Chapter 11: Kissimmee River Restoration and Upper Basin Initiatives

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SUMMARY

The Kissimmee watershed forms the headwaters of the Kissimmee-Okeechobee-Everglades system (**Figure 11-1**). The watershed encompasses a diverse group of wetland and aquatic ecosystems, including more than two dozen lakes, their tributary streams, and the Kissimmee River. The key strategic priority of the Kissimmee Division is to integrate Kissimmee watershed management strategies with Kissimmee River restoration. In line with this priority, the primary goals of the Kissimmee Division are to restore ecological integrity to the Kissimmee River and its floodplain ecosystem, develop a long-term management plan for resolving water and other management issues in the Kissimmee Chain of Lakes, and retain the existing level of flood control in the Kissimmee watershed.

Major initiatives in the Kissimmee watershed are the Kissimmee River Restoration Project (KRRP), which includes the Kissimmee River Restoration Evaluation Program (KRREP) and Kissimmee Basin Modeling and Operations Study (KBMOS); Kissimmee River Headwaters Revitalization Project (KRHRP); and Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP) (**Figure 11-2**). A number of activities are associated with these projects including ecosystem restoration, restoration evaluation, aquatic plant management, land management, water quality improvement, and water supply planning.

The primary goal of the Kissimmee River Restoration Project is to reestablish the ecological integrity of the river-floodplain system, which is defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community having species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley, 1981). Restoration of ecological integrity requires reconstruction of the physical form of the river (i.e., canal backfilling, removal of water control structures, and elimination of secondary drainage ditches, levees, and roads) and reestablishment of historic (pre-channelization) hydrologic (i.e., discharge and stage) characteristics.

The KRREP is a key element of the restoration project. In addition to assessing restoration success, the evaluation program will provide scientific information for fine-tuning future project phases and for management of the water resources of the recovering and restored ecosystem. To address the goal of ecological integrity, the evaluation program has a broad scope encompassing hydrology, geomorphology, water quality, and major biological communities including plants, invertebrates, reptiles, amphibians, fish, and birds. All evaluation components were monitored prior to restoration to establish a baseline for evaluating future changes. The KRREP will continue until 2017, five years beyond completion of project construction.

A comprehensive description of the restoration evaluation program and initial responses (as of WY2004) to restoration activities in the Phase I area were reported in the 2005 and 2006 SFER – Volume I, Chapter 11. A subset of evaluation projects were monitored during WY2006, and these results are reported in this chapter. Results from WY2006 include: (1) mean concentration of dissolved oxygen (DO) in the restored river channel continues to exceed baseline (pre-restoration) values, (2) turbidity and total suspended solids in the river channel water column remain low, (3) neither the loads nor concentrations of total phosphorus have declined at the water S-65C structure lying just downstream of the Phase I area, and (4) highest densities thus far were recorded of both long-legged wading birds and waterfowl on the restored floodplain.

Phase I of the Kissimmee River Restoration Project was completed in February 2001. This effort involved filling approximately 7.5 miles (12 kilometers, or km) of the C-38 canal, recarving approximately 1.25 miles (2 km) of river channel, and demolishing the S-65B structure to reconnect 15 miles (24 km) of continuous river channel. A second phase of backfilling was initiated in June 2006. This phase will backfill an additional 1.9 miles (3 km) of canal, remove three navigable sheet pile weirs located on C-38, and excavate a small section of new river channel. Construction for KRRP is projected to be completed in 2012.

The primary purpose of the Kissimmee River Headwaters Revitalization Project, which will be completed in 2011, is to provide the water storage and regulation schedule modifications needed to approximate the historical flow characteristics of the Kissimmee River system. A secondary project purpose is to increase the quantity and quality of lake littoral zone habitat in Lakes Kissimmee, Hatchineha, Tiger, and Cypress for the benefit of fish and wildlife (USACE, 1996; Sections 1.3.2, 5.1). In June 2001, in an effort to improve water deliveries to the Kissimmee River until KRHRP is completed, an interim operation schedule was implemented for water control structure S-65, which regulates discharge from Lake Kissimmee into the Kissimmee River. This interim schedule provides a strategy for meeting KRRP needs for continuous flow by allocating water for discretionary releases. Although beneficial to the river, the interim schedule does not provide all of the benefits of the KRHRP.

The Kissimmee Basin Modeling and Operations Study, which is funded under KRRP, will assess how existing operations in both the Upper and Lower Basin can be modified to meet the hydrologic requirements for KRRP; achieve a more acceptable balance among basin operating objectives for flood control, water supply, aquatic plant management, and natural resource water management; and balance impacts across ecosystems including Lake Okeechobee. The geographic scope of the project includes both the Upper and Lower Basins. The KBMOS will evaluate alternative operations for the 13 structures controlling flow through the Kissimmee Chain of Lakes and the Kissimmee River. During Water Year 2006 (WY2006) (May 1, 2005–April 30, 2006), drafts were developed of evaluation performance measures that will be used to select among alternative operations schedules. Two sets of modeling tools were also under development during WY2006, including an OASIS water budget model, which is a management simulation engine that will be used for the screening of conceptual alternatives and a MIKE SHE/MIKE 11 hydrologic/hydraulic model that will be used as the alternative formulation/evaluation tool. The KBMOS is scheduled for completion in December 2007.

The Kissimmee Chain of Lakes Long-Term Management Plan was initiated in April 2003 through SFWMD Governing Board Resolution No. 2003-468, which directed SFWMD staff to work with the U. S. Army Corps of Engineers (USACE) and other interested parties to improve the health and sustainability of the Kissimmee Chain of Lakes by developing a long-term management plan for 19 regulated lakes in the Upper Basin. During the last year, a Conceptual Ecological Model (CEM) of a generalized KCOL lake was completed. The model was composed of a hierarchy of anthropogenic drivers, stressors, ecological effects, and attribute categories. Altered hydrology, drainage of wetlands, fire suppression, dense exotic plants, and altered nutrient levels were identified as the primary human-related stressors of the system. Assessment performance measures and indicator measures that fall under each of the attribute categories are currently under development in collaboration with interagency partners. These measures will be used to track status of KCOL water bodies. In association with performance and indicator measures, a recommended data collection and monitoring plan is also being developed.

During WY2006, rainfall in the Upper Basin totaled 52.91 inches, which exceeded the historical average by 2.82 inches, and the Lower Basin totaled 48.50 inches, which exceeded the long-term average by 4.05 inches. Notable rainfall patterns included a wet June, high rainfall in October associated with Hurricane Wilma, and a very dry spring. For the fifth consecutive year, continuous releases from Lake Kissimmee into the Kissimmee River via the S-65 structure were maintained. The total volume discharged at S-65 was 1,468,257 acre-feet (ac-ft), and approximately half of that volume was made at discharges >3,000 cubic feet per second for flood control.

INTRODUCTION

The Kissimmee watershed of South-Central Florida forms the headwaters of the Kissimmee-Okeechobee-Everglades (KOE) ecosystem, and encompasses an area of approximately 3,000 square miles, or mi^2 (7,800 square kilometers, or km^2) (SFWMD, 2003). The watershed includes the basins of the Kissimmee River (Lower Basin), the Kissimmee Chain of Lakes (Upper Basin), and Lake Istokpoga (**Figure 11-1**). The Kissimmee Chain of Lakes/Kissimmee River system is the single largest source of surface water for Lake Okeechobee, accounting for approximately 34 percent of inputs (SFWMD, 2002). The key strategic priority of the Kissimmee Division is to integrate Kissimmee Watershed management strategies with Kissimmee River restoration. In line with this priority, the primary goals of the Kissimmee Division are to restore ecological integrity to the Kissimmee River and its floodplain ecosystem, develop a long-term management plan for resolving water and other management issues in the Kissimmee Chain of Lakes, and retain the existing level of flood control in the Kissimmee Watershed.

Major initiatives in the watershed are the Kissimmee River Restoration Project (KRRP), which includes the Kissimmee River Restoration Evaluation Program (KRREP) and the Kissimmee River Headwaters Revitalization Project (KRHRP); the Kissimmee Basin Modeling and Operations Study (KBMOS); and Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP) (**Figure 11-1**). A number of activities are associated with these projects including ecosystem restoration, restoration evaluation, aquatic plant management, land management, water quality improvement, and water supply planning.

Successful restoration of the Kissimmee River is largely dependent on reestablishing hydrologic conditions that are similar to the pre-channelization period (Toth, 1990a). The Kissimmee River Headwaters Revitalization Project was designed to help meet this requirement and to maintain the existing level of flood control within the Kissimmee Basin (USACE, 1996). The project involves Lakes Kissimmee, Hatchineha, Cypress, and Tiger (**Figure 11-2**) and includes land acquisition, adjustment of the S-65 regulation schedule, and modifications to structures and canals. The Kissimmee Basin Modeling and Operations Study and associated Environmental Impact Statement (EIS) for Modification of Kissimmee Basin Structure Operations are components of the KRRP. The KBMOS will assess how existing operations in both the Upper and Lower basins can be modified to meet the hydrologic requirements for KRRP, achieve a more acceptable balance between basin operating objectives for flood control, water supply, aquatic plant management, and natural resource water management objectives, and balance impacts across ecosystems including Lake Okeechobee. The project will evaluate alternative operations for the 13 structures controlling flow through the KCOL and the

Kissimmee River. Impacts of the alternative plans on discharges to Lake Okeechobee will be considered in the selection of an alternative. Together, the KRRP and KRHRP will restore ecological integrity to approximately 40 mi^2 (104 km^2) of the river-floodplain system (USACE, 1991; 1996). Restoration success will be evaluated via a comprehensive ecological monitoring program (Anderson et al., 2005; Bousquin et al., 2005).

The Kissimmee Chain of Lakes Long-Term Management Plan was initiated in April 2003 through SFWMD Governing Board Resolution No. 2003-468, which directed SFWMD staff to work with the U.S. Army Corps of Engineers (USACE) and other interested parties to improve the health and sustainability of the Kissimmee Chain of Lakes by developing a long-term management plan for 19 regulated lakes in the Upper Basin (**Figure 11-2**). This plan is currently under development and will address five goals: (1) hydrologic management, (2) habitat preservation and enhancement, (3) aquatic plant management, (4) water quality improvement, and (5) recreation and public use.

The objectives of this chapter are to describe the historical and current hydrologic status of the Kissimmee watershed, and provide an update of key Kissimmee Division initiatives; specifically, progress of the Kissimmee River Restoration Project, Kissimmee River Headwaters Revitalization Project, Kissimmee Basin Modeling and Operations Study, and Kissimmee Chain of Lakes Long-Term Management Plan.

KISSIMMEE WATERSHED HYDROLOGY

HISTORICAL CONDITIONS

Historically, the Kissimmee Chain of Lakes and the Kissimmee River were one integrated system comprised of headwater lakes connected by broad shallow marshes and creeks that eventually drained into the Kissimmee River. Lakes would rise in the wet season and overflow onto adjacent lands. The marshes were highly productive, supported diverse fish and wildlife populations, and served as natural water retention reservoirs that provided storage in the wet season and continuous discharge to the Kissimmee River throughout the year (USFWS, 1959). Annual discharge typically peaked in October through November, and decreased through the dry season (Obeysekera and Loftin, 1990).

The historical Kissimmee River meandered 103 mi (166 km) within a 1–2 mi (1.5–3 km) wide floodplain (USACE, 1991). The low-gradient [0.3 ft/mi (0.07 m/km)] river gradually sloped from an elevation of 51 ft (15.5 m) at Lake Kissimmee to 15 ft (4.6 m) at Lake Okeechobee (USACE, 1991). Pre-channelization stage and discharge records (1942–1960) suggest that continuous flow and seasonal water level fluctuations were integral hydrologic characteristics of the unmodified system (Obeysekera and Loftin, 1990; Anderson and Chamberlain, 2005). Discharge exceeded 250 cfs (7 m^3/s) during 95 percent of the period of record, with overbank flow typically occurring when flows exceeded 1,400 cfs (40 m^3/s) in the upper reaches and 2,000 cfs (57 m^3/s) in the lower reaches (Anderson and Chamberlain, 2005). Stage duration data and floodplain elevations adjacent to gauging stations suggest that 94 percent of the floodplain was inundated over 50 percent of the time (Koebel, 1995). When inundated, water depths were generally 1–2.3 ft (0.3–0.7 m), with depths greater than 3 ft (1 m) likely occurring over 40 percent of the floodplain (Koebel, 1995).

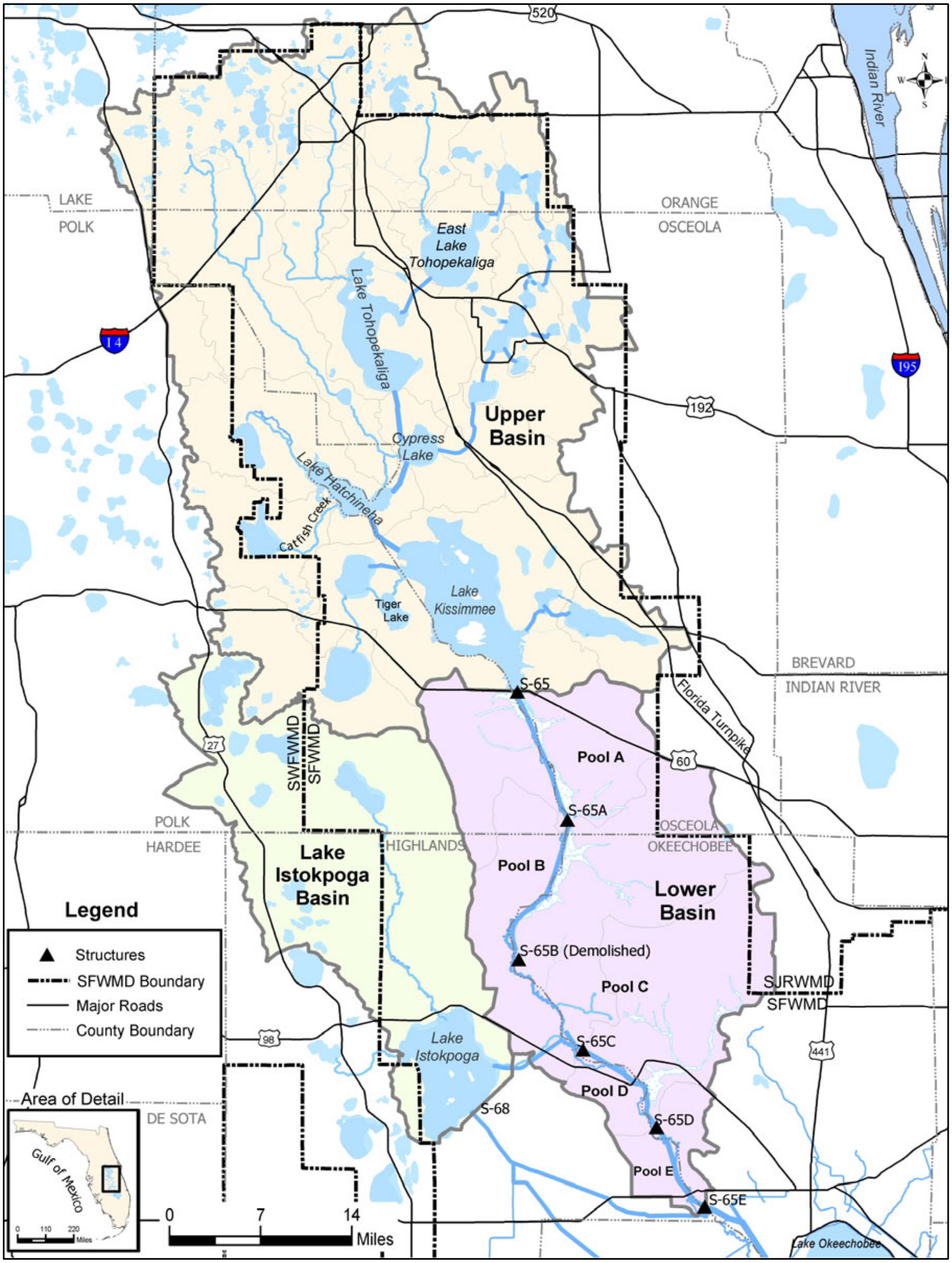


Figure 11-1. Geographic locations of the Upper Basin, Lower Basin, and Lake Istokpoga Basin of the Kissimmee watershed.

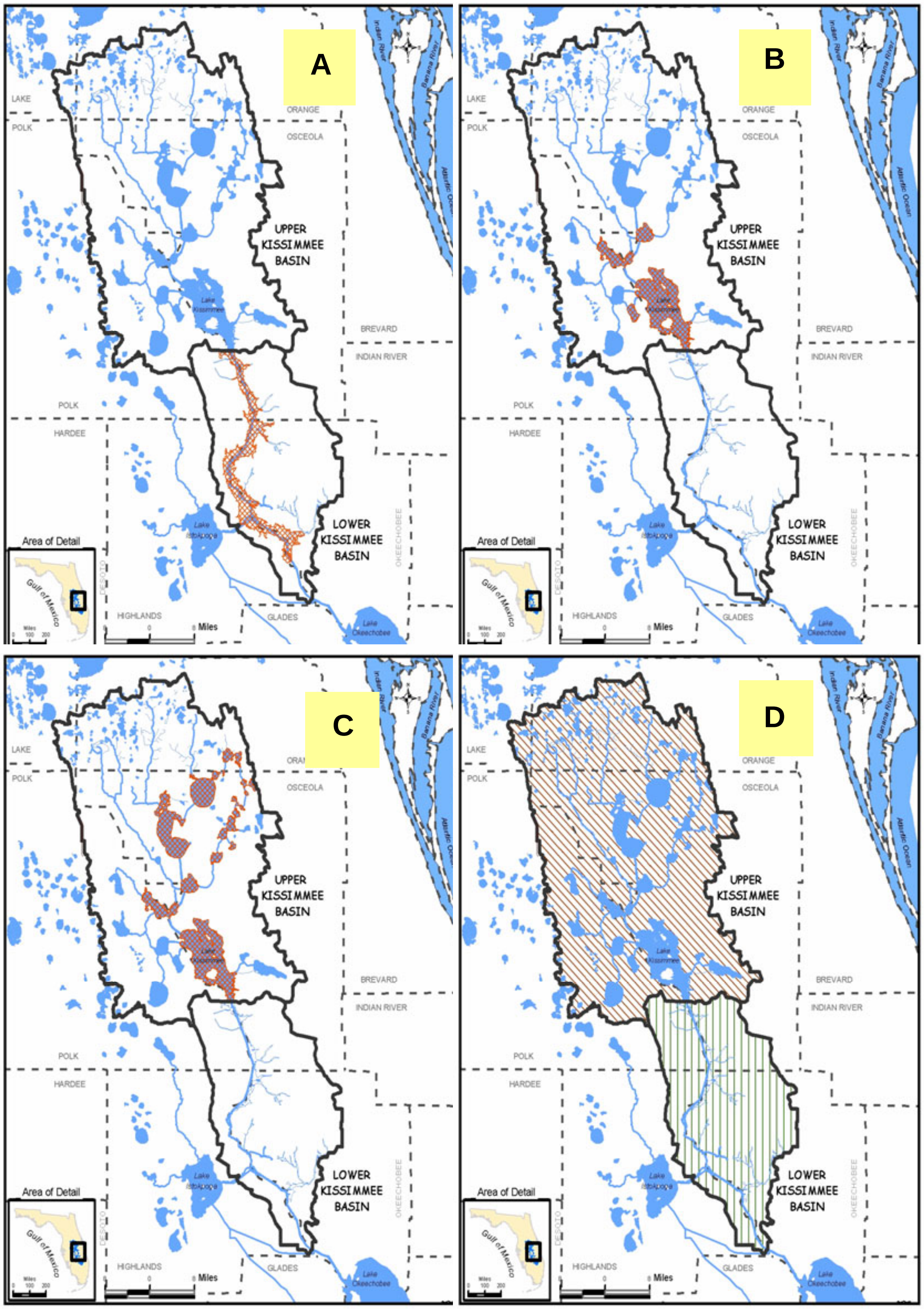


Figure 11-2. Geographic scopes (colored areas on maps) of major initiatives in the Kissimmee Basin. Initiatives include the (A) Kissimmee River Restoration Project, (B) Kissimmee River Headwaters Revitalization Project, (C) Kissimmee Chain of Lakes Long-Term Management Plan, and (D) Kissimmee Basin Modeling and Operations Study.

CENTRAL AND SOUTHERN FLORIDA PROJECT

Two major hurricanes in the late 1940s led to mass flooding and extensive property damage throughout the KCOL, prompting the state of Florida to petition the federal government to prepare a flood control plan for Central and South Florida. In 1948, the U.S. Congress authorized the USACE to initiate construction of the Central and Southern Florida (C&SF) Project for flood control and other purposes. Flood control works for the Kissimmee watershed were authorized by the Federal Rivers and Harbors Act of 1954 as an addition to the C&SF Project. The primary project purposes were to relieve flooding and minimize flood damages within the Kissimmee watershed and to improve navigational opportunities originally provided in the Congressional Act of 1902. Between 1962 and 1971, the meandering Kissimmee River was channelized and transformed into a 56 mi (90 km) long by 30 ft (9 m) deep canal that varied between 90 and 300 ft (27 and 91 m) in width, and was regulated by a series of five water control structures (USACE, 1991) (**Figure 11-1**). The KCOL project features were constructed between 1964 and 1970 and included dredging of canals between lakes and installation of water control structures to regulate lake levels and outflow (USACE, 1991).

The Kissimmee Basin is the headwaters to South Florida and the Kissimmee River is the largest tributary to Lake Okeechobee. Rainfall over the Kissimmee Basin can greatly influence the volume of water discharged to Lake Okeechobee and decisions about operations can greatly influence the timing of those discharges. Operations of the C&SF water control structures in the Kissimmee Basin are coordinated with those for the rest of the SFWMD in several ways. First, conditions in the Kissimmee Basin are formally considered in the decision tree used for managing water levels in Lake Okeechobee. Second, at weekly interagency meetings, District operations staff and representatives of the different components of the South Florida ecosystem review conditions and discuss recommendations for adjusting operations. Third, the potential impacts on Lake Okeechobee were considered in the development of the current operating rules (stage regulation schedules) for water control structures in the Kissimmee Basin and are being considered in the current evaluation of the operating rules in KBMOS (see the *Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Study* section of this chapter).

CURRENT CONDITIONS: WATER YEAR 2006 SUMMARY

Hydrologic conditions in the Kissimmee watershed were dominated by the quantity and seasonal distribution of rainfall in Water Year 2006 (WY2006) (May 1, 2005–April 30, 2006). As with recent years, the temporal variability of rainfall continued to pose a challenge for water management. Of particular importance were three events: (1) intense June rainfall, (2) intense rainfall associated with Hurricane Wilma, and (3) dry spring. This section describes those events, corresponding changes in stage and discharge, and associated changes in operations.

Seasonality of Rainfall

Most rainfall occurred during the wet season (June–October), with almost every wet season month totaling at least 6 inches of rainfall in the Upper Basin and 4 inches in the Lower Basin (**Figure 11-3**). June and October were exceptionally wet months. For the Upper Basin, June rainfall totaled 13.82 inches, which exceeded the 20-year wet return period. Above-average June rainfall was due to multiple events throughout the month. In October, the Upper Basin received 9.89 inches of rainfall, which exceeded the 50-year wet return interval; the Lower Basin totaled 8 inches of rainfall, which exceeded the 20-year wet return intervals. Over half of the October rainfall was associated with Hurricane Wilma, which made landfall on October 24. Rainfall on October 24–25 totaled 5.72 inches in the Upper Basin and 4.84 inches in the Lower Basin.

Much less rainfall occurred during the November–April period. Monthly rainfall totals did not exceed 2.5 inches in the Upper Basin and did not exceed 4 inches in the Lower Basin. In almost every month of this period, potential evapotranspiration exceeded monthly rainfall (**Figure 11-3**). In the Upper Basin, the March rainfall totaled only 0.18 inches, exceeding the 50-year dry return interval. The total WY2006 rainfall was above average in both basins. The Upper Basin totaled 52.91 inches, exceeding the historical average by 2.82 inches, and the Lower Basin totaled 48.50 inches, exceeding the long-term average by 4.05 inches. Without the rainfall associated with Hurricane Wilma at the end of the wet season, the total WY2006 rainfall would have been slightly below average. Additional information on WY2006 hydrology in the Kissimmee Basin is presented in Chapter 2 of this volume.

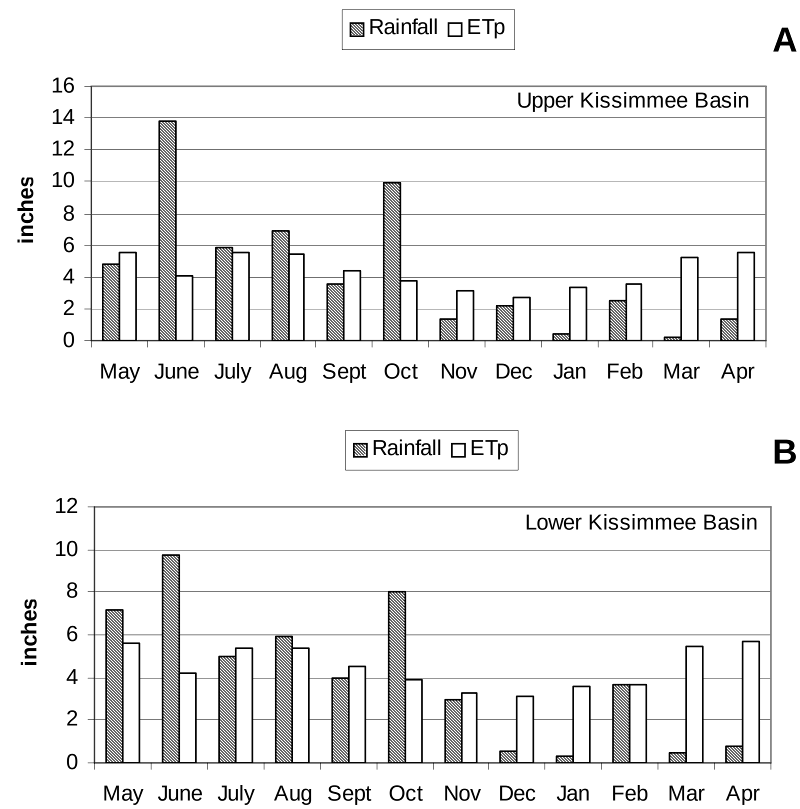


Figure 11-3. Seasonality of rainfall and potential evapotranspiration in the (A) Upper Basin and (B) Lower Basin during WY2006 (based on data presented in Chapter 2 of this volume).

Seasonality of Lake Stage and Discharge to the Kissimmee River

At the beginning of the water year, lake stages were decreasing according to their respective regulation schedules to the low point of the schedule (low pool stage) by May 31 (see **Figure 11-4** for Lakes Cypress, Hatchineha, and Kissimmee). On June 1, the regulation schedules jump from the low pool stage to a plateau for the summer (summer pool stage). With the June rainfall, lake stages increased rapidly until they exceeded the summer pool stage of their respective regulation schedules by late June. As lake stage exceeded the regulation schedule line to enter Zone A of the schedule, flood control releases were made downstream throughout the basin. These releases continued well into July until lake stage dropped below Zone A. At S-65, peak discharge exceeded 9,000 cfs during this event (**Figure 11-4** bottom). Stages occasionally entered Zone A in late September and August but moderate releases for flood control quickly brought lake stage back to the schedule line. In the fall, lake stages were allowed to increase again because the regulation schedules increase from the summer pool to the highest elevation in the schedule (high pool stage) by late October.

As the lake stage was approaching the high pool stage, the Upper Basin received 5.72 inches of rainfall over two days as Hurricane Wilma crossed the basin. This rainfall event increased lake stages above regulation schedule at the very end of the wet season. This situation was similar to that in 2004 when rainfall associated Hurricane Jeanne in late September caused lake stages to exceed the regulation schedule very late in the wet season. As in 2004, Water Control Operations requested assistance from the Emergency Modeling Team (Hydrologic Environmental Systems Modeling) with support from the Kissimmee Division to assist with guiding operations. The objective was to determine a schedule for reducing discharges from the Upper Basin that would lower lake stages back to regulation schedule and allow for a slow stage recession rate for the Kissimmee River without exhausting the water storage in the Upper Basin lakes. Ideally, the stage recession rate in the Kissimmee River for the entire event (from the highest stage to the lowest) would not exceed the equivalent of 1 ft/30 d. A gradual recession in stage as discharge is decreased from 3,000 cfs to about 1,000 cfs helps provide the duration, depth, and extent of floodplain inundation needed by wetland plant communities and by the animals that use these wetlands. These issues were discussed in more detail in the 2006 SFER – Volume I, Chapter 11.

Following Hurricane Wilma, discharge at S-65 was increased fairly rapidly to >8,000 cfs and held there for several days (**Figure 11-5**). Lower Basin runoff and increasing discharge from the Upper Basin caused stage to increase rapidly at a series of downstream sites. The upstream most of these sites is Weir1, which is located in the C-38 canal just upstream of the river channel reconnected by Phase I of the Kissimmee River Restoration Project. In downstream order, KRDR, KRBN, and PC11 are located in the reconnected river channel. PC11 is located downstream of the terminus of backfilling in the C-38 and is strongly influenced by the headwater stage at the S-65C water control structure. Consequently, it shows little fluctuation in stage.

Between November 1 and November 13, discharge at S-65 was reduced to approximately 3,000 cfs (**Figure 11-5**). This reduction in discharge was accompanied by a rapid decrease in stage. Over the next two weeks, discharge was decreased from 3,000 cfs to 1,400 cfs. During this period, the stage at Weir1 had a recession rate equivalent to 3 ft/30 d. More gradual changes in discharge were made over the remainder of the water year. The recession rate for this event is discussed below.

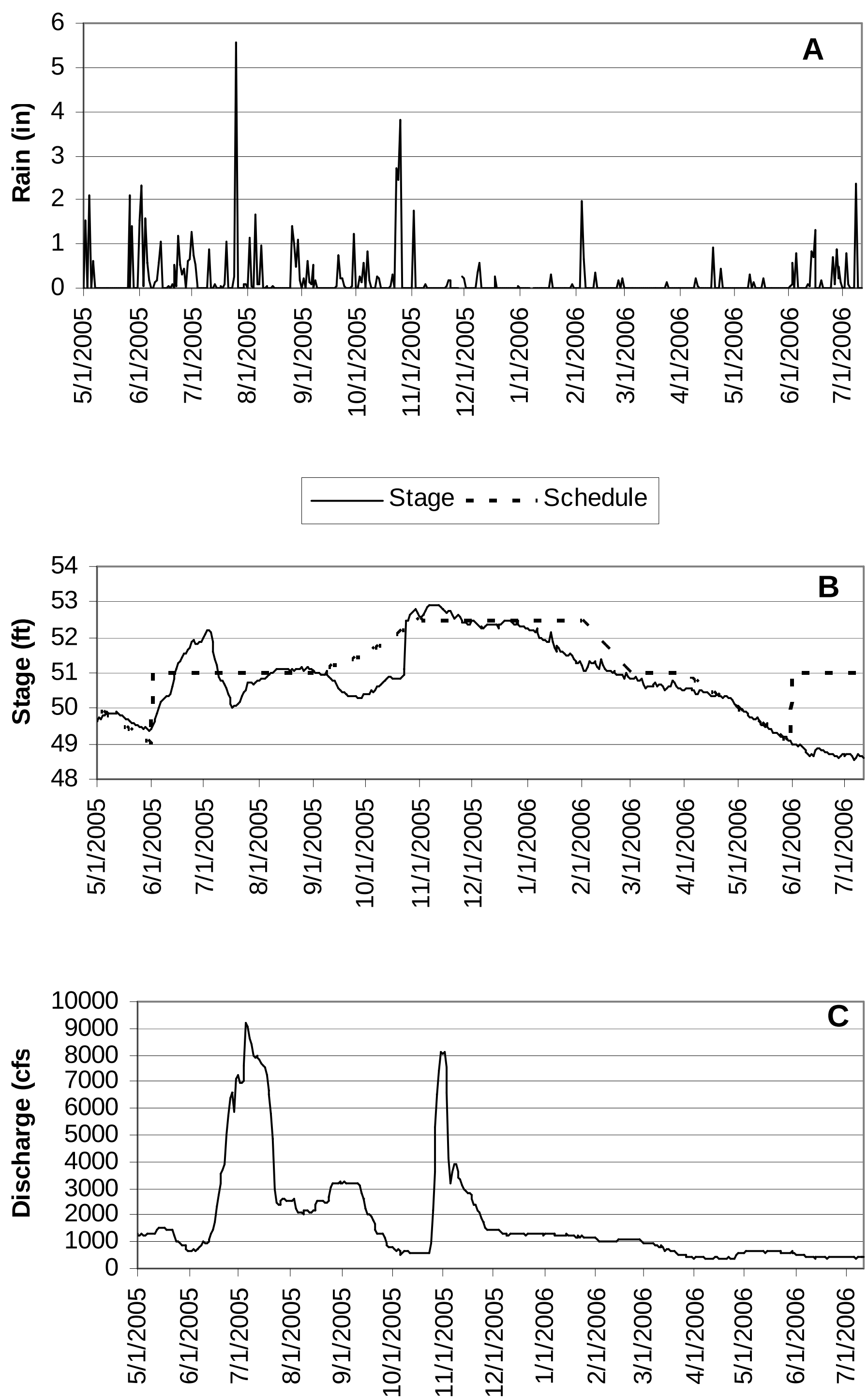


Figure 11-4. (A) Daily rainfall, (B) headwater mean daily stage and the stage regulation schedule, and (C) mean daily discharge at S-65 for WY2006.

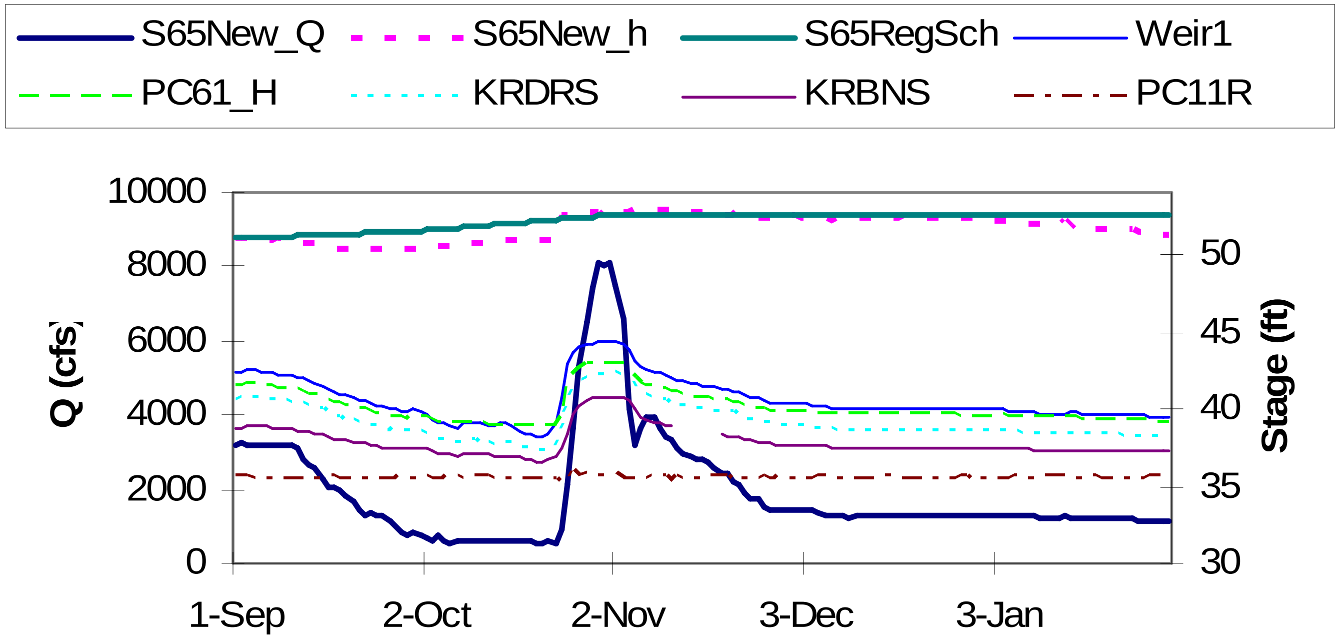
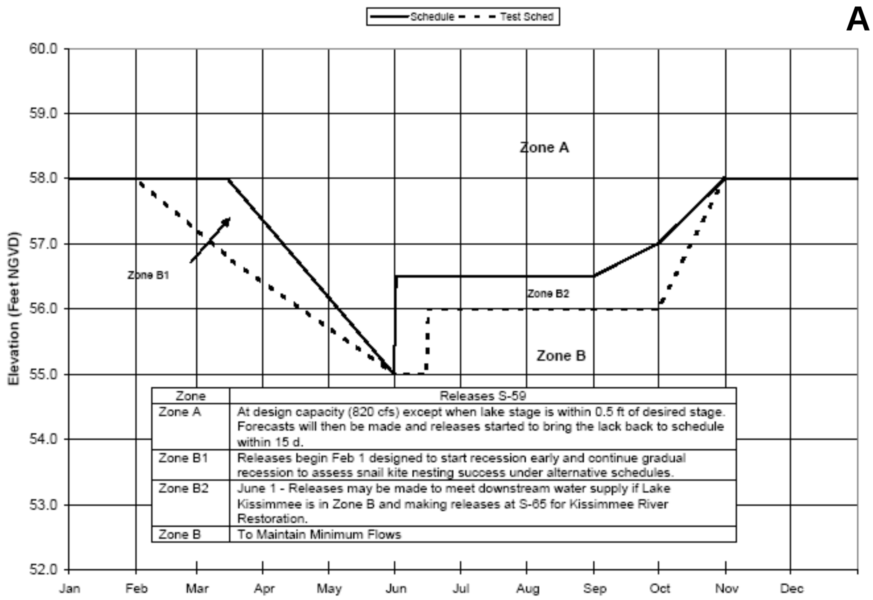


Figure 11-5. The regulation schedule, headwater stage, and discharge at S-65 and stage for a series of downstream stations (Weir1, PC61, KRDR, KRBN, and PC11) before and after Hurricane Wilma.

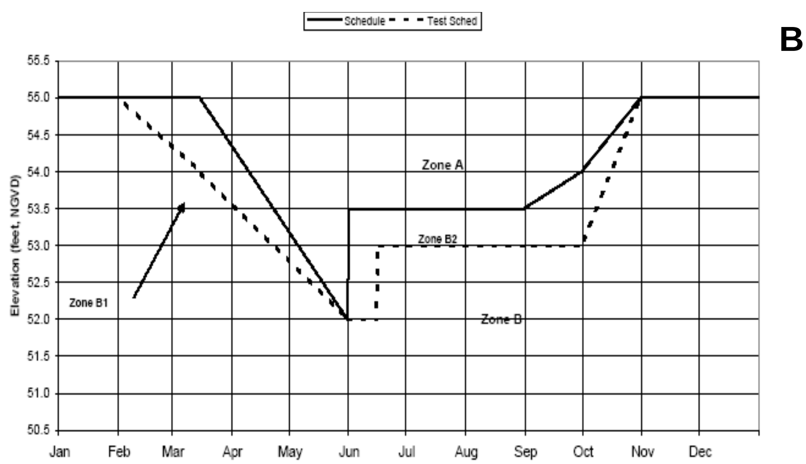
Hurricanes, a recurring event in South Florida, have passed over the Kissimmee Basin about once every seven years for the last 129 years. Increasing water storage capacity is the chief means of mitigating impacts of the intense rainfall that can accompany hurricanes and other tropical systems. In the Kissimmee Basin, storage is increased in several ways. First, regulation schedules for lakes are designed to lower water levels and increase water storage capacity for the wet/hurricane season. Second, the Headwaters Revitalization Project, when complete, will provide an additional 100,000 ac-ft of storage in lakes Kissimmee, Cypress, and Hatchineha. Third, future Comprehensive Everglades Restoration Plan (CERP) projects will provide additional storage of Kissimmee Basin water before it enters Lake Okeechobee.

During winter 2006, operational modifications of the regulation schedules for Lake Tohopekaliga (Lake Toho) and East Lake Tohopekaliga (East Lake Toho) were considered by staff from Operations Control & Engineering Department with input from the Kissimmee Division. These modifications involved specifying environmental releases when lake stage was in Zone B of the regulation schedule and would not affect operations in Zone A for flood control purposes. These releases were intended to address several concerns. First, environmental releases have been made at S-65 for the Kissimmee River Restoration Project since July 2001. These discharges at S-65 were solely dependent on the volume of water stored in Lakes Cypress, Hatchineha, and Kissimmee. Supplementing the environmental releases from S-65 with releases from Lake Toho and East Lake Toho would replace some of the water being released from Lakes Cypress, Hatchineha, and Kissimmee. A second issue involved the effect of rapidly dropping water levels on the nesting success of the federally endangered Everglade snail kite (*Rostrhamus sociabilis plumbeous*) in the Upper Basin. Problems encountered in 2005 with rapid decreases in stage are summarized in the 2006 SFER – Volume I, Chapter 11. In an effort to minimize future problems, Kissimmee Division staff consulted with biologists, who were familiar with snail kite issues, from the U.S. Fish and Wildlife Service (USFWS) and the Florida Fish and Wildlife Conservation Commission (FWC). These discussions resulted in a proposal to specify environmental releases for Zone B of the regulation schedules for Lake Toho and East Lake Toho. These releases are referred to as Zone B1 and allow releases from these lakes to begin earlier in the year at the same high pool stage and finish at the same low pool stage on May 31 (**Figure 11-6**). Thus, the spring recession would begin earlier and happen more slowly. These changes may benefit snail kites nesting on these lakes in two ways: (1) initiating releases earlier would provide a cue near the beginning of the nesting season that water levels will be fluctuating, and (2) a slower recession rate increases the chances that the eggs will have time to hatch and the young fledge before water levels drop low enough to expose the nest to terrestrial predators.

In addition to the Zone B1 releases to be made between February and May 31, a Zone B2 was also considered to make releases from June 1 through October 31 when releases are also being made from Lake Kissimmee for the Kissimmee River Restoration Project. Zone B2 creates a two-week window during which releases could keep the lake at the low pool stage. These releases should increase the amount of time spent at the low pool stage and possibly allow some consolidation and oxidation of sediments along the lake margin. After June 14, Zone B2 allows releases to be made when stage is within six inches of the regulation schedule. These releases should result in a more natural pattern of stage fluctuation, which should provide some benefit to the plants and animals that live at the lake’s edge.



Zone	Releases S-59
Zone A	At design capacity (820 cfs) except when lake stage is within 0.5 ft of desired stage. Forecasts will then be made and releases started to bring the lack back to schedule within 15 d.
Zone B1	Releases begin Feb 1 designed to start recession early and continue gradual recession to assess snail kite nesting success under alternative schedules.
Zone B2	June 1 - Releases may be made to meet downstream water supply if Lake Kissimmee is in Zone B and making releases at S-65 for Kissimmee River Restoration.
Zone B	To Maintain Minimum Flows



Zone	Releases S-61
Zone A	At design capacity (2300 cfs) except when lake stage is within 0.5 ft of desired stage. Forecasts will then be made and releases started to bring the lack back to schedule within 15 d.
Zone B1	Releases begin Feb 1 designed to start recession early and continue gradual recession to assess snail kite nesting success under alternative schedules.
Zone B2	June 1 - Releases may be made to meet downstream water supply if Lake Kissimmee is in Zone B and making releases at S-65 for Kissimmee River Restoration.
Zone B	To Maintain Minimum Flows

Figure 11-6. Experimental stage regulation schedules (dashed lines) specifying releases for (A) Zone B1 and Zone B2 for East Lake Toho and (B) Lake Toho.

Staff from the District's Hydrologic Environmental Systems Modeling Department provided modeling support to evaluate the implementation of Zone B1 and B2. This evaluation involved comparing the existing operating rules with 16 alternatives (different rules for Zone B1 and B2 releases). The comparisons were based on a 36-year simulation with the UKISS model and performance measures representing (1) lake recessions, (2) flood protection, (3) releases to Lake Okeechobee, and (4) water supply. Details of this study are summarized in Appendix 11-1. This study concluded that modest releases would allow the desired lake recession in the spring and result in slight reductions in peak stages in Lake Toho and East Lake Toho.

The District sought agreement from the USACE (letter from George Horne to Steven Duba on May 17, 2006) to implement Zone B1 and Zone B2 releases as a one-time experiment in coordinated water management under the existing authority to make releases for environmental purposes in Zone B (USACE, 1994). The USACE agreed with that assessment, as reflected in their letter of response dated June 28, 2006. Zone B1 releases began in February from both Lake Toho and East Lake Toho (**Figure 11-7**). The recessions in both lakes for Zone B1 were followed and reported at weekly meetings of the Environmental Advisory Team. Implementation of the Zone B1 releases was facilitated by a dry spring. The USFWS has been tracking snail kite nesting around these lakes. When the final results are available for 2006, it will be interesting to compare them with the 2005 results.

The conceptualization of the Zone B1 and Zone B2 releases and the experimental implementation of these operational changes are providing useful insight into how operating rules might be modified for the Kissimmee Basin Modeling and Operations Study, described later in this chapter.

Kissimmee River

During WY2006, water was discharged continuously from S-65 for flood control, when the lake stage was above the regulation schedule line (Zone A), and for the Kissimmee River Restoration Project, when lake stage was below the regulation schedule line (Zone B) (**Figure 11-4**). The total volume at S-65 discharged was 1,468,257 ac-ft, and approximately one-half of that volume was made at discharges >3,000 cfs for flood control. Releases made from Zone B for the Kissimmee River Restoration Project account for the other half. Maintaining inflow from the Upper Basin throughout the year has long been one of the criteria for successful restoration of the Kissimmee River (Anderson and Chamberlain, 2005). This is the fifth year that flow has been continuously maintained from the Upper Basin since Phase I of the restoration project was completed in February 2001.

During WY2006, mean daily discharge at S-65 ranged from 378 cfs to 9,191 cfs and averaged 2,032 cfs. The peak discharge occurred during flood control releases associated with above rainfall in June. Discharge following the rainfall associated with Hurricane Wilma peaked at about 8,100 cfs. Since March 2006, discharge at S-65 has been less than 1,000 cfs. Because of continued dry conditions, the discharge at S-65 has continued to decrease. Releases from Lake Kissimmee ended in July and releases from S-65 were matched to those from Lake Toho at S-61. This operation essentially passes water from Lake Toho through Lake Kissimmee to the Kissimmee River. As Lake Toho stages decreased, these releases were decreased to 150 cfs on August 14 and are expected to end shortly.

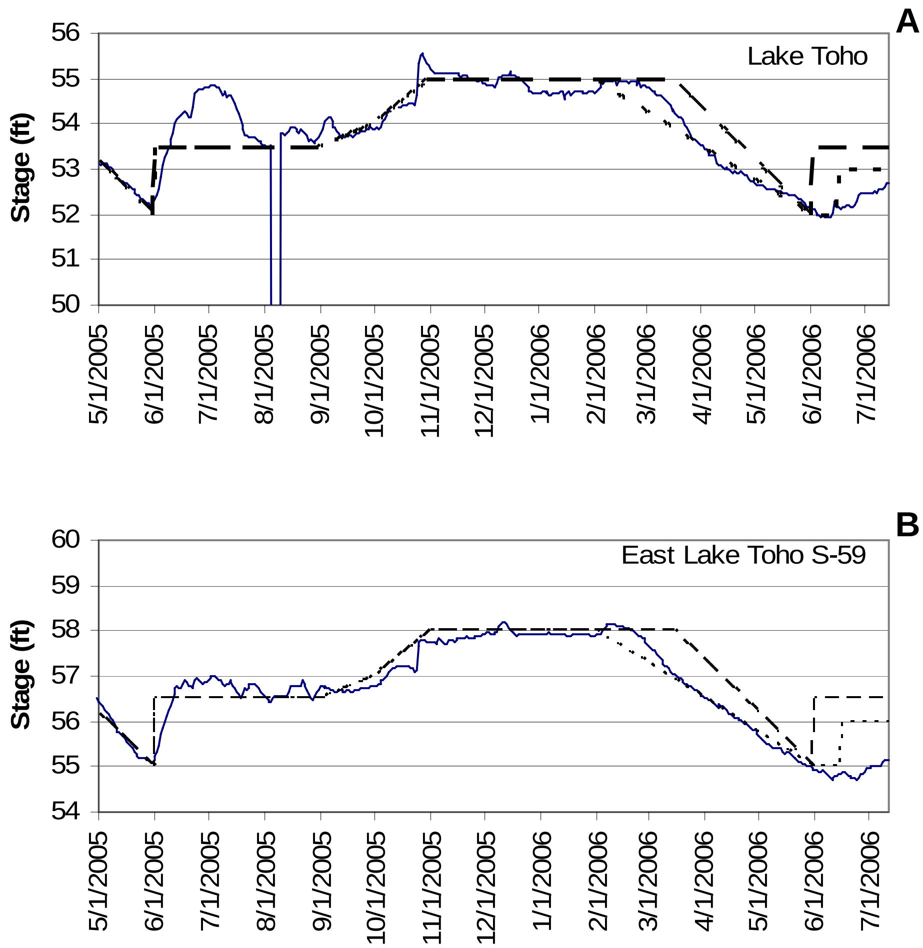


Figure 11-7. Observed stage recession in (A) Lake Toho and (B) East Lake Toho relative to the experimental stage regulation.

The rate of stage recession has been a continuing concern in managing the Kissimmee River. A slow recession rate on the floodplain is necessary to create desirable hydroperiods for floodplain wetland vegetation. Rapid recession rates on the floodplain have been linked to anoxic conditions and a fish kill (see details in the 2006 SFER – Volume I, Chapter 11). For the restored river, a desirable recession event is described as peaking in the wet season and extending into the dry season with an average duration of ≥173 d and a recession rate that does not exceed 1 ft/30 d (Anderson and Chamberlain, 2005). Parts of three recession events occurred in WY2006 (**Figure 11-8**). The first of these events began at the end of WY2005 and lasted 63 days (March 28–May 30, 2005). It involved a 3.03 ft decrease in stage, which was equivalent to a recession rate of 1.44 ft/30 d. The second event lasted 103 days (July 10–October 21, 2006). It involved a 7.18-ft decrease in stage and was equivalent to 2.09 ft/30 d. The onset of the last event was associated with Hurricane Wilma, and it lasted 222 days. This last event has so far involved an 8.56-foot decrease in stage for a recession rate of 1.16 ft/30 d. Of the three events, only the last one comes close to meeting the criteria for a desirable recession event.

Comparing the third recession event (November through July) with previous years (**Figure 11-6**) shows that it was intermediate among the previous years. This recession event appears more steady than WY2003, WY2004, and WY2005 and spends more time (December through mid-March) near the bankfull stage (approximately 39–40 ft) than WY2002.

This summary of WY2006 demonstrates the hydrologic coupling of the Upper and Lower basins and the importance of implementing the headwaters revitalization component of the Kissimmee River Restoration Project. A key element of this component is to implement a new schedule that will raise the high pool stage 1.5 ft and create an additional 100,000 ac-ft of storage. This additional storage should reduce the need to make the extremely high discharges during flood control releases and to store more water to maintain releases through the dry season.

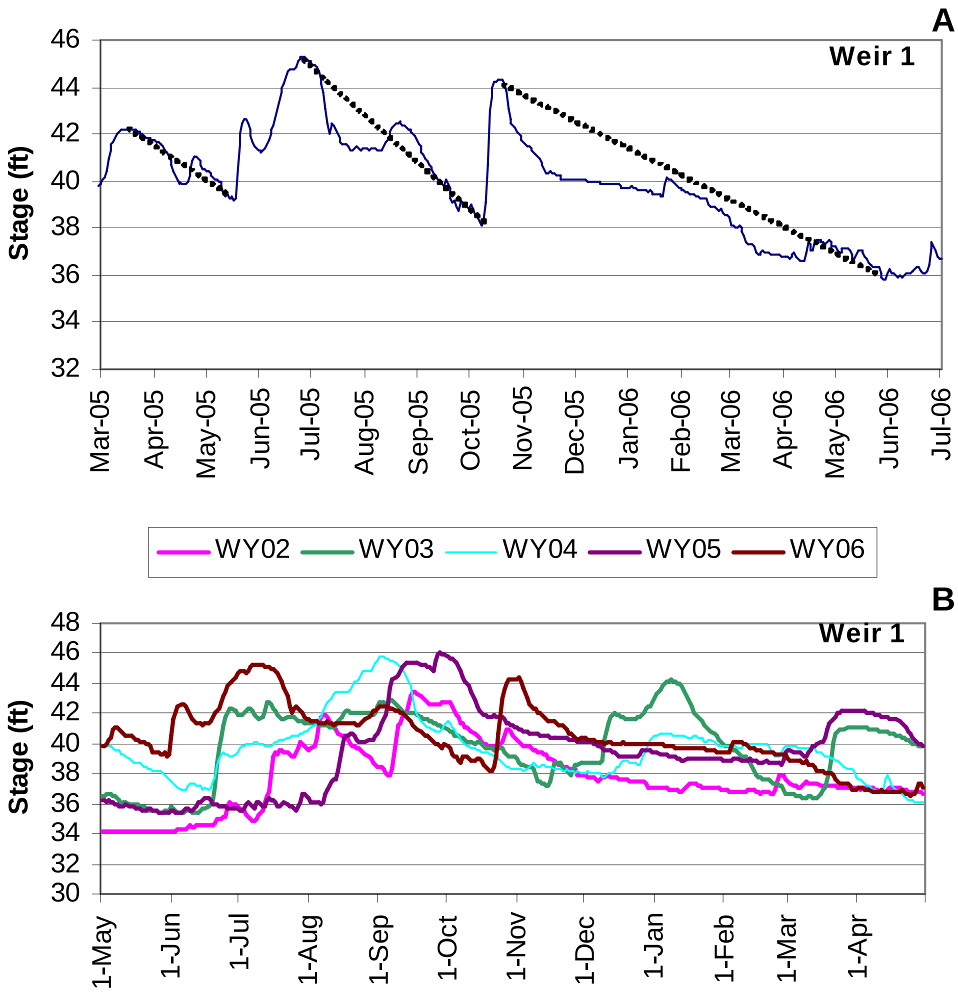


Figure 11-8. (A) Stage recession events (dotted lines) at Weir 1 during WY2006 and (B) stage at Weir 1 for WY2002–WY2006.

KISSIMMEE WATERSHED ACTIVITIES

The purpose of this section is to provide background information for and annual updates of Kissimmee Division initiatives within the Kissimmee watershed. The section begins with the Kissimmee River Restoration Project, including plans for implementation and evaluation, an update of evaluation program results, and an update of the progress of the Kissimmee Basin Modeling and Operations Study. Next, background and progress of the Kissimmee Chain of Lakes Long-Term Management Plan is detailed. Thirdly, progress of tributary restoration projects within the Kissimmee watershed is updated. Finally, Kissimmee watershed water quality programs are described.

KISSIMMEE RIVER RESTORATION PROJECT

Impacts of the C&SF Project on the Kissimmee Watershed

Although the C&SF Project was extremely successful at achieving its flood control objective within the Kissimmee watershed, it dramatically altered hydrologic conditions in the Kissimmee River and Kissimmee Chain of Lakes (Obeysekera and Loftin, 1990; Anderson and Chamberlain, 2005). Water levels in the Kissimmee Chain of Lakes were brought under the control of nine structures that regulate the amount and timing of discharges between lakes and to the Kissimmee River. The range of fluctuation in lakes following regulation has been strongly compressed, decreasing from an historical range of 2–10 ft (0.6–3.0 m) to approximately 2–4 ft (0.6–1.2 m) after regulation (Obeysekera and Loftin, 1990). The historical, pre-regulated pattern of seasonal fluctuations provided periods of flooding and drying that played a critical role in maintaining lake health and supported biological communities adapted to and dependent upon these fluctuations (Perrin et al., 1982). Reducing the range of fluctuations has dampened this natural cycle and promoted growth of dense vegetation that has resulted in the accumulation of organic material in littoral zones of these lakes (USACE, 1996). Smaller fluctuations also have allowed agricultural, residential, and commercial land uses to encroach upon historic flood zones surrounding the lakes, resulting in significant loss of wildlife habitat and higher nutrient inputs to the lakes (USACE, 1996).

Within the Kissimmee River, the physical effects of channelization, including alteration of the system's hydrologic characteristics, drastically reduced the extent of floodplain wetlands and severely degraded fish and wildlife resources of the basin (USACE, 1991; Bousquin et al., 2005). Approximately 21,000 ac (8,500 hectares, or ha) of floodplain wetlands were drained, covered with spoil material, or converted into canal (USACE, 1991; Carnal and Bousquin, 2005). No-flow regimes in remnant channels encouraged extensive growth of floating vegetation, which impeded navigation (Toth, 1990b; Bousquin, 2005). Senescence and death of encroaching vegetation covered the shifting sand substrate with large amounts of organic matter, greatly increasing the biological oxygen demand of the system (Toth, 1990a; Colangelo and Jones, 2005). Waterfowl densities and species richness declined sharply (Williams and Melvin, 2005). Diverse and abundant wading bird populations declined and were largely replaced by the cattle egret (*Bubulcus ibis*), a species generally associated with upland, terrestrial habitats (Perrin et al., 1982; Williams and Melvin, 2005). The highly recognized largemouth bass (*Micropterus salmoides*) fishery was decimated, while fish species tolerant of low DO and reduced water quality, such as Florida gar (*Lepisosteus platyrhincus*), increased (Perrin et al., 1982; Glenn, 2005). Aquatic invertebrate taxa of the channelized system were typical of those found in lakes and reservoirs rather than riverine systems (Harris et al., 1995; Koebel et al., 2005). Stabilized water levels greatly reduced river-floodplain interactions, disrupting critical food web linkages dependent on seasonal flooding and protracted floodplain recession rates (Harris et al., 1995; Anderson and Chamberlain, 2005).

Restoration Project Impetus and Implementation

The environmental degradation described in the previous section and growing concerns over the contributions of channelization to eutrophication of Lake Okeechobee were the impetus for an initiative to restore the Kissimmee River. As early as 1971, prior to completion of the channelization project, environmental conservation organizations called for restoration of the Kissimmee River. Over 20 years (1971–1991) of restoration-related efforts and consistent support from the state's governors, legislature, and congressional delegations culminated with the 1992 Water Resources Development Act (Public Law 102-580), which authorized "the ecosystem restoration of the Kissimmee River, Florida" and secondarily "to construct the Kissimmee River headwaters revitalization project." The project goal is to restore ecological integrity to the river-floodplain ecosystem. This goal is defined as the "reestablishment of a river-floodplain ecosystem that is capable of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." Successful restoration of the Kissimmee River depends on both the KRRP and the KRHRP.

The purpose of the KRHRP is to approximate the historical flow characteristics from headwater lakes into the Kissimmee River system, and secondarily to increase the quantity and quality of lake littoral zone habitat for the benefit of fish and wildlife (USACE, 1996; Sections 1.3.2, 5.1). The strategy for accomplishing these objectives involves increasing the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 ac-ft (12,340 ha-m) and by increasing the conveyance capacity of the canals and structures to accommodate these increased storage volumes. The KRHRP is scheduled for completion in 2011 **(Figure 11-9)**. In June 2001, an interim operation schedule was implemented for S-65 in an effort to improve water deliveries to the Kissimmee River until KRHRP is completed. This interim schedule provides a strategy for meeting the river restoration project needs for continuous flow by allocating water for discretionary releases. The interim schedule will remain in place until the new schedule is implemented. Although beneficial to the river, this schedule does not raise the high pool stage and thus does not allow the expected natural river flows. Moreover, the interim schedule does not provide the benefits to littoral zone habitats in headwater lakes that will be realized with the headwaters revitalization schedule.

The river restoration (KRRP) component involves a plan to (1) backfill a section of C-38 approximately 22 mi (35 km) in length from the lower end of Pool D to the middle of Pool B, (2) reconnect remnant river channels by recarving sections of river channel destroyed during C-38 construction, (3) remove the S-65B and S-65C water control structures and tieback levees, and (4) evaluate restoration success through a comprehensive ecological monitoring program. Backfilling of C-38 and recarving of river channels will be implemented in a series of construction phases projected to be completed in 2012; evaluation of restoration success will continue through 2017 (**Figure 11-9**). Ultimately, the project will restore approximately 52 km^2 (20 mi^2) of river-floodplain ecosystem, including 70 km (44 mi) of continuous river channel.

Phase I construction of the KRRP was completed in February 2001. Approximately 7.5 mi (12 km) of flood control canal was filled in Pool C and the southern portion of Pool B. Nearly 1.3 mi (2 km) of river channel was recarved and water control structure S-65B was demolished. These efforts reconnected 15 mi (24 km) of continuous river channel and allow for intermittent inundation of approximately 6,000 ac (2,400 ha) of floodplain. In June 2006, a second construction phase (Phase IVa) was initiated at the northern terminus of the Phase I project area. This phase will backfill an additional 1.9 miles (3.0 km) of canal, remove three navigable sheet pile weirs located on C-38, and excavate a small section of new river channel. The excavation of a new river channel is required to reestablish the historic river connection, which

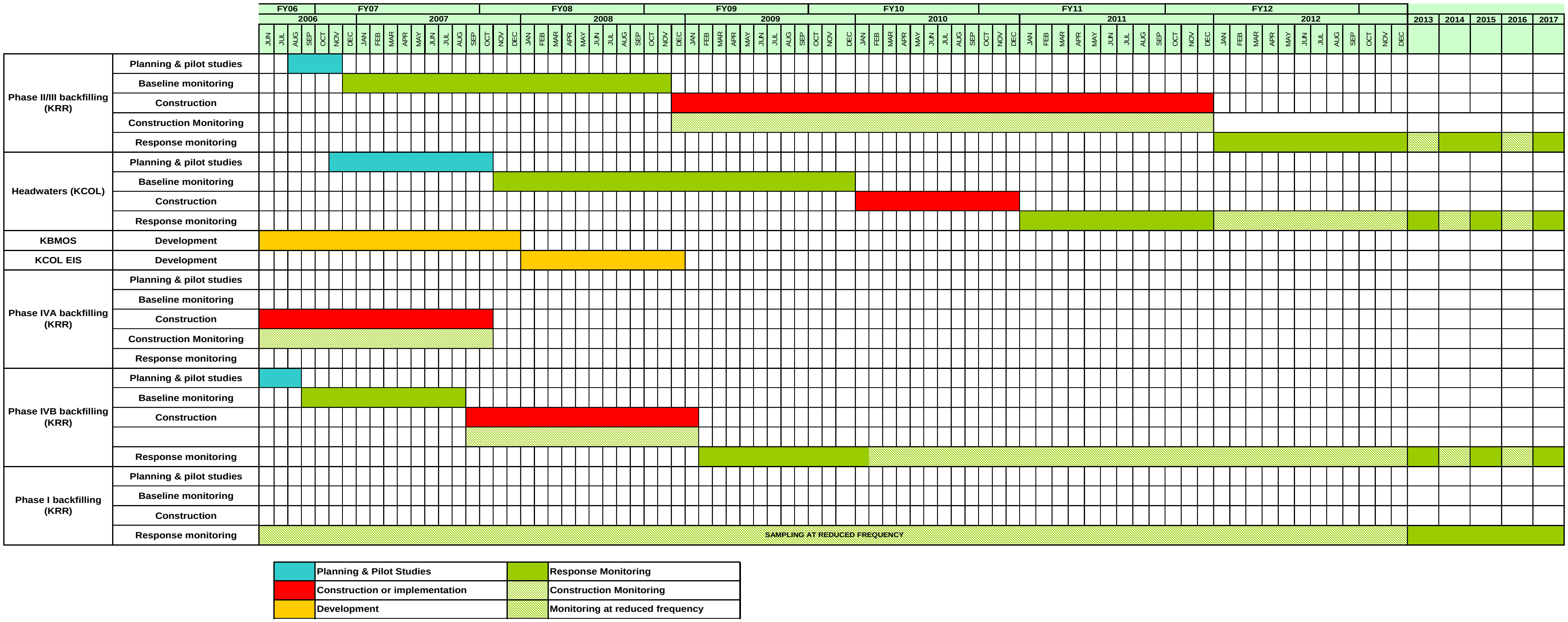


Figure 11-9 Schedule of major construction, modeling, and monitoring efforts for the Kissimmee River Restoration and Kissimmee River Headwaters Revitalization projects.

will allow for diversion of flows from the canal upstream of the backfill. Construction is expected to take approximately 16 months, and be completed in October 2007. Afterwards, an additional 4 mi (6.4 km) of historic river channel and 155 ac (63 ha) of floodplain wetlands will be restored within the project area. Phase IVa represents a portion of a construction phase (Phase IV) that was originally scheduled for the end of the restoration project. The Phase IV project has now been divided into Phase IVa and Phase IVb, with construction of Phase IVb to be completed between September 2007 and January 2009 (**Figure 11-9**).

Planning efforts for KRREP studies associated with Phase II/III of restoration are currently under way. The goal of Phase II/III studies is to better identify the mechanisms driving individual components of ecosystem response to restoration through increased integration of a subset of Phase I baseline studies. Planning of pilot KRREP studies to evaluate vegetation response to Headwaters Revitalization will begin in late 2006 and focuses on littoral and wetland vegetation community response to implementation of the revitalization regulation schedule. The headwaters revitalization regulation schedule is zoned to provide varying discharges based on season and water level (**Figure 11-10**). Specifically, these modifications allow for a wider range of lake stage fluctuations, with maximum lake stages increasing from 52.5 ft (15.9 m) to 54.0 ft (16.4 m) NGVD. The new regulation schedule with increased maximum stage was designed to facilitate the reestablishment of pre-channelization seasonal outflow characteristics from Lake Kissimmee to the Lower Basin and benefit the lakes by expanding littoral zones and peripheral wetlands by approximately 14,000 ac (5,700 ha) (USACE, 1996). Additionally, the increase in the range of lake stage fluctuation is expected to improve the overall quality and productivity of littoral and wetland habitats. Studies on vegetation response to Headwaters Revitalization will combine analysis of aerial photography and ground transects. Implementation of Phase II/III and Headwaters Revitalization studies is contingent on the USACE construction schedule and is subject to change.

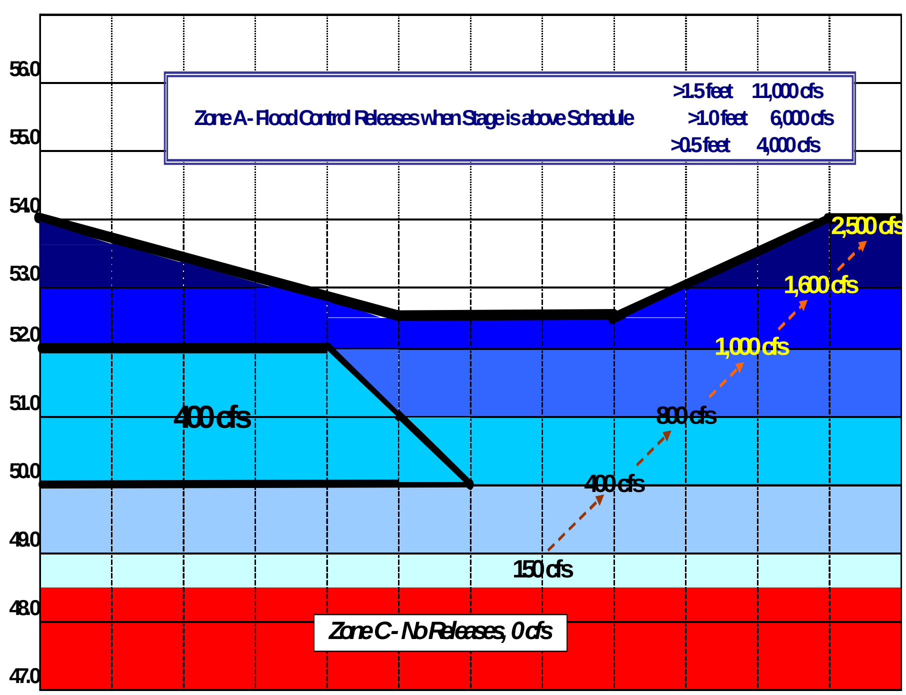


Figure 11-10. Revised regulation and operational schedule for the Upper Basin Kissimmee Chain of Lakes (KCOL) including lakes Kissimmee, Hatchineha, Cypress, and Tiger, controlled by S-65.

Restoration Evaluation Program Overview

A key element of the KRRP is a comprehensive ecological evaluation program (KRREP) to (1) assess achievement of the project goal of ecological integrity, (2) establish causality between the restoration project and observed changes, and (3) support adaptive management in the later phases of the project. The major elements of this program are outlined in the authorized feasibility plan for Kissimmee River restoration (USACE, 1991). Restoration evaluation, as outlined in the feasibility study, is also part of the 1994 50/50 Cost-Sharing Project Cooperative Agreement between the SFWMD and USACE. In addition, restoration evaluation relates directly to the District's mission, "to manage and protect water resources of the region by balancing and improving water quality, flood control, naturals systems, and water supply." Finally, restoration evaluation has already demonstrated its value for this project in the assessment of multiple restoration options during the Pool B Demonstration Project (Toth, 1993), and in the assessment of the feasibility of backfilling C-38 and potential impacts on water quality (Koebel et al., 1999).

To evaluate attainment of the goal of ecological integrity, the KRREP is broad in scope and includes major abiotic components of the ecosystem (hydrology, geomorphology, and water quality) and major biological communities (e.g., plants, invertebrates, fish, and birds). The strategy for evaluating restoration success centers around two key activities: (1) monitoring to assess changes in important metrics that represent the condition of the river-floodplain ecosystem, and (2) development of restoration expectations (**Table 11-1**). To detect system change, data were collected prior to Phase I construction to establish a baseline for evaluating future responses. Baseline studies were conducted primarily in Pool C, which included most of the area impacted by Phase I construction. Most studies also employed Pool A, which is upstream of the area to be restored, as a control site in order to utilize the Before-After/Control-Impact (BACI) design (Stewart-Oaten et al., 1986). The BACI design can be used to detect changes at an impact site (Pool C for Phase I) relative to changes at a control site, but in a strict sense it does not allow inferences about the causes of change. Causality will have to be established through a weight of argument, as used in epidemiological and ecotoxicology studies (e.g., Stewart-Oaten et al., 1986; Anderson and Dugger, 1998). Baseline data will be compared to data collected after construction and restoration of pre-channelization hydrologic conditions. Information about observed changes in the system will be compared to anticipated changes described by individual restoration expectations to evaluate whether the expectation has been achieved. If an expectation is not achieved, there will be an opportunity to consider if adaptive management strategies should be implemented. In the context of KRREP, adaptive management is the adjustment of management strategies based on information gained from monitoring. The data are used to learn about system responses and to suggest changes in or additional management actions that may be needed to meet restoration expectations. Over the course of the restoration project, most of the evaluation studies will continue data collection at least intermittently until the necessary hydrologic components of restoration are in place, and for five years following completion of the project (USACE, 1991). Periodic monitoring is necessary to allow early detection of possibly unexpected responses; monitoring over an extended period is necessary to assure that responses have stabilized. However, the frequency and intensity of monitoring associated with the restoration expectations varies according to the needs of individual studies, and at any given time not all studies are collecting data, resulting in efficient use of project resources (**Figure 11-9**).

In late 2005, the SFWMD published two volumes of research that summarize key aspects of the evaluation program of the Kissimmee River Restoration Project. Volume I, Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River (Bousquin et al., 2005) summarizes baseline data collected on the channelized river and floodplain prior to Phase I of restoration construction. Studies of hydrology, geomorphology, DO, water quality, algae, vegetation, aquatic invertebrates, amphibians, reptiles, fish, and birds are represented in Volume I. These studies fulfill the initial steps of the KRREP process by reporting field measurements obtained during the channelized period for use as a benchmark against which to compare future change in the ecosystem. The studies also document pre-channelization (reference) conditions when available, which are used both for estimation of the effects of channelization and for prediction of the anticipated effects of the restoration project when complete. The predictions made in Volume I are developed into formal restoration expectations (performance measures) in Volume II of the series, Defining Success: Expectations for Restoration of the Kissimmee River (Anderson et al., 2005), which presents the 25 restoration expectations defined for Phase I of the KRREP (**Table 11-1**).

Restoration Evaluation Program: Status and Results

With completion of Phase I construction in early 2001, which backfilled 7.5 miles of the C-38 canal and reconnected 15 miles of river channel in Pool C and lower Pool B, restoration evaluation monitoring of the Phase I area entered the post-construction period. The first of four restoration construction stages, Phase I is being monitored by Kissimmee Division scientists as will selected successive phases of restoration.

Most of the Phase I studies are already indicating significant changes consistent with those predicted by the expectations (**Table 11-1**). It is important to note, however, that many of the restoration expectations are dependent on full implementation of a revised water regulation schedule under the Headwaters Revitalization Project (USACE, 1996), which will more closely simulate historic hydrology than is currently possible under the present regulation schedule. The Headwaters Revitalization project, which will provide the necessary storage volume in the KCOL to provide the water needed for the Kissimmee River Restoration, is scheduled to be implemented in 2011. A comprehensive update of the status of initial responses of the river to Phase I restoration was published in the 2005 SFER – Volume I, Chapter 11. Additionally, results for a suite of interrelated river channel studies were presented in the 2006 SFER – Volume I, Chapter 11. The sections presented below provide the current status of Phase I evaluation studies that have been updated since the 2006 SFER.

Table 11-1. Restoration expectations (performance measures) of the Kissimmee River Restoration Evaluation Program. See Anderson et al. (2005) for more details.

EXPECTATIONS FOR THE KISSIMMEE RIVER RESTORATION PROJECT

Hydrology

1. The number of days that discharge is equal to 0 cfs in a water year will be zero for the restored channel of the Kissimmee River.
2. Intraannual monthly mean flows will reflect historic seasonal patterns and have interannual variability (coefficient of variation) < 1.0.
3. River channel stage will exceed the average ground elevation for 180 days per water year and stages will fluctuate by 3.75 feet.
4. An annual prolonged recession event will be reestablished with an average duration ≥ 173 days and with peak stages in the wet season receding to a low stage in the dry season at a rate that will not exceed 1.0 ft (30 cm) per 30 days.
5. Mean velocities within the main river channel will range from 0.8 to 1.8 ft/s (0.2 to 0.6 m/s) a minimum of 85% of the year.

Geomorphology

6. In restored river channels, mean thickness of substrate-overlying river bed deposits will decrease by ≥ 65%, percent of samples without substrate-overlying river bed deposits will increase by ≥ 165%, and the thickness of substrate-overlying river bed deposits at the thalweg (deepest point of the channel) will decrease by ≥ 70%.
7. Point bars will form on the inside bends of river channel meanders with an arc angle > 70°.

Water Quality

8. Mean daytime concentration of dissolved oxygen in the Kissimmee River channel at 0.5–1.0 m depth will increase from < 1–2 mg/L to 3–6 mg/L during the wet season (June–November) and from 2–4 mg/L to 5–7 mg/L during the dry season (December–May). Mean daily concentrations will be greater than 2 mg/L more than 90% of the time. Dissolved oxygen concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50% of the time.
9. Mean turbidity in the restored river channel will not differ significantly from mean turbidity in similar South Florida streams (3.9 NTU), and the median total suspended solids concentration will not exceed 3 mg/L.

Vegetation

10. Littoral vegetation beds will persist in restored river channels, but their mean widths will decrease to: (a) Five meters or less from the bank on inner channel bends. (b) Four meters or less from the bank on straight channel reaches.
11. Littoral plant community structure will undergo the following changes in restored river channels: (a) Combined mean relative cover of emergent species will increase to > 80%. (b) Combined mean relative cover of floating and mat-forming species will decrease to <10%.
12. Wetland plant communities will cover >80% of the area of the restored floodplain in Phases I-IV.
13. Broadleaf marsh will cover at least 50% of the restored floodplain in Phases I-IV.
14. Wet prairie communities will cover at least 17% of the restored floodplain in Phases I-IV of the restoration project.

Aquatic Macroinvertebrates

15. Macroinvertebrate drift composition will be dominated by Coleoptera, Diptera, Ephemeroptera, and Trichoptera.
16. The passive filtering-collector guild will account for the greatest proportion of mean annual density, mean annual biomass, and mean annual snag-dwelling macroinvertebrate production.
17. Aquatic macroinvertebrate species richness and species diversity will be ≥ 65 and ≥ 2.37 respectively, in restored broadleaf marsh (currently pasture in the channelized system).
18. The macroinvertebrate fauna of river channel benthic (bottom associated) habitats will primarily consist of taxa that are common and characteristic of sandy substrates.

Amphibians and Reptiles

19. At least 24 wetland amphibian and reptile taxa will be found in broadleaf marsh habitats that have been restored from pasture.
20. Larval amphibians will be present for at least seven months each year in broadleaf marsh habitats that have been restored from pasture.

Fish

21. Mean annual density of small fishes (fishes < 10 cm total length) within restored marsh habitats will be ≥ 18 fish/m^2.
22. Mean annual relative abundance of fishes in the restored river channel will consist of ≤ 1% *Amia calva* (bowfin), ≤ 3% *Lepisosteus platyrhincus* (Florida gar), ≥ 16% *Lepomis auritus*, redbreast sunfish, and ≥ 58% centrarchids (sunfishes).
23. Off-channel dependents will comprise > 50% of fish assemblage composition in restored floodplain habitats and will be represented by ≥ 12 taxa. Young-of-the-year or juveniles will comprise ≥ 30% of the off-channel dependent guild.

Birds

24. Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be ≥ 30.6 birds/km^2.
25. Winter densities of waterfowl within the restored area of floodplain will be ≥ 3.9 ducks/km^2. Species richness will be ≥ 13.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is one of the most frequently used indicators of water quality because it is easy to understand and relatively simple to measure (Belanger et al., 1985). DO is essential to the metabolism of most aquatic organisms and can influence growth, distribution and structural organization of aquatic communities (Wetzel, 2001). Oxygen distribution also affects the solubility and availability of many nutrients and can impact the productivity of aquatic ecosystems (Wetzel, 2001). For these reasons, DO has been identified as a key indicator of ecological integrity and an essential component of the KRREP. Mean DO concentration in the Kissimmee River channel is expected to increase significantly after flow is restored. Restoration of continuous flow should increase reaeration rates and decrease sediment oxygen demand by flushing organic deposition from the underlying sandy river bottom. Continuous flow also should restrict mid-channel growth of aquatic macrophytes and increase light availability (and therefore oxygen production) in the water column. Concentrations should be within the range of values reported for reference streams and show similar seasonal patterns. Four metrics were chosen to evaluate changes in DO as restoration proceeds: (1) mean wet season daytime DO concentration at 0.5 m, (2) mean dry season daytime concentration of dissolved oxygen at 0.5 m, (3) annual percentage of samples with DO concentrations >2 mg/L, and (4) percent of time DO concentrations within 1 m of the channel bottom are >1 mg/L.

DO was monitored continuously at a depth of approximately 1 m in three remnant river run stations in Pools A and C. Continuous monitoring is essential for detection of oxygen sags, which may occur at night. When conditions are such that there is a high probability for dissolved oxygen sags (warm water temperatures, cloudy days, low flow, etc.), additional sensors can be deployed near the river channel bottom so that the entire water column is sampled. Sampled river channels were approximately 20–30 m wide and 2–3 m deep. DO was also sampled monthly within seven remnant river runs in Pools A and C. DO data were not collected prior to channelization; therefore, the reference condition was derived from data on seven free-flowing, blackwater streams in South Florida. Each stream had at least 11 samples collected over a minimum of one year and some streams were sampled for more than 10 years. The mean DO concentration in the reference streams was 4.8 mg/L during the wet season and 6.6 mg/L during the dry season (**Figure 11-11**). In five of the eight streams, DO was >5 mg/L in more than 50 percent of the samples. In seven of the eight streams, more than 90 percent of the samples had concentrations >2 mg/L.

Within the channelized river, DO concentrations were frequently below 1 mg/L throughout the water column at all times of day. A gradient in DO concentration (DO decreasing with depth) was observed during May through June 1999. DO concentrations near the surface could be as high as 4-5 mg/L while concentrations near the bottom were lower than the detection limit (<0.2 mg/L). During 1996–1999, mean DO concentrations in remnant river runs in Pool A and C were 1.4 and 1.2 mg/L, respectively, during the wet season, and 3.1 and 3.3 mg/L, respectively, during the dry season (**Figure 11-11**). DO concentrations exceeded 2 mg/L for 22 percent of the baseline period, and 5 mg/L for 6 percent of this period.

Following completion of construction for Phase I of the restoration, mean daytime DO concentrations within the restored area averaged 2.9 mg/L during the wet season and 5.9 mg/L during the dry season (**Figure 11-11**). Post-construction DO concentrations in the control area (Pool A) averaged 1.5 and 3.3 mg/L during the wet and dry seasons, respectively (**Figure 11-11**). Mean annual DO concentrations in the restoration area (Pool C) increased from <3.0 mg/L before construction to >4.0 mg/L in 2005 (**Figure 11-12)**. Mean daily water column DO concentrations were >2.0 mg/L for 70 percent of the time in 2005. Dissolved oxygen concentrations within one meter of the channel substrate were >1.0 mg/L over 50 percent of the time. After restoration of flow, the previously observed DO gradient vanished. DO concentrations were similar throughout the water column.

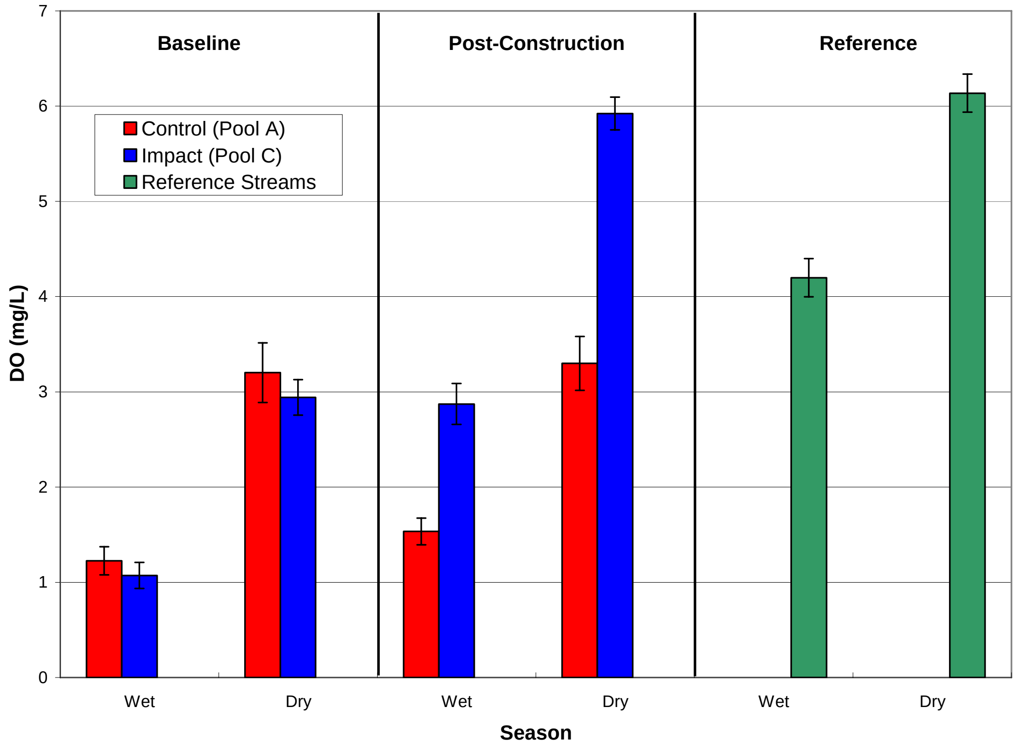


Figure 11-11. Mean (± S.E.) dissolved oxygen (DO) concentrations (mg/L) in reference streams and control and impact areas during the wet and dry season, before and after Phase I construction.

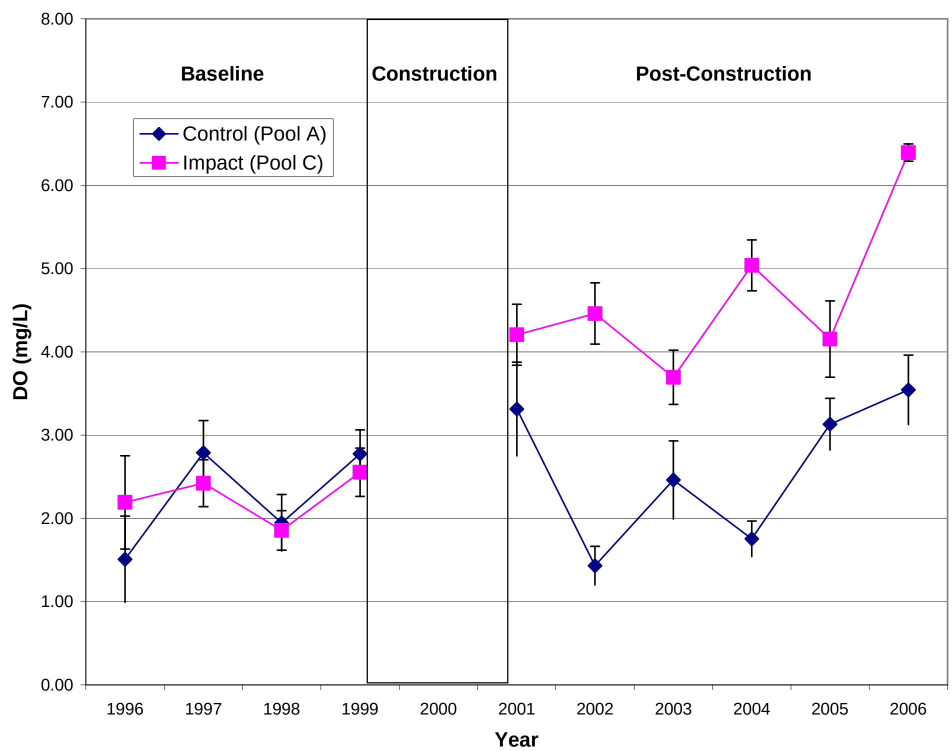


Figure 11-12. Mean (± S.E.) annual DO concentrations (mg/L) in the Kissimmee River.

It is important to note that post-construction DO concentrations of <1 mg/L have been recorded in the river channel during the wet season and, in some cases, low DO concentrations have persisted for as long as several months. As noted previously, low DO concentrations can affect the availability of nutrients, including phosphorus. The possibility that low DO leads to release of phosphorus from river channel sediments has not been examined. The amount of phosphorus released from sediment in the restored river channel is believed to be relatively small compared to the amount of phosphorus transported downstream from sources throughout the basin. Nevertheless, planning for the next KRREP phase will consider proposals to study phosphorus assimilation and release in the river channel as well as the restored wetlands in the Pool D floodplain.

Despite some periods of low oxygen levels, DO has improved substantially following restoration. Although the restoration expectation for DO concentrations in the restored river channel is intended to be evaluated after implementation of the Kissimmee River Headwaters Revitalization Project regulation schedule, two of the four metrics used to evaluate DO response are already being met under the interim regulation schedule.

TURBIDITY

The Kissimmee River is a slow-flowing system in a basin with nearly flat terrain. Consequently, turbidity and total suspended solids (TSS) concentrations have been very low and are expected to remain low after restoration. Baseline turbidity and TSS were sampled monthly during 1996–1999 in seven remnant river runs of Pools A and C (**Table 11-2**). Mean turbidity at these locations was very low, ranging from 1.3–3.5 nephelometric turbidity units (NTU). TSS concentrations were ≤ 25 mg/L, and were usually lower than the detection limit (i.e., <3 mg/L). Slightly higher turbidity values were measured in summer and appear to reflect greater densities of phytoplankton, as indicated by chlorophyll *a* concentrations.

No turbidity or TSS data were collected from the Kissimmee River before it was channelized, so the reference condition was derived from general knowledge of pre-channelized conditions and data on other South Florida streams. Turbidity in the former river is assumed to have been very low due to (1) the river's location in a watershed with nearly flat topography, sandy soils, and low-intensity land use; (2) headwater inflow from Lake Kissimmee, which supplied 58 percent of total river discharge (Bogart and Ferguson, 1955); (3) groundwater seepage from aquifers underlying upland areas (Parker, 1955); (4) low channel velocities; and (5) filtering effects of marsh and littoral vegetation. Floods in the Kissimmee Basin were characterized by slow changes in stage, low flow velocities, and long periods of recession. Floodwaters were relatively clear and little silt was left after floods passed (Bogart and Ferguson, 1955). This suggests that suspended material associated with surface runoff did not significantly influence water quality during high discharges, and any turbidity in the river would have been primarily due to plankton, suspended detritus, or erosion of channel sediment during extreme flows. In a flowing, blackwater river surrounded by dense vegetation, phytoplankton blooms would have been rare, so turbidity and TSS would have remained low (turbidity <5 NTU and TSS <3 mg/L) even during low flows that would otherwise favor phytoplankton. In summary, reference conditions for turbidity and TSS probably did not differ significantly from baseline measurements, except that maximum values may have been lower due to a reduced likelihood of algal blooms.

Table 11-2. Turbidity and total suspended solids (TSS) in remnant river runs of Pools A and C from March 19, 1996 to June 8, 1999 (see Jones, 2005 for details).

Water Body and SFWMD Station ID	Turbidity (NTU)				TSS (mg/L)[1]		
	N	Median	Mean ± Std. Error	Max.	N	Median	Max.
Ice Cream Slough Run-–Pool A (KREA 97)[2]	31	2.5	2.5 ± 0.2	6.5	31	< 3.0	11.0
Rattlesnake Ham. Run–Pool A (KREA 91)	331	2.2	2.3 ± 0.2	4.5	31	< 3.0	7.0
Schoolhouse Run–Pool A (KREA 92)	335	2.4	3.5 ± 0.5	17.3	35	< 3.0	25.0
Montsdeoca Run–Pool C (KREA 98)[3]	117	1.2	1.3 ± 0.2	3.6	18	< 3.0	3.0
Oxbow 13–Pool C (KREA 93)	332	1.9	2.1 ± 0.1	3.7	33	< 3.0	13.0
Micco Bluff Run–Pool C (KREA 94)	331	1.6	1.9 ± 0.2	5.5	32	< 3.0	18.0
MacArthur Run–Pool C (KREA 95)	334	1.6	1.8 ± 0.2	6.3	35	< 3.0	5.0

1 Most total suspended solids (TSS) values were below detection limit (usually < 3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

2 Ice Cream Slough Run data begins in November 1996.

3 Montsdeoca Run data begins in December 1997.

Due to the lack of reference data from the pre-channelized river, eight free-flowing, blackwater streams in South Florida were selected as reference sites. These streams and their watersheds share some features of the former Kissimmee River (e.g., low topographic relief, sandy substrate, presence of swamps or marshes, low velocity), although other characteristics may differ (e.g., watershed size, discharge, watershed development and artificial drainage). Turbidity and TSS values in these streams are low (mean turbidity = 2.0–6.5 NTU) and are probably typical of the former Kissimmee River (**Table 11-3**). Values have ranged up to two orders of magnitude higher in these streams, but such events are rare and were sometimes caused by surface runoff and local disturbances. The pre-channelized Kissimmee River probably did not exhibit these extremes due to the characteristics of the river and its watershed.

Although Pool C river runs were expected to be temporarily affected by mobilization of accumulated vegetation and organic deposits as the restoration project reestablished flow in reconnected remnant river channels, turbidity and TSS were expected to return to reference levels after one full year of moderate flow (20–40 m^3 per second) through the restored river channel. This expectation has been met for turbidity.

Following Phase I construction, turbidity remained low in the restored reach of the river during WY2002–WY2006. Turbidity averaged 2.8–5.7 NTU at the four stations in the restored reach (**Table 11-4**). The overall average was 4.7 NTU. Maximum values at these stations ranged up to 14.3 NTU. Turbidity levels were consistent between the four years. These data are not statistically different from the reference stream data.

Table 11-3. Turbidity and TSS data for Florida stream reference sites (from Jones, 2005).

	Turbidity (NTU)				TSS (mg/L)[1]		
Water Body	N	Median	Mean ± Std. Error	Max.	N	Median	Max.
Fisheating Creek	393	1.6	3.8 ± 0.9	290.0	365	< 3.0	986.7
Arbuckle Creek	85	2.9	3.4 ± 0.2	14.4	39	< 3.0	24.0
Lake Marian Creek	37	2.0	4.5 ± 1.9	70.0	13	4.0	15.0
Reedy Creek	150	1.3	2.0 ± 0.2	18.9	99	< 3.0	58.0
Tiger Creek	33	3.9	3.9 ± 0.3	8.7	12	3.0	8.0
Josephine Creek	85	2.2	2.4 ± 0.2	10.5	39	< 3.0	14.0
Boggy Creek	204	2.0	6.5 ± 2.8	570.0	116	< 3.0	416.0
Catfish Creek, S. Branch	11	3.8	4.8 ± 0.8	11.1	4	4.5	11.0

[1] Most TSS values were below detection limit (usually < 3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

Table 11-4. Turbidity and total suspended solids in river runs of Pools A and C after Phase I construction (May 1, 2001 to April 30, 2006).

	Turbidity (NTU)				TSS (mg/L)[1]		
Water Body and SFWMD Station ID	N	Median	Mean ± Std. Error	Max.	N	Median	Max.
Ice Cream Slough Run-–Pool A (KREA 97)[2]	32	3.3	3.4 ± 0.3	10.4	32	5.0	10.0
Rattlesnake Ham. Run–Pool A (KREA 91)[2]	44	2.5	2.7 ± 0.2	6.6	44	3.3	18.8
Schoolhouse Run–Pool A (KREA 92)	56	2.2	2.4 ± 0.1	6.4	58	< 3.0	9.8
Montsdeoca Run–Pool C (KREA 98)	55	4.4	4.9 ± 0.3	13.7	55	7.0	14.0
Oxbow 13–Pool C (KREA 93)	56	5.1	5.4 ± 0.3	14.3	56	7.6	17.2
Micco Bluff Run–Pool C (KREA 94)	56	5.4	5.7 ± 0.3	13.2	57	8.0	19.1
MacArthur Run–Pool C (KREA 95)	55	2.1	2.8 ± 0.3	10.7	56	< 3.0	16.8

[1] Many TSS values were below detection limit (usually < 3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

[2] Ice Cream Slough Run and Rattlesnake Hammock Run were not sampled during certain periods due to inaccessibility. Most data from Ice Cream Slough Run are from the last three water years.

TSS concentrations have been slightly higher than expected. Median TSS concentrations at the four stations within the restored reach ranged from 3.0–8.0 mg/L (**Table 11-4**). Nevertheless, the difference between these concentrations and concentrations in the reference streams is probably not ecologically significant. No effect on TSS or turbidity was recorded after Hurricane Wilma passed through South Florida in October 2005.

PHOSPHORUS

The Kissimmee River is Lake Okeechobee's largest tributary and contributes 34 percent of the lake's surface water input of phosphorus (SFWMD, 2002). Construction of C-38 and lateral drainage ditches has presumably contributed to Lake Okeechobee's excessive total phosphorus (TP) load by facilitating downstream transport of phosphorus runoff and limiting opportunity for detention and assimilation in floodplain wetlands. While Pools A, B, and C (**Figure 11-1**) are not major exporters of phosphorus, Phase I restoration of the river and floodplain may eventually promote lower inputs from these pools and reduced loading from the headwater lakes. Restoration of sloughs and marshes along the river may increase retention of phosphorus from tributary watersheds and headwater lakes as flow velocities decrease and phosphorus settles out of the water column or is assimilated by wetland periphyton and macrophytes. Filling of lateral ditches and removal of cattle from the floodplain also may help to lower TP loads from tributaries.

Baseline and post-construction TP data have been obtained from routine monitoring at each C-38 water control structure. TP concentrations were determined from weekly to monthly grab samples and composite samples collected by auto-samplers. Estimates of daily TP loads were computed from measured or interpolated TP concentrations and daily discharge data and then summed annually. Annual TP loads were divided by annual discharges to obtain flow-weighted mean (FWM) TP concentrations at each structure. Because TP loads can vary greatly between wet years and dry years, FWM concentrations provide a more useful metric for evaluating trends.

Calendar years 1974 through 1995 were chosen as the baseline period of record. During those 22 years, TP loading averaged 51 metric tons per year (mt y^{-1}) at S-65C and 83 mt y^{-1} at S-65D (**Figure 11-13**). These amounts comprised 43 and 71 percent of the average load at S-65E, respectively. Annual FWM TP concentrations averaged 53 parts per billion (ppb) at S-65C (ranged from 33–87 ppb), and 78 ppb at S-65D (ranged from 47–141 ppb) (**Figure 11-14**). Concentrations were greater during years of lowest flow (1981 and 1985). At S-65, upstream of the restoration project area, the mean loading rate was 35 mt/y (**Figure 11-13**) and the FWM TP concentration was 43 ppb (**Figure 11-14**).

Reference conditions for TP loads and concentrations of the Kissimmee River cannot be determined with any certainty because phosphorus was not routinely monitored before channelization. Nevertheless, knowledge of former characteristics of the river, its floodplain, and its watershed make it reasonable to assume that concentrations were lower in the pre-channelized river. Restoration should tend to favor a return to lower concentrations, but not until a natural river-floodplain hydroperiod and stable wetland ecosystem become established. These conditions will not be achieved until the Headwaters Revitalization Project regulation schedule is implemented in 2011. In the meantime, TP concentrations may increase periodically as the nutrient is released from former pastures and the floodplain transitions from terrestrial to wetland vegetation.

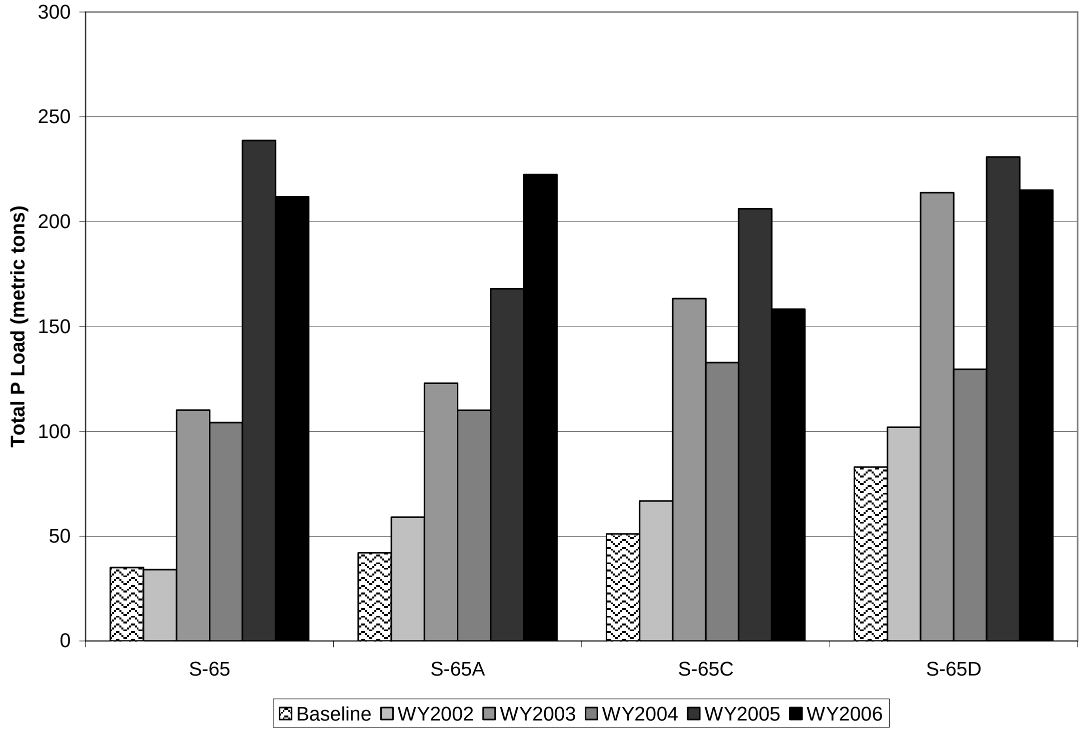


Figure 11-13. Annual total phosphorus (TP) loads (metric tons, or mt) from C-38 structures in comparison to baseline (1974–1995) loads.

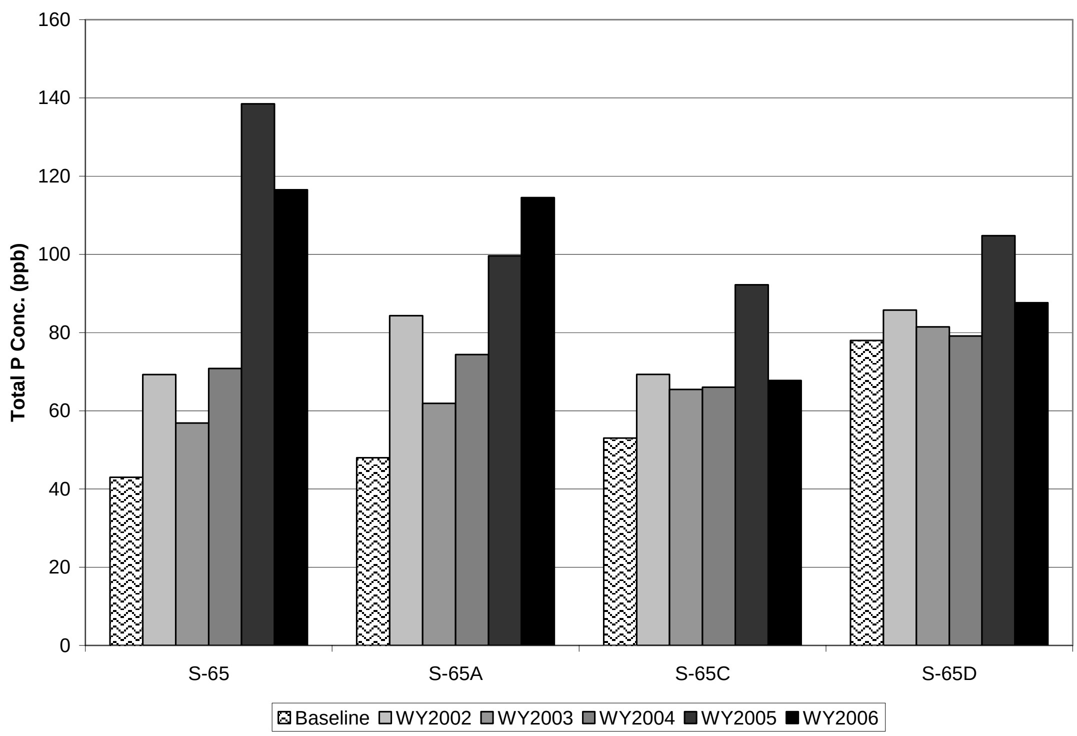


Figure 11-14. Annual flow-weighted mean (FWM) TP concentrations (parts per billion, or ppb) at C-38 structures in comparison to baseline (1974–1995) concentrations.

Under the interim regulation schedule, floodplain in the Phase I restoration area has undergone a number of wet/dry cycles. Observational data suggest that much of the terrestrial vegetation has disappeared from the floodplain and that wetland plant species have begun recolonizing the restored area. However, the interim regulation schedule has not allowed for the pattern of floodplain inundation that is expected once the Headwaters Revitalization Project regulation schedule is implemented. Thus, in the transitional years since Phase I was completed, the developing broadleaf marsh is not likely to have been assimilating incoming phosphorus at its highest efficiency.

To date, neither TP loads nor concentrations have declined at S-65C and S-65D since the baseline period. In fact, they have been higher (**Figures 11-13** and **11-14**). TP loads were especially high in WY2005 due to the 2004 hurricane but were not quite as high in WY2006, except at S-65A. Hurricane Wilma did not substantially increase the annual loading. Annual FWM TP concentrations also declined from WY2005 to WY2006 except at S-65A. However, these concentrations continued to be relatively high at S-65 and S-65A. Further examination of the data from these two structures revealed that TP concentrations were frequently above 100 ppb from June to November and then dropped to more moderate levels for the rest of the water year. The annual FWM TP concentration at S-65C, immediately downstream of the Phase I restoration area, was 68 ppb in WY2006 and has been consistently above the baseline level of 53 ppb since WY2002.

Historically, TP concentrations throughout the upper reach of C-38 have been influenced by discharges from the Lake Kissimmee outlet (S-65). Therefore, an understanding of what influences fluctuations at S-65 is an important key to managing concentrations and loads in C-38. Not enough information is available at this time to determine the causes of these high TP concentrations at S-65, which have been measured since the 1990s. In most cases, these elevated concentrations cannot be attributed to increases in Lake Kissimmee or other lakes in the KCOL. Instead, recent evidence points to sources at the southern end of Lake Kissimmee that are increasing concentrations at the lake's outlet. Efforts to identify sources of elevated phosphorus will be discussed in the 2008 SFER. If sources of phosphorus at the lake's southern end can be identified and controlled, then phosphorus inputs into the Kissimmee River and, ultimately, Lake Okeechobee could decrease.

BIRDS

Birds are both integral to the Kissimmee River/floodplain ecosystem and highly valued by its human users. While quantitative pre-channelization data are sparse, available data and anecdotal accounts indicate that the system supported an abundant and diverse bird assemblage (National Audubon Society, 1936–1959; FGFWFC, 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Further, since many bird groups (e.g., wading birds, waterfowl) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller, 1995). Detailed information regarding the breadth of the avian evaluation program can be found in the 2005 SFER – Volume I, Chapter 11. This section highlights portions of the avian program for which data were collected during WY2006.

Aerial surveys were used to measure the densities of wading birds and waterfowl within the 100-year flood line, as well as to search for rookeries of nesting wading birds on or near the floodplain. Surveys were conducted approximately monthly during the baseline period (pre-restoration; 1996–1998) and have continued after Phase I of the restoration project was completed. Restoration is expected to bring increased use of the floodplain by both long-legged wading birds (excluding cattle egrets) and waterfowl. Furthermore, mixed species wading bird rookeries are anticipated to regularly form on and near the floodplain and tributary sloughs once abundant food resources and appropriate hydrology have been reestablished.

To investigate densities of wading birds and waterfowl on the floodplain, east-west aerial transects (n = 218) were established at 200 m (656 ft) intervals beginning at the S-65 structure and ending at the S-65D structure (see **Figure 11-1** for structure locations). Each month, transects were randomly selected for counts until a minimum of 15 percent of the 100-year floodplain was surveyed in both the Phase I and unrestored portion of the river/floodplain. Surveys were conducted via helicopter flying at an altitude of 30.5 m (100 ft) and a speed of 130 km/hr (70 knots). A single observer counted all wading birds and waterfowl within 200 m of one side of the transect line. Because it is not always possible to distinguish tricolored herons (*Egretta tricolor*) from adult little blue herons (*E. caerulea*) during aerial surveys (Bancroft et al., 1990), the two are lumped into the category, small dark herons. Likewise, snowy egrets (*E. thula*) and immature little blue herons were classified as small white herons (Bancroft et al., 1990). Densities of wading birds and waterfowl were calculated separately for restored and unrestored areas using the ratio method of Jolly (1969). In addition to surveys of wading bird densities, systematic aerial searches for wading bird colonies were flown during the nesting season. Each colony survey flight spans Pools A–D and covers the entire 100-year floodplain plus an additional 3 km to the east and west of its border. Once a colony is located, the numbers and species of nesting wading birds are counted from the air and, when possible, verified through ground surveys.

Because no quantitative data are available for densities or relative abundances of long-legged wading birds or waterfowl of the pre-channelized Kissimmee River, restoration expectations for responses by these groups to the KRRP are based on reference data from aerial surveys of a flow-through marsh in Pool B (wading birds and waterfowl) that was built as part of the Kissimmee River Demonstration Project and for floodplain areas along Paradise Run (wading birds), a portion of the Kissimmee River near Lake Okeechobee that still retains some channel flow and periodic floodplain inundation (Toland, 1990; Perrin et al., 1982). The 3.5 km^2 flow-through marsh was constructed just south of the S65-A tieback levee during 1984–1985 and was manipulated to simulate inundation and overland flow that were typical of the pre-channelized Kissimmee River floodplain (Toth, 1991). Based on these reference data, it is expected that annual dry season (December–May) densities of long-legged wading bird (excluding cattle egrets) will be ≥30.6 birds/km^2 and winter (November–March) waterfowl densities will be ≥3.9 ducks/km^2. No quantitative data are available for the numbers, locations, and species composition of wading bird nesting colonies within the pre-channelized Kissimmee River/floodplain system and no appropriate reference data were identified. Therefore, a restoration expectation was not developed for reproductive effort by colonially nesting wading birds. However, this key aspect of ecological integrity of the restored Kissimmee system will be monitored throughout the restoration evaluation program.

Prior to Phase I construction (baseline period), mean annual dry season densities of long-legged wading birds in the Phase I area averaged (± SE) 3.6 ± 0.9 birds/km^2 in 1997 and 14.3 ± 3.4 birds/km^2 in 1998. Since completion of Phase I, densities of long-legged wading birds have exceeded the restoration expectation of 30.6 birds/km^2 each year, averaging 37.8 ± 15.4 birds/km^2, 61.7 ± 14.5 birds/km^2, 59.6 ± 24.4 birds/km^2, and 103.0 ± 31.5 birds/km^2 in the 2002, 2004, 2005, and 2006 dry seasons, respectively (Note that 2003 data were not collected; see **Figure 11-15**). Furthermore, the lower limit of the 95 percent confidence interval (95% C.I.) has exceeded the expectation in three of four years. White ibis was the most common species in all 2006 dry season surveys, with great egret, small white heron (snowy egret and immature little blue heron), glossy ibis, wood stork, and great blue heron also commonly encountered.

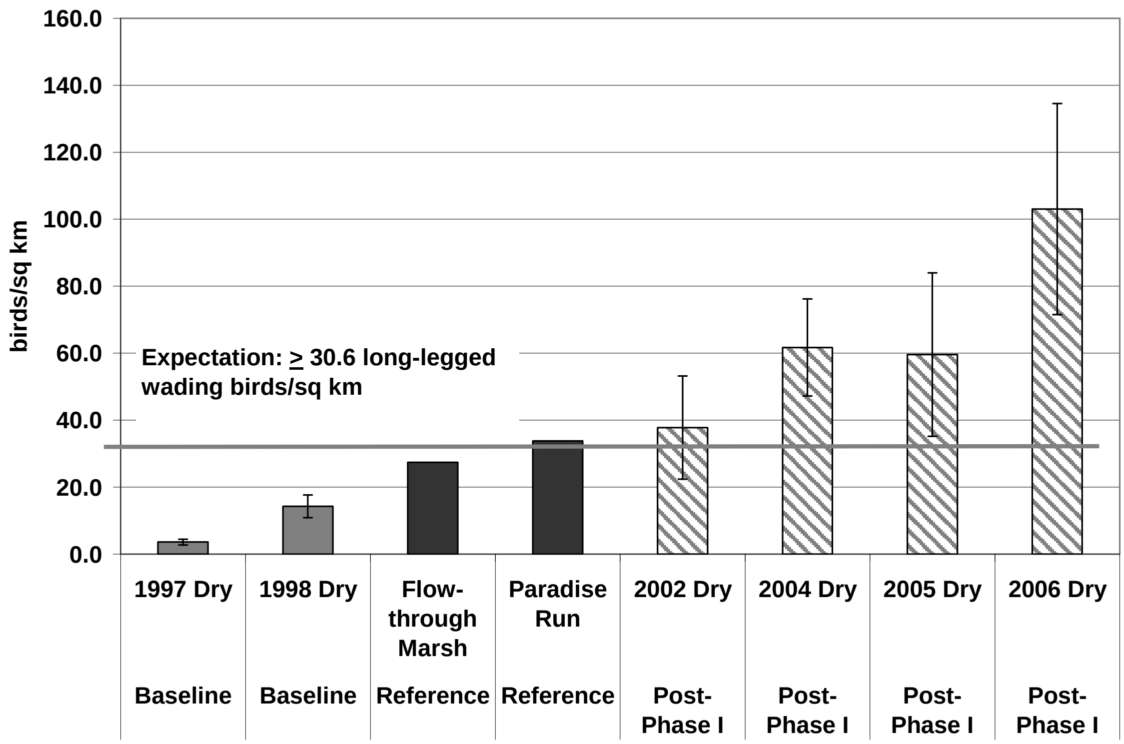


Figure 11-15. Baseline, reference, and post-Phase I densities (± SE) of long-legged wading birds (excluding cattle egrets) within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately 10 months following completion of Phase I.

While there has been a strong numerical response by foraging long-legged wading birds to the first phase of restoration, reproductive effort has not followed suit. Baseline aerial surveys indicated no active breeding colonies on the floodplain in 1996, one colony of cattle egrets and little blue herons in Pool B in 1997, and one colony of great egrets and anhingas (*Anhinga anhinga*) in Chandler Slough in Pool D in 1998. Both colonies were small, with less than 100 pairs. Post-Phase I breeding colony surveys were conducted in 2004, 2005, and 2006. During 2004, no colonies were found. In 2005, three colonies containing an estimated 516 total nests were observed. Of this number, 400 were cattle egrets and 30 were anhingas; long-legged wading birds (great egret, great blue heron) constituted the remainder (n = 86) of nests. In 2006, five colonies with an estimated 657 nests were observed, including 133 great egret, 4 great blue heron, 500 cattle egret, and 20 anhinga. Three of five colonies were limited to great egrets; all 500 cattle egret nests were from a single colony.

Anecdotal observations within the Phase I area suggest that ample wetland shrub vegetation exists for nesting. A vegetation mapping project of the 2003 Kissimmee River and floodplain that is nearing completion will provide enhanced quantitative information regarding the amounts and locations of suitable nesting sites for wading birds. Several factors may account for the lack of nesting effort following Phase I backfilling. First, it may take a number of years following backfilling for populations of prey items to reach levels capable of supporting breeding colonies. Second, the timing of floodplain inundation and recession may not yet be appropriate for rookery formation. Implementation of the regulation schedule for the Headwaters Revitalization Project in 2010 will allow water managers to more closely mimic the historical stage and discharge characteristics of the river, presumably leading to suitable hydrologic conditions for wading bird nesting colonies.

Responses by long-legged wading birds (foraging density and reproductive effort) to the restoration project will be measured across the entire restoration area (Phases I–IV). Monitoring will continue until five years after completion of the last phase of the restoration project.

Four duck species, blue-winged teal (*Anas discors*), green-winged teal (*A. crecca*), mottled duck (*A. fulvigula*), and hooded merganser (*Lophodytes cullulatus*) were detected during baseline aerial surveys; during the same time period, casual observations of wood duck (*Aix sponsa*) were made during ground surveys for other projects (Williams and Melvin, 2005). Mean winter density (± SE) was 0.4 ± 0.1 ducks/km^2 in the Phase I area, well below the restoration expectation of 3.9 ducks/km^2. Following completion of Phase I, average annual duck densities have exceeded the restoration expectation during all five years and the lower limit of the 95% C.I. has exceeded the expectation in four of five years (**Figure 11-16**). Mean winter density during 2005/2006 was the highest recorded thus far, averaging 37.0 ± 22.5 bird/km^2. The American wigeon (*A. americana*), northern pintail (*A. acuta*), northern shoveler (*A. clypeata*), ring-necked duck (*Aythya collaris*), mallard (*A. platyrhynchos),* and black-bellied whistling duck (*Dendrocygna autumnalis*) were not detected during baseline surveys, but have been present following restoration. Blue-winged teal and mottled duck have been the two most commonly observed species during both baseline and post-Phase I surveys. Restoration of the physical characteristics of the Kissimmee River and floodplain along with the hydrologic characteristics of headwater inputs is expected to produce hydropatterns and hydroperiods on the floodplain that will lead to the development of extensive areas of wet prairie and broadleaf marsh, two preferred waterfowl habitats (Chamberlain, 1960; Bellrose, 1980). Changes in the species richness and density of waterfowl within the restoration area are likely to be directly linked to the rate of development of floodplain plant communities and the faunal elements they support. Extrinsic factors such as annual reproductive output on summer breeding grounds and local and regional weather patterns may also play a role in the speed of recovery of the waterfowl community. Responses by waterfowl to the restoration project will be measured across the entire restoration area (Phases I–IV). Waterfowl monitoring will continue until five years after completion of the last construction phase of the restoration project.

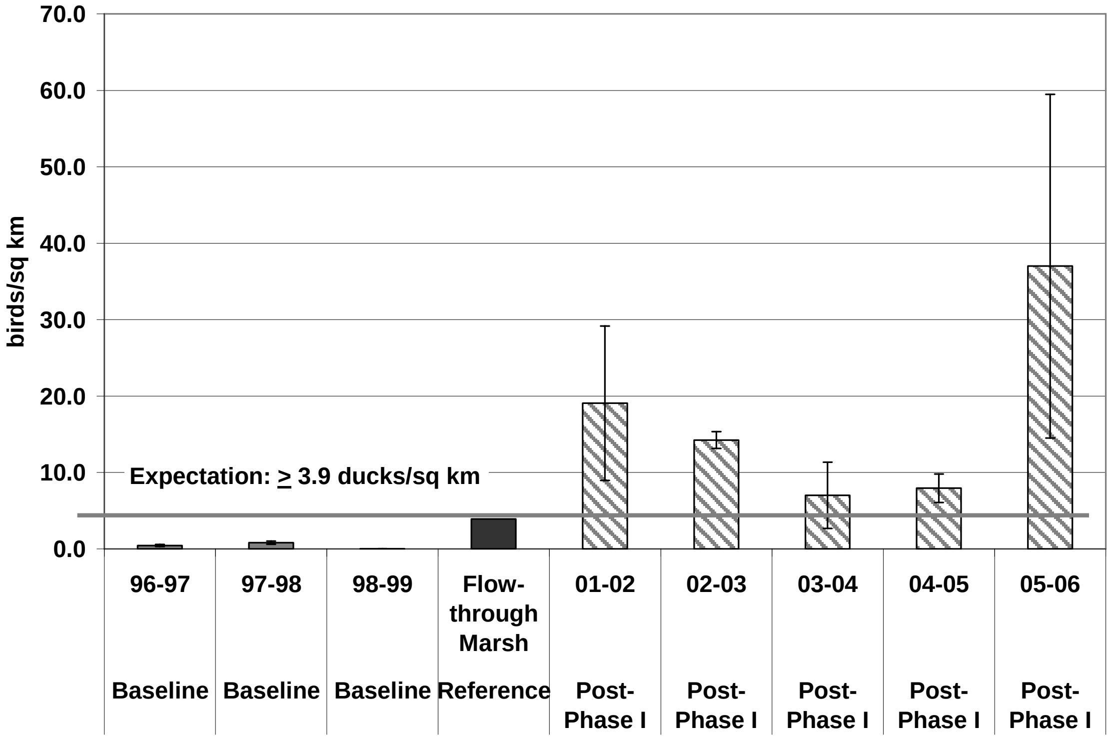


Figure 11-16. Baseline, reference, and post-Phase I densities (± SE) of waterfowl within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately 9 months following completion of Phase I.

KISSIMMEE BASIN HYDROLOGIC ASSESSMENT, MODELING, AND OPERATIONS STUDY

The Kissimmee Basin Modeling and Operations Study (KBMOS) is an SFWMD initiative to identify alternative water control structure operating criteria to meet the flood control, water supply, aquatic plant management, and natural resource operations objectives of the Kissimmee Basin and its associated water resource projects. The KBMOS component of the KRRP will define the required water control structure operations needed to meet its hydrologic requirements and achieve a more acceptable balance between operations objectives associated with flood control, water supply, aquatic plant management, natural resource requirements of the Kissimmee River Restoration and the Kissimmee Chain of Lakes (KCOL), and Lake Okeechobee. Operating criteria will be developed to effectively meet these various objectives with complete reliance on the existing water management infrastructure and the land interests of the State of Florida and the SFWMD. The KBMOS is independent of but closely related to the KCOL Long-Term Management Plan (KCOL LTMP) that is discussed in greater detail later in this chapter.

Phase I of the KBMOS was completed in June 2005. Findings from the Phase I hydrologic assessment of the Kissimmee Basin (Earth Tech, 2005a) were used to develop a work plan for future phases of the study and provide the justification for model tool development and the approach for alternative plan formulation. Phase II, initiated in July 2005, includes the development of evaluation performance measures, modeling tools, and an alternative plan formulation process. The KBMOS is scheduled for completion in December 2007. The final deliverable will be modified interim and long-term operating criteria for Kissimmee Basin water control structures. Study components associated with Phase I and II and their relationship to one another are illustrated in **Figure 11-17**.

Phase II

The objectives of Phase II of the KBMOS are (1) the creation of a suite of modeling tools that are capable of modeling water levels and flows in the Kissimmee Basin and (2) their application for the selection of an alternative plan that will propose revised operating criteria for the Kissimmee Basin. Because an alternative plan can propose modified operating criteria for each of the thirteen water control structures in the basin, there are an infinite number of operating criteria combinations that could be considered. To support evaluation of a large number of alternative plans, a multi-level evaluation approach was developed. This alternative plan formulation process will use a set of modeling tools that can evaluate, at increasing levels of detail, the operating criteria that will make up the alternatives for the KBMOS. The evaluation of alternatives will be completed by measuring the influence operating criteria have on water levels and flows and comparing those results with hydrologic performance measures that define how well (or poorly) an alternative meets a specific objective.

ALTERNATIVE PLAN FORMULATION

The three levels of evaluation that will be used for the KBMOS are screening, formulation, and evaluation. The screening level will use a management simulation engine to develop operating rule forms for conceptual alternatives and promote alternatives to the formulation level that meet a subset of the evaluation performance measures. The formulation level will use a hydraulic routing model to adjust operating parameters within operating rule forms. Alternatives will be evaluated relative to a larger set of hydrologic performance measures and ranked. A limited number of alternatives, at the top of that ranking, will be promoted for full evaluation against the complete set of evaluation performance measures using a fully integrated hydrologic and hydraulic modeling tool (Earth Tech, 2005b).

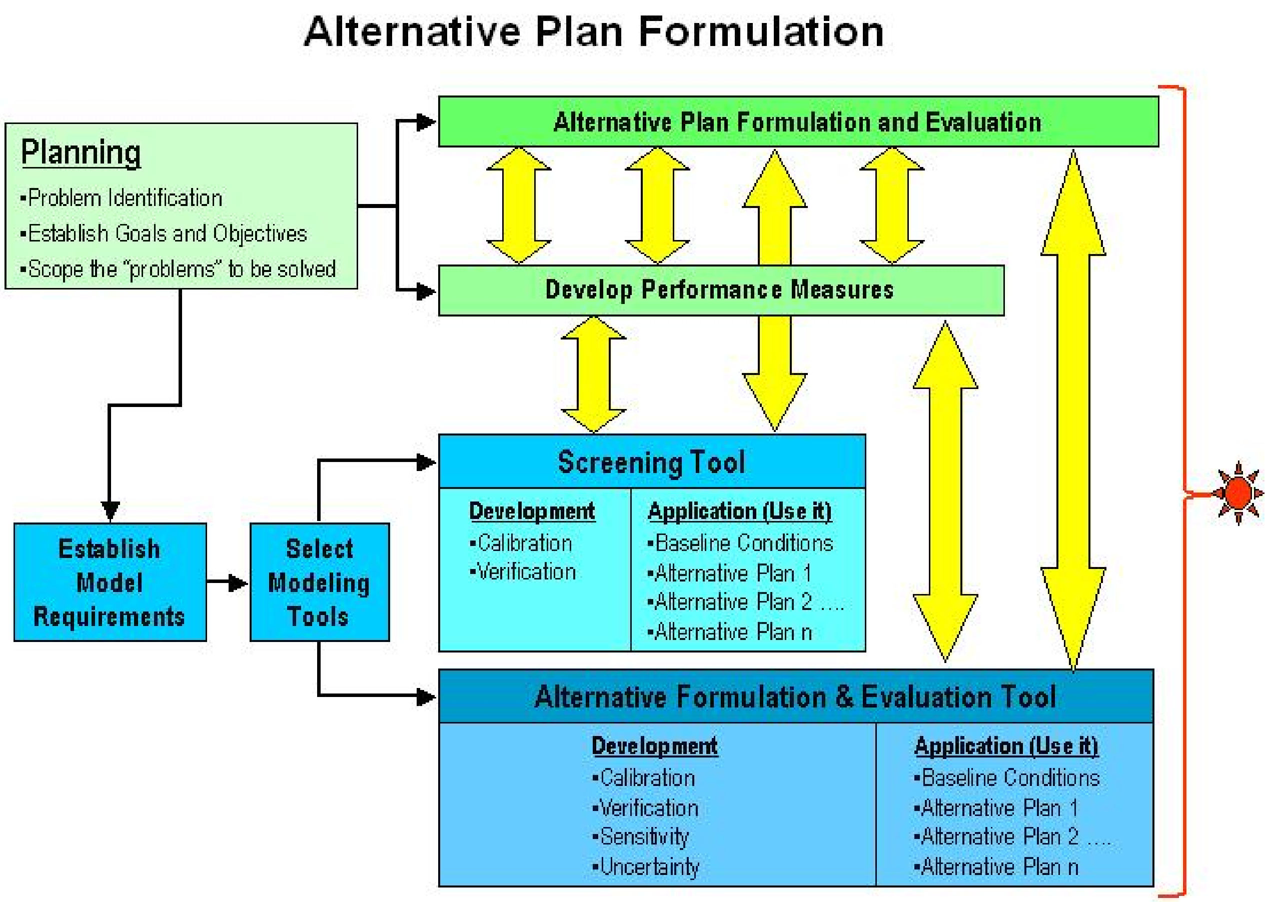


Figure 11-17. Relationship among components of the Kissimmee Basin Modeling and Operations Study (KBMOS).

SCREENING

The management simulation engine that will be used for the screening of conceptual alternatives is the OASIS model from Hydrologics, Inc. OASIS is a water budget model that simulates water control structure operations. OASIS simulates daily flows and can use surrogates to estimate peak daily stages. It has short run times and has been peer reviewed by the SFWMD for similar studies.

The OASIS model being developed for the KBMOS has been named OKISS. Tool development, calibration, and training are scheduled for completion in November 2006. Application of the tool will initiate in November and continue through April 2007.

ALTERNATIVE FORMULATION/EVALUATION TOOL

The MIKE SHE/MIKE 11 model was selected as the alternative formulation/evaluation tool through a multi-step, consensus building process. This tool simulates the hydrologic and hydraulic components of the watershed. MIKE 11 is a hydraulic routing tool that is capable of simulating the complex structure operations in the SFWMD. MIKE SHE is a hydrologic model that accounts for overland and groundwater flow as well as flow in the unsaturated zone.

Following calibration/verification of the integrated model, the MIKE 11 model will be decoupled and used as the Alternative Formulation Tool. The integrated MIKE 11/MIKE SHE model will be used as the Alternative Evaluation Tool.

The MIKE SHE/MIKE 11 model being developed for the KBMOS is referred to as the Alternative Formulation and Evaluation Tool (AFET). Model development, calibration, verification, and training are scheduled for completion in January 2007. Base condition simulation runs will begin in February 2007. Alternative formulation and evaluation are expected to initiate in May 2007 and run through July 2007.

EVALUATION PERFORMANCE MEASURES

Performance measures will be used to evaluate how well alternative plans meet the diverse water management objectives of the KBMOS. These performance measures are being developed by leveraging the local knowledge and understanding of engineers, scientists, planners, hydrologists, hydrogeologists, and operations personnel from the SFWMD and an Interagency Study Team. The Interagency Study Team consists of staff from the USACE, USFWS, U.S. Environmental Protection Agency (USEPA), FWC, Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), local governments, and stakeholders.

Evaluation performance measure development began in July 2005. The SFWMD worked closely with the Interagency Study Team to assess, collate, and organize information resources into synopses of data that conceptualize the current understanding of how biology and hydrology of the basin interact. Potential linkages between the data, conceptual understandings, and the hydrological features of the Kissimmee River, the Kissimmee Chain of Lakes (KCOL), and Kissimmee Basin were distilled and form the basis of the draft evaluation performance measures.

Initially, meetings were held with Interagency Study Team points of contact for flood control, water supply, aquatic plant management, natural resources and downstream ecosystems. Meetings were then held with all senior scientists from the District's Kissimmee Division to discuss ongoing projects, data collection, and research activities as well as to discuss the specific biological attributes required to achieve the ecological integrity goal of the Kissimmee River Restoration Project. Additional background information, experience, guidance, basin knowledge, and data from all ongoing major projects in the Kissimmee Basin were gathered to support the development of evaluation performance measures.

Performance measures are currently in draft form and will continue to be refined and consolidated through April 2007. **Table 11-5** provides a list and brief description of the draft evaluation performance measures that have been developed by the Interagency Study Team as of February 2006 (PBS&J, 2006).

Table 11-5. Titles and brief descriptions of draft evaluation performance measures that will be used to evaluate alternative structure operation plans as part of the KBMOS.

No.	Title	Description
1	Kissimmee River Continuous Flow	Magnitude, duration and timing of low flow events
2	Seasonality and Variability of Kissimmee River Flow	Timing of maximum and minimum flow and variability of flow
3	Kissimmee River Stage Hydrograph	River channel stage hydrograph characteristics
4	Kissimmee River Stage Ascension/Recession Rate	Ascension and recession event characteristics
5	Kissimmee River Channel Velocity	Percent of time river channel velocity is within specified ranges
6	Kissimmee River Energy Grade Line	The degree and persistence of energy grade line discontinuities
7	Kissimmee River Floodplain Inundation	Floodplain hydroperiod characteristics and flood control level of service
8	Flow Duration	Characterization of flood regime type and the ability to sustain flows during dry periods
9	Stage Duration	Percentage of time that stage equals or exceeds a specified stage value specifically for navigation
10	Probable High Lake Stages	Flood control level of service
11	Seasonality and Variability of Lake Stages	Timing of maximum and minimum stage and the intra-annual and inter-annual stage variation
12	Frequency and Duration of High and Low Lake Stages	Frequency and duration of maximum and minimum lake stages
13	Lake Stage Recession Rate	Lake stage recession event characteristics
14	Lake Littoral Zone Inundation	Area of littoral zone inundation at critical lake depths
15	Sub-watershed Runoff Volume	Total runoff volume for each sub-watershed
16	Water Supply for Consumptive Use	Lake stage conditions that enable consumptive use of surface water
17	Lake Discharges for Hydrilla Management	Lake discharge conditions required for cost-effective hydrilla management
18	Lake Stages for Hydrilla Management	Lake stage conditions required for cost-effective hydrilla management
19	Kissimmee River Flows to Lake Okeechobee	Discharge volumes from the Kissimmee River to Lake Okeechobee
20	Protection of Wetlands	Wetland hydroperiod characteristics

PUBLIC OUTREACH

A public outreach process is incorporated into the KBMOS to coincide with the performance measure development and alternative plan screening, formulation and evaluation. The outreach component consists of Interagency Study Team and Public workshops. These workshops are intended to involve stakeholders in performance measure development and alternative plan formulation.

During September 2005 through June 2006, seven performance measure development and refinement workshops were held to provide a forum to present and discuss performance measures with the Interagency Study Team and interested stakeholders. Proposed evaluation performance measures were presented and stakeholders were encouraged to discuss views and exchange ideas.

During the same time period, two public workshops were conducted. The first introduced the KBMOS and the performance measures concept. The second presented the first draft of the performance measures and the alternative plan formulation concept. Future workshops will present the process and tools that will be used to develop and evaluate alternative plans as well as the modeling and evaluation results.

Draft Environmental Impact Statement for Modification of Kissimmee Basin Structure Operating Criteria

Changing operational rules for water control structures requires that an Environmental Impact Statement be developed by USACE. To shorten the amount of time between completion of KBMOS and completion of the associated EIS, USACE is developing the EIS in parallel to KBMOS. The draft Environmental Impact Statement (EIS) required for modification of structure operating criteria within the Kissimmee Basin is a USACE project that is being conducted in parallel with the KB Modeling and Operations Study. The study area includes the Kissimmee River, the Kissimmee Chain of Lakes, and the associated tributaries and drainage areas. The lakes include Lakes Kissimmee, Hatchineha, and Cypress; Lake Tohopekaliga; East Lake Tohopekaliga, Fell’s Cove, and Lake Ajay; Lakes Hart and Mary Jane; Lakes Joel, Myrtle, and Preston; the Alligator Chain of Lakes (Lakes Alligator, Brick, Lizzie, Coon, Center, and Trout); and Lake Gentry (Appelbaum, 2005).

The draft EIS includes participation of the USACE staff in the KBMOS and completion of National Environmental Policy Act investigations associated with a proposal to modify a federal project. The draft EIS is expected to be completed 9–12 months after the completion of the KBMOS.

KISSIMMEE CHAIN OF LAKES LONG-TERM MANAGEMENT PLAN

The Kissimmee Chain of Lake Long-Term Management Plan (KCOL LTMP) is a multiagency/stakeholder project that was initiated by the passage of SFWMD Governing Board Resolution 2003-468. This resolution directed SFWMD staff to work with the USACE and other interested parties to improve the health and sustainability of the Kissimmee Chain of Lakes by developing a long-term management plan for regulated lakes in the Upper Basin (**Figure 11-2**). The SFWMD is the lead agency responsible for coordinating KCOL LTMP interagency activities and producing the plan. Other cooperating agencies include the FWC, FDEP, FDACS, USACE, USFWS, USEPA, local governments and community leaders, and other stakeholders.

After identifying existing water resource issues and conflicts within the KCOL, partner agencies decided the plan should focus on hydrologic management, habitat preservation and enhancement, aquatic plant management, water quality, and public use and recreation. It was agreed that plan partner agencies should seek consensus among stakeholders on the resources that need to be protected and preserved through interagency management practices and mandates. The plan is intended to complement existing local government and watershed projects such as the Kissimmee Basin Water Supply Plan, Total Maximum Daily Loads, Lake Okeechobee Protection Plan, and SFWMD land management activities.

Scheduled for public release in July 2007, the plan will include those measures of ecosystem health and quality agreed upon by stakeholders. The plan will also contain a summary of scientific and management practices/tools developed to assist in management decision-making within the KCOL, including the following:

- Conceptual ecological model
- Stakeholder value survey
- Assessment performance measures and indicator measures for lakes
- Data collection and monitoring plan
- Assessment of current lake conditions
- Partner agency action plans

In the past year, a conceptual ecological model has been completed for the KCOL LTMP and work has continued on the development and refinement of assessment performance measures and indicator measures. Concurrent with performance and indicator measure development has been the identification of data collection/monitoring needs to support their evaluation.

Conceptual Ecological Model

As a step in the process toward performance measure development, KCOL LTMP partner agencies and stakeholders drafted a conceptual ecological model (CEM) for the KCOL. This model indicates, using a simple box-and-arrow diagram, how various cultural stressors affect attributes of the ecosystem that are of value to nature and society. The model is based on the Lake Okeechobee/CERP template and is comprised of a top-to-bottom hierarchy of drivers, stressors, ecosystem effects, and priority attributes of the ecosystem. In the CEM diagram (**Figure 11-18**), five drivers, or forcing variables, are linked to five stressors (changes within a lake and adjacent wetlands). These stressors are linked to various ecological effects such as shifts in littoral plant communities and alterations to fish and wildlife habitat. Relationships between stressors and ecological effects represent significant management issues. The ecological effects are connected to five sets of lake-attribute categories that are considered representative of the overall ecological condition of a generalized lake within the KCOL.

The first driver, WATER MANAGEMENT, includes regulation of water levels and flows. Water level regulation is perhaps the system's most influential driver of change. It leads directly to three stressors: altered hydrology of KCOL lakes, decreased instances of lakeshore fires, and drainage of adjacent wetlands. These stressors lead to changes in native plant communities and development of unnaturally dense stands of plants. Additional ecological effects include more tussock formation, accumulation of decomposed plant matter, reduced exposure of sandy substrate, and general alteration of fish and wildlife habitat. Littoral vegetation that becomes excessive may require expensive treatment or removal that can disrupt recreational use of the lake.

The next driver, SHORELINE DEVELOPMENT, leads to two ecosystem stressors: drainage of wetlands and fire suppression. Again, these stressors can result in the ecological effects mentioned above, although in some cases, lakefront development has led to clearing of vegetation or even elimination of the littoral plant community entirely.

The third and fourth drivers are INTRODUCTION OF EXOTIC PLANTS and AQUATIC PLANT MANAGEMENT. Invasive exotic plants produce stress in multiple ways. Numerous exotic plants have become established within the KCOL, with hydrilla being one of the most common and problematic species. Proliferation of exotic species impacts native plant communities and contributes to sediment accumulation and biochemical oxygen demand. Control of these invasive plants has become extremely important to lake management and has itself shaped the habitat of some lakes in the Kissimmee Chain. Consequently, AQUATIC PLANT MANAGEMENT is itself considered as a driver of the ecosystem, although it is unique in that it helps control some sources of stress, thus providing benefits to the system. These benefits include control of overgrowth of native vegetation in addition to exotic plants. However, in the process of reducing proliferation of exotic plants and native vegetation, AQUATIC PLANT MANAGEMENT may introduce complications, including negative impacts on non-target plant species and ecological stresses resulting from hydrologic manipulations to facilitate treatments.

The last driver, INTENSIFIED LAND USE, is thought to cause stress to the KCOL primarily through its effects on various aspects of lake water quality, especially alterations to nutrient levels. Nutrient enrichment leads to multiple ecological effects, including increased prevalence of algal blooms, higher turbidity, decreases in submerged aquatic vegetation, changes in aquatic plant communities, and more internal nutrient loading within lakes.

Current and Future Efforts

Assessment performance measures and indicator measures for the KCOL are currently under development. These measures tie directly to the attribute categories identified at the bottom of the CEM diagram (**Figure 11-18**). Both performance measures and indicator measures represent attributes that are responsive to management and indicative of lake health. The difference between the two types of measures is that assessment performance measures have numerical targets, while indicator measures do not. In a number of instances, important ecological attributes of the KCOL have been identified for which little or no reference information exists (e.g., number of wading bird colonies/nests). While it is impossible to develop meaningful numerical targets in these situations, KCOL LTMP cooperators have agreed that they are still important to monitor, leading to development of indicator measures. **Table 11-6** presents a list of candidate measures that are under development as either assessment performance measures or indicator measures. Related to performance measures is an assessment of the condition of individual KCOL water bodies relative to performance measure targets. This assessment will both provide insight into the current status of the lakes as well as identify gaps in current knowledge of lake health. The data collection and monitoring plan, which is under development, will provide recommendations for data collection programs needed to support ongoing assessment of performance measures and indicator measures. Partnering agencies will be asked to develop agency action plans once lake ecosystem health has been assessed. The intent of these plans is to identify ways in which mandates and resources of each agency can collectively be applied to both monitor and improve lake ecosystem health.

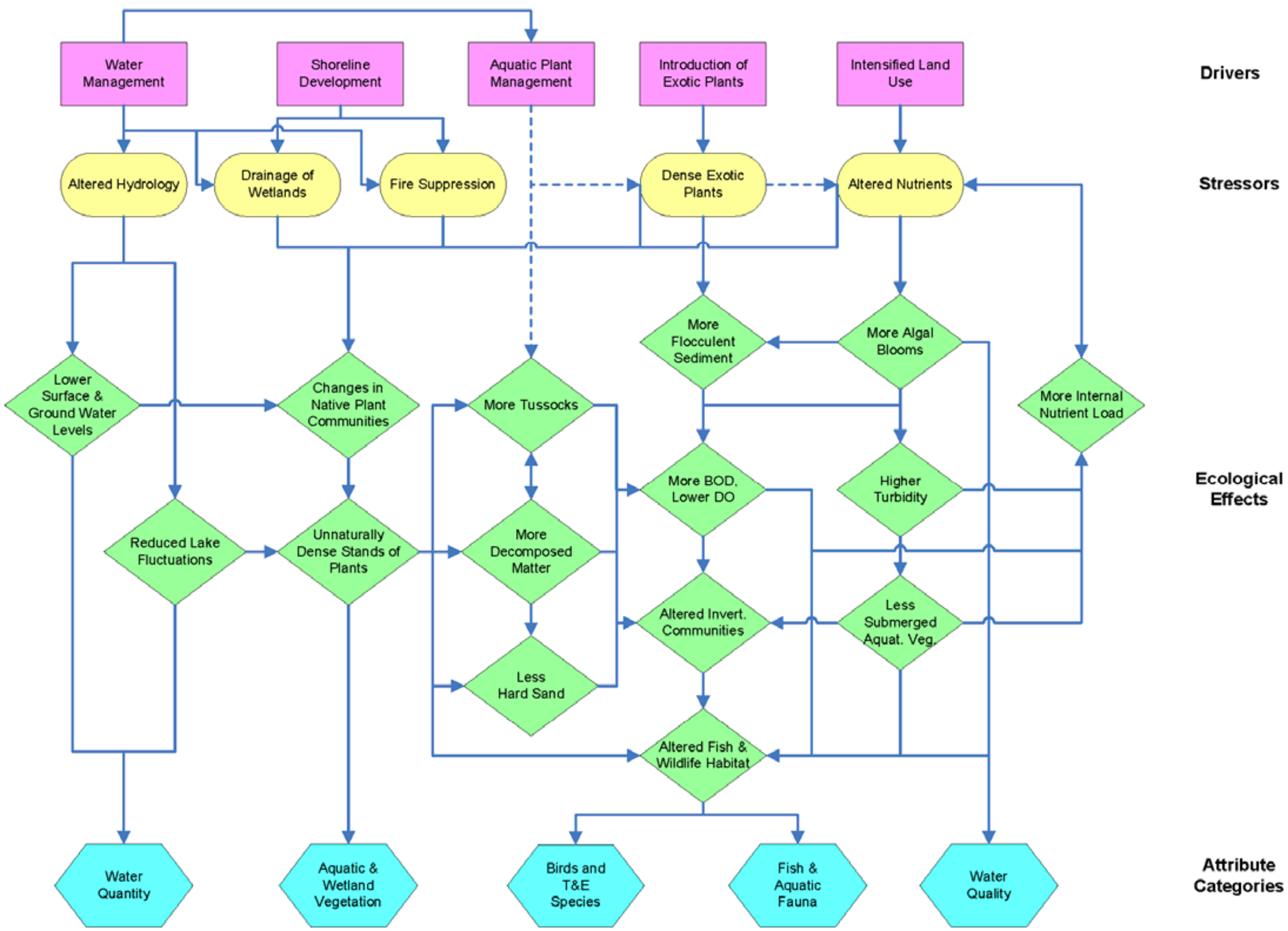


Figure 11-18. Conceptual ecological model for a generalized lake within the KCOL. The top row shows drivers or sources of anthropogenic stress to lake ecosystems. These drivers lead to stressors, which in turn lead to ecological effects. These effects are associated with categories of lake attributes that will be used in development of performance measures for lake management. Dashed arrows represent activities that moderate or control an effect resulting from another driver or stressor. For instance, aquatic plant management is conducted to reduce nuisance growth of littoral vegetation and invasive plants such as hydrilla.

Table 11-6. Preliminary list of measures that are under development as either assessment performance measures or indicator measures for the KCOL LTMP. Attribute categories correspond to those in the Conceptual Ecological Model.

Attribute category	Attribute	Measure
Water Quantity	Surface water	Placeholder (one or more measures to be evaluated later)
Aquatic and Wetland Vegetation	Hydrilla	Hydrilla abundance and control
Aquatic and Wetland Vegetation	Remnant littoral wetlands	Remnant littoral wetlands
Aquatic and Wetland Vegetation	Palustrine wetlands	Palustrine wetlands
Aquatic and Wetland Vegetation	Littoral vegetation	Extent of littoral zones
Aquatic and Wetland Vegetation	Littoral sedimentation	Accumulation and extent of organic sediment in littoral wetlands
Aquatic and Wetland Vegetation	Littoral vegetation - Animal habitat metrics	Littoral vegetation community structure (waterfowl habitat)
Aquatic and Wetland Vegetation	Littoral vegetation - Animal habitat metrics	Littoral vegetation community structure (wading bird habitat)
Aquatic and Wetland Vegetation	Littoral vegetation - Animal habitat metrics	Littoral vegetation community structure (reptile and amphibian habitat)
Aquatic and Wetland Vegetation	Littoral vegetation - Animal habitat metrics	Littoral vegetation community structure (alligator habitat)
Birds and T & E Species	Wading birds	Wading bird nesting effort
Birds and T & E Species	Bald eagle	Number of bald eagle nests/fledglings
Birds and T & E Species	Snail kite	Snail kite nesting success
Fish and Aquatic Fauna	Aquatic invertebrates	Lake condition index
Fish and Aquatic Fauna	Aquatic invertebrates	Apple snail density and spatial distribution
Fish and Aquatic Fauna	Alligator	Size distribution and relative abundance of alligators
Fish and Aquatic Fauna	Amphibians and reptiles	Relative abundance of selected amphibians
Fish and Aquatic Fauna	Amphibians and reptiles	Relative abundance of selected small reptiles
Fish and Aquatic Fauna	Amphibians and reptiles	Amphibian and reptile habitat
Fish and Aquatic Fauna	Largemouth bass	Catch per unit effort (CPUE) for largemouth bass
Fish and Aquatic Fauna	Largemouth bass	Largemouth bass recruitment
Fish and Aquatic Fauna	Largemouth bass	Size distribution and age distribution largemouth bass
Fish and Aquatic Fauna	Largemouth bass	Size distribution, age distribution largemouth bass
Fish and Aquatic Fauna	Largemouth bass	Angler success (largemouth bass)
Fish and Aquatic Fauna	Littoral fish	Relative abundance, species richness, diversity, and/or biomass of littoral fish (CPUE)
Fish and Aquatic Fauna	Littoral fish	Relative to dissolved oxygen, ratio of tolerant to intolerant fish species
Water Quality	Phosphorus	Annual phosphorus loading from lake watershed
Water Quality	Algae	Frequency and duration of algal blooms
Water Quality	Phosphorus	Phosphorus assimilation capacity and organic content of mid-lake sediments
Water Quality	Trophic state	Trophic state index
Water Quality	Class III water quality parameters	Dissolved oxygen (littoral and limnetic); bod (limnetic); total & fecal coliforms; trace metals; pesticides; polyamomatic hydrocarbons & phenols

WATERSHED WATER QUALITY

Ambient Water Quality Monitoring

The SFWMD maintains a water quality sampling program in five major lakes of the Kissimmee Chain (East Lake Tohopekaliga, Lake Tohopekaliga, Lake Cypress, Lake Hatchineha, and Lake Kissimmee) and three main tributaries to these lakes (Boggy Creek, Shingle Creek, and Reedy Creek). Monitoring is conducted for phosphorus, nitrogen, phytoplankton chlorophyll *a*, turbidity, water transparency, DO, and other constituents. Despite continuing development around the lakes, annual mean TP concentrations have remained stable.

Kissimmee Basin TMDL Water Bodies

A Total Maximum Daily Load (TMDL) is a written, quantitative plan and analysis for attaining and maintaining water quality standards in all seasons for a specific water body and parameter. Thirty-four water bodies in the Kissimmee Basin are currently listed for TMDL development for several parameters including dissolved oxygen, nutrients, fecal coliforms, mercury (in fish tissue), lead, and copper. The timeline for TMDL development is 2005–2011. As the lead agency responsible for TMDL development, the FDEP is approaching water quality improvement in the Kissimmee Basin from a watershed perspective. Water bodies in the Kissimmee Basin that are listed for TMDL development are subject to Florida Class III water quality standards. Class III is a designated use for waters, which means surface waters for recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

In general, sections of the Kissimmee River within the restoration project area are expected to experience improvement in water quality due to reestablishment of natural filtration, reaeration, and biological processes. Consequently, these sections have been exempted from TMDL development according to rules established by the FDEP (Impaired Waters Rule, Chapter 62-303, Florida Administrative Code).

Lake Okeechobee Protection Plan

The Kissimmee Basin falls within the geographic jurisdiction of the Lake Okeechobee Protection Act (LOPA). The LOPA requires that applicable water quality criteria be achieved and maintained in Lake Okeechobee and its tributary waters. This act sets forth a series of activities and deliverables for the coordinating agencies, which include the SFWMD, FDEP, and FDACS.

On January 1, 2004, the three coordinating agencies completed the Lake Okeechobee Protection Plan (LOPP), which was authorized under the LOPA. The LOPP identifies areas for future legislative support to successfully implement the state's commitment to protect and restore this resource and to achieve the TMDL for Lake Okeechobee. These agencies are currently seeking funding to implement the LOPP. One aspect of this plan addresses the need to fund cost-share best management practices (BMPs) on agricultural lands. The funding needed in the Upper Basin is approximately $5 million. These BMPs are planned to be implemented beginning in 2009. Additional information on the LOPP can be found in Chapter 10 of this volume.

The LOPP presents an innovative protection program that is both comprehensive and phased in its implementation. In the Upper Basin, initial TP reductions and other water quality improvements will be achieved through implementation of agricultural BMPs using a voluntary program coordinated through the FDACS. The FDEP will coordinate implementation of non-agricultural, non-point source BMPs, such as septic systems and urban stormwater runoff.

TRIBUTARY RESTORATION PROJECTS

Restoration of Packingham and Buttermilk Sloughs

The KICCO Wildlife Management Area is an approximate 7,400-ac (3000-ha) property in Polk County. The property is managed by the District's Land Stewardship Division and was purchased under the Save Our Rivers Program in 1985 as part of the KRRP. The area is located on the west side of the C-38 Canal in Pool A of the Kissimmee River (**Figure 11-1)**. The north border is State Highway 60, and the south border lies south of the S-65A water control structure.

The C-38 canal will not be backfilled north of S-65A. Therefore, flow will not be restored to the remnant Kissimmee River in Pool A. Although restoration of the river will not take place in Pool A, there are smaller projects within the pool that will serve to increase water storage capacity, improve water quality, mitigate flooding, and restore the wetland community in portions of the floodplain associated with the river's tributaries. The purpose of the project is to restore historic (Pre-C&SF flood control project) floodplain hydroperiods to Packingham and Buttermilk sloughs. Benefits will include increased wetland habitat for wildlife and creation of a "wetland corridor" between Lake Kissimmee and the restored portion of the Kissimmee River.

The main features of the restoration plan are the creation of two containment levees, backfilling of drainage ditches, and installation of gated water control structures. Water depth in each impoundment will be managed to mimic the historic surface water levels in the basin according to a predictive model developed from historic data at nearby Fort Kissimmee.

Hydraulic and hydrologic modeling was completed in March 2005. Model results showed that water levels within the impoundments will be adequate for restoration of the historic floodplain hydroperiod without impacting property outside of the 100-year flood line. Detailed design was completed in February 2006. Construction is scheduled to begin in late 2006 depending on funding.

Rolling Meadows Wetland Restoration

Rolling Meadows Ranch lies on the south shore of Lake Hatchineha (**Figure 11-1**). The 2,260-acre property was purchased by SFWMD and the FDEP as part of the Kissimmee River Restoration Project. Currently, this property is leased back to the previous owner and operated as a sod farm.

The restoration plan identifies the construction of a 1,670-acre impounded wetland, possibly fed by water from Lake Hatchineha when lake stage exceeds a certain elevation and from Catfish Creek which historically entered Lake Hatchineha 2,000 feet north of the property. The impounded wetland will be managed to mimic the natural hydroperiod of the lake and will provide enhanced wetland habitat for wildlife. The upland area outside the impounded wetland may be incorporated into the Lake Kissimmee State Park, which is operated by the FDEP.

The property also will be used for temporary storage of spoil dredged from C-37 by the USACE as part of the KRRP. The spoil will be used for backfilling farm ditches, strengthening levees, and creating a scenic road around the property. The USACE has agreed to build the wetland impoundment in exchange for the temporary storage of the spoil material.

To assess how water will be delivered to the impoundment, hydrologic modeling of Catfish Creek was needed. The Catfish Creek Wetland Restoration Study Hydrologic and Hydraulic Modeling Report was completed in March 2004. According to this report, there are three options for providing water to the impoundment: (1) Catfish Creek would be allowed to discharge directly into Lake Hatchineha, and Rolling Meadows impoundment would receive water directly from Lake Hatchineha through a water control structure; (2) Catfish Creek would be diverted to discharge directly into the impoundment; the impoundment would discharge into Lake Hatchineha through a weir and when lake stage is high, water from the lake would enter the impoundment; and (3) discharge from Catfish Creek would be split between Lake Hatchineha and the impoundment; the impoundment would discharge into Lake Hatchineha through a weir and when lake stage is high, water from the lake would enter the impoundment. A contract to develop a conceptual restoration plan for the Rolling Meadows/Catfish Creek property is currently under way and will be complete in 2007.

CONCLUSIONS

Implementation of the Kissimmee River Restoration Project continued in 2006. Following the success of KRRP Phase I, in which 15 miles of former river channel was reconnected in 2001, restoring approximately 12,000 ac (4,900 ha) of floodplain, a new phase of KRRP construction (Phase IVa) was initiated in June 2006. This phase, which is beginning prior to Phase II/III of the project because of logistical issues, will backfill approximately 1.9 miles (3.0 km) of canal at the northern end of the previous construction and excavate new river channel to reestablish the historic river connection, which will allow for diversion of flows upstream of the backfill. At its conclusion, an additional 4 mi (6.4 km) of historic river channel and 155 ac (63 ha) of floodplain wetlands will be restored within the Phase IVa area.

The Restoration Evaluation Program is proceeding with planning efforts for studies associated with both the Phase II/III area and the Kissimmee River Headwaters Revitalization Project. Data collection for a subset of studies within the Phase I area also continues. A primary goal of Phase II/III studies is to better identify the mechanisms driving individual components of ecosystem response to restoration through increased integration of a subset of Phase I baseline studies. Planning of pilot studies to evaluate vegetation response to KRHRP will begin in late 2006 and focus on vegetation community response to implementation of the revitalization water regulation schedule. Studies of responses to Phase I restoration continue to indicate changes consistent with those predicted by restoration expectations. Mean DO concentrations remain at levels that are appropriate for supporting riverine invertebrates and fishes. Turbidity is low in restored river channels. Densities of long-legged wading birds and waterfowl on the restored floodplain have exceeded restoration expectations each year. TP concentrations (for which there is no restoration expectation) have increased since Phase I completion, but the cause of this increase has not been determined.

The Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Study will develop a hydrologic/hydraulic model to be used to identify alternative structure operating criteria to meet the hydrologic requirements for KRRP, achieve a more acceptable balance between basin operating objectives for flood control, water supply, aquatic plant management, and natural resource water management objectives, and balance impacts across ecosystems including Lake Okeechobee. During WY2006, KBMOS efforts focused on (1) developing a suite of modeling tools that can model water levels and flows in the Kissimmee Basin, including an OASIS water budget model and a MIKE SHE/MIKE 11 hydrologic/hydraulic model and (2) drafting evaluation performance measures that will be used as criteria to select among alternative operations schedules.

The Kissimmee Chain of Lakes Long-Term Management Plan has the purpose of improving and/or sustaining lake ecosystem health in the KCOL. During the last year, a Conceptual Ecological Model of a generalized KCOL lake was completed. The model was composed of a hierarchy of anthropogenic drivers, stressors, ecological effects, and attribute categories. Altered hydrology, drainage of wetlands, fire suppression, dense exotic plants, and altered nutrient levels were identified as the primary human-related stressors of the system. Assessment performance measures and indicator measures that fall under each of the attribute categories are currently under development. These measures will be used to track status of KCOL water bodies. In association with performance and indicator measures, a recommended data collection and monitoring plan is also being developed.

During WY2006, rainfall in the Upper Basin totaled 52.91 inches, exceeding the historical average by 2.82 inches, and the Lower Basin totaled 48.50 inches, exceeding the long-term average by 4.05 inches. Notable rainfall patterns included a wet June, high rainfall in October associated with Hurricane Wilma, and a very dry spring. For the fifth consecutive year, continuous releases from Lake Kissimmee into the Kissimmee River via the S-65 structure were maintained. The total volume discharged at S-65 was 1,468,257 ac-ft, and approximately half of that volume was made at discharges >3,000 cfs for flood control.

LITERATURE CITED

Anderson, D.H. and B.D. Dugger. 1998. A Conceptual Framework for Evaluating Restoration Success. *Transactions of the North American Wildlife and Natural Resource Conference*, 63: 111-121.

Anderson, D.H. and J.R. Chamberlain. 2005. Impacts of Channelization on the Kissimmee River, Florida. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Anderson, D.H., S.G. Bousquin, G.E. Williams and D.J. Colangelo (eds.). 2005. Defining Success: Expectations for Restoration of the Kissimmee River. South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #433.

Appelbaum, S. 2005. Scoping Letter, Modification of Kissimmee Basin Structure Operating Criteria. U.S. Army Corps of Engineers, Jacksonville, FL.

Bancroft, G.T., S.D. Jewell and A.M. Strong. 1990. Foraging and Nesting Ecology of Herons in the Lower Everglades Relative to Water Conditions. Final Report to the South Florida Water Management District, West Palm Beach, FL.

Belanger, T.V., F.E. Dierberg and J. Roberts. 1985. Dissolved Oxygen Concentrations Florida's Humic Colored Waters and Water Quality Standard Implications. *Florida Scientist*, 48: (2) 107-119.

Bellrose, F.C. 1980. *Ducks, Geese, and Swans of North America*. Third Edition. Stackpole Books, Harrisburg, PA.

Bogart, D.B. and G.E. Ferguson. 1955. Surface Water. G.G. Parker, G.E. Ferguson and S.K. Love, eds. pp. 291-510. In: *Water Resources of Southeastern Florida*. U.S. Geological Survey, Supply Paper 1255.

Bousquin, S.G. 2005. Littoral Vegetation in the Channelized Kissimmee River. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Bousquin, S.G., D.H. Anderson, G.E. Williams and D.J. Colangelo (eds.). 2005. Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River. South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Carnal, L.L. and S.G. Bousquin. 2005. Areal Coverage of the Floodplain Plant Communities in Pool C of the Channelized Kissimmee River. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Chamberlain, Jr., E.B. 1960. Florida Waterfowl Populations, Habitats, and Management. Technical Bulletin No. 7, Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

Colangelo, D.J. and B.L. Jones. 20005. Dissolved Oxygen in the Channelized Kissimmee River and Seven Reference Streams. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, D., eds. In: *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Earth Tech. 2005a. Kissimmee Basin Assessment Report, Kissimmee Basin Hydrologic Modeling, and Operations Planning. Contract Number CN040920-WO02. Final Report prepared for the South Florida Water Management District, West Palm Beach, FL.

Earth Tech 2005b. Task 1.9 Kissimmee Basin Model Development Work Plan, Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Study. Contract Number CN040920-WO02. Report prepared for the South Florida Water Management District, West Palm Beach, Florida.

FGFWFC. 1957. Recommended Program for Kissimmee River Basin. Florida Game and Fresh Water Fish Commission, Tallahasee, FL.

Glenn III, J.L. 2005. Status of Fish Assemblages of the Kissimmee River Prior to Restoration: Baseline Conditions and Expectations for Restoration. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee Rive*r, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Harris, S.C., T.H. Martin and K.W. Cummins. 1995. A Model for Aquatic Invertebrate Response to the Kissimmee River Restoration. *Restoration Ecology*, 3: 181-194.

Jolly, G.M. 1969. Sampling Methods for Aerial Censuses of Wildlife Populations. *East African Agricultural and Forestry Journal*, Special Issue, 1969: 46-49.

Jones, B.L. 2005. Water Quality in the Channelized Kissimmee River. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-Restoration Studies of the Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Karr, J.R. and D.R. Dudley. 1981. Ecological Perspectives on Water Quality Goals. *Environmental Management*, 5: 55-68.

Koebel, J.W. 1995. An Historical Perspective on the Kissimmee River Restoration Project. *Restoration Ecology*, 3: 149-159.

Koebel J.W., Jr., B.L. Jones and D.A. Arrington. 1999. Restoration of the Kissimmee River, Florida: Water Quality Impacts from Canal Backfilling. *Environmental Monitoring and Assessment*, 57: 85-107.

Koebel, J.W., Anderson, D.H. and L.M. Rojas. 2005. Aquatic Invertebrate Community Structure and Functional Characteristics in the Kissimmee River-Floodplain Ecosystem: Baseline and Reference Conditions and Expectations for Restoration. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

National Audubon Society. 1936–1959. Audubon Warden Field Reports. National Audubon Society, Tavernier, FL.

Obeysekera, J.T. and M.K. Loftin. 1990. Hydrology of the Kissimmee River Basin – Influence of Man-Made and Natural Changes. M.K. Loftin, L.A Toth and J.T Obeysekera, eds. pp. 211-222. In: *Kissimmee River Restoration Symposium*, South Florida Water Management District, West Palm Beach, FL.

Parker, G.G. 1955. Geomorphology. G.G. Parker, G.E. Ferguson and S.K. Love, eds. pp. 127-155. In: *Water Resources of Southeastern Florida*, U.S. Geological Survey - Supply Paper 1255.

PBS&J. 2006. Draft Evaluation Performance Measures, Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Planning Study. Contract Number CN040899-WO06. Report prepared for the South Florida Water Management District, West Palm Beach, FL.

Perrin, L.S., M.J. Allen, L.A. Rowse, F. Montalbano, III, K.J Foote and M.W. Olinde. 1982. A Report on Fish and Wildlife Studies in the Kissimmee River Basin and Recommendations for Restoration. Florida Game and Freshwater Fish Commission, Okeechobee, FL.

SFWMD. 2002. Surface Water Improvement and Management (SWIM) Plan Update for Lake Okeechobee. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2003. Surface water improvement and management (SWIM) plan: Update for Lake Okeechobee. South Florida Water Management District, West Palm Beach, FL.

Stewart-Oaten, A.J., W.W. Murdoch and K.R. Parker. 1986. Environmental Impact Assessment: “Pseudoreplication” in Time? *Ecology*, 67: 929-940.

Toland, B.R. 1990. Effects of the Kissimmee River Pool B Restoration Demonstration Project on Ciconiiformes and Anseriformes. M.K. Loftin, L.A. Toth and J.T Obeysekera, eds. pp. 83-91 In: P*roceedings of the Kissimmee River Restoration Symposium*, South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1990a. An Ecosystem Approach to Kissimmee River Restoration. pp. 125-133. M.K. Loftin, L.A. Toth and J.T. Obeysekera, eds. In: *Kissimmee River Restoration Symposium*, South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1990b. Impacts of Channelization on the Kissimmee River Ecosystem. pp. 47-56. M.K. Loftin, L.A. Toth and J.T. Obeysekera, eds. In: *Kissimmee River Restoration Symposium*, South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1991. Environmental Responses to the Kissimmee River Demonstration Project. Technical Publication 91-02, South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1993. The Ecological Basis of the Kissimmee River Restoration Plan. *Florida Scientist*, 56(1): 25-51.

USACE. 1991. Final Integrated Feasibility Report and Environmental Impact Statement, Environmental Restoration, Kissimmee River, Florida. U.S. Army Corps of Engineers, Jacksonville, FL.

USACE. 1994. Master Water Control Manual for Kissimmee River-Lake Istokpoga Basin. U.S. Army Corps of Engineers, Jacksonville District, FL.

USACE. 1996. Central and Southern Florida Project, Kissimmee River Headwaters Revitalization Project: Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement. U.S. Army Corps of Engineers, Jacksonville, FL.

USFWS. 1959. Appendix A: A Detailed Report of the Fish and Wildlife Resources in Relation to the Corps of Engineers' Plan of Development, Kissimmee River Basin, Florida. In: *Central and Southern Florida Project for Flood Control and Other Purposes: Part II, Supplement 5 – General Design Memorandum*, Kissimmee River Basin. U.S. Army Engineers, Office of the District Engineer, Jacksonville, FL.

Weller, M.W. 1995. Use of Two Waterbird Guilds as Evaluation Tools for the Kissimmee River Restoration. *Restoration Ecology*, 3: 211-224.

Wetzel, R.G. 2001 *Limnology.* Academic Press, San Diego, CA.

Williams, G.E. and S.L. Melvin. 2005. Studies of Bird Assemblages and Federally Listed Bird Species of the Channelized Kissimmee River, Florida. S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. In: *Establishing a Baseline: Pre-Restoration Studies of the Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.