation** | **$81,250,000** | **$36,522,473** | **$44,727,527** |
| 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 |
| **Total Outside Agency State Appropriation** | **$20,700,000** | **$20,700,000** | **$0** |
| **Total for Lake Okeechobee Program** | **$101,950,000** | **$57,222,473** | **$44,727,527** |

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