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. The watershed encompasses a diverse group of wetland and aquatic ecosystems, including more than two dozen lakes, their tributary streams, and the Kissimmee River. This chapter summarizes the mission-critical activities of the South Florida Water Management District (District or SFWMD) for flood control, water supply, water quality, and natural systems in the Upper and Lower Basins of the Kissimmee watershed. Major projects in the watershed are the Kissimmee River Restoration Project (KRRP), Kissimmee River Headwaters Revitalization Project (KRHRP), and the Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP). 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 Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization projects were jointly authorized in the 1992 Water Resources Development Act. The two projects have an estimated combined cost of $578 million (Fiscal Year 2004). They will be completed in several phases, with the final phase of construction scheduled for completion in 2012 and the restoration evaluation to be completed in 2017.

The primary goal of the KRRP 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 primary purpose of the KRHRP 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; Section 1.3.2).

A key element of the KRRP is a comprehensive restoration evaluation program for tracking ecological responses to restoration. 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.

In June 2001, 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 raise the high pool stage and thus does not fully allow for the expected natural river flows, nor does it provide benefits to littoral zone habitat in headwater lakes.

The KRHRP includes revisions to the interim regulation schedule along with structure and canal modifications to accommodate the increased capacity associated with the increased lake storage volumes needed to fully meet the requirements of the restoration. Presently, SFWMD has acquired the majority of lands that will be inundated as a result of increased lake stages. Canal and structure modifications will be completed by 2006, at which point the revised regulation schedule will be implemented.

Phase I of the KRRP was completed in February 2001. This effort involved filling approximately 7.5 miles (12 kilometers) of the C-38 canal, recarving approximately 1.25 miles (2 kilometers) of river channel, and demolishing the S-65B structure to reconnect 15 miles (24 kilometers) of continuous river channel. Continuous flow and intermittent inundation of approximately 12,000 acres (4,900 hectares) of restored floodplain have been achieved although the revised regulation schedule has not yet been implemented.

Initial responses to restoration activities in the Phase I area include (1) maintenance of continuous flow for over three years in the reconnected river channel; (2) a reduction in the quantity and distribution of organic/marl deposition on the river channel bed; (3) an increase in the number of river bends with active formation of point sand bars; (4) an increase in the mean concentration of dissolved oxygen in the river channel from 1.2 to 3.3 milligrams per liter (mg/L) during the wet season and from 3.3 to 6.1 mg/L during the dry season; (5) a reduction in the mean width of littoral vegetation beds in reconnected river channels; (6) a shift in the structure of littoral plant communities from slight dominance by floating/mat forming species to heavy dominance by emergent species; (7) colonization by wetland vegetation of the filled C-38 and degraded spoil mounds; (8) colonization of mid-channel benthos by invertebrate species indicative of reestablished sand channel habitats; (9) dominance of woody snag invertebrate communities by passive filter-feeding insects, which require flowing water; (10) increased mean density of wading birds, including the endangered wood stork, from approximately 6 birds per square kilometer in the unrestored area to 20 to 24 birds per square kilometer in the restored area; (11) a decline in the abundance of the terrestrial cattle egret relative to aquatic wading birds on the floodplain; and (12) establishment of a new bald eagle nesting territory adjacent to the area of Phase I.

The Long-Term Management Plan for the Kissimmee Chain of Lakes was initiated in April 2003 through SFWMD Governing Board Resolution No. 2003-468. The project's purpose is to improve and sustain the ecosystem health of the KCOL regulated lakes while minimizing adverse impacts to downstream ecosystems. When implemented, the KRHRP will provide greater and more natural lake level fluctuations, expanded lake littoral zone habitat for fish and wildlife, and operational flexibility to meet the needs of the restoration. The management plan for the KCOL is intended to pick up where the KRHRP leaves off.

During the last year, a series of interagency planning meetings were completed. As a result of these meetings, two discrete KCOL work efforts have emerged. The first will define and assess ecosystem health within the KCOL. The second is an initiative to model and evaluate alternative water regulations within the Kissimmee watershed. The first work effort has evolved into the KCOL LTMP and will focus on development of performance measures and assessment of baseline conditions for the KCOL. The latter effort spans the entire watershed and will focus on regulation of the KCOL and KRRP in accordance with each other and with flood control, water supply, aquatic plant management, and natural resource operations objectives for both of these systems and Lake Okeechobee. This effort will be coordinated throughout the SFWMD to ensure that the resulting regulation schedules consider the needs of a number of other activities including those associated with aquatic plant management, land management, and water supply planning.

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 Upper Basin, and Lake Istokpoga (**Figure 11-1**). The Kissimmee Upper Basin/Kissimmee River system is the single largest source of surface water for Lake Okeechobee, accounting for approximately 34 percent of inputs (SFWMD, 2002). The major projects within the watershed are the Kissimmee River Restoration Project (KRRP), Kissimmee River Headwaters Revitalization Project (KRHRP), and the Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP). A number of other activities are carried out in association with these projects. These include aquatic plant management, land management, water quality improvement, and water supply planning.

Congress jointly authorized the KRRP and the KRHRP in the 1992 Water Resources Development Act (Public Law 102-580). The goal of the restoration project 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 is largely dependent on reestablishing hydrologic conditions that are similar to the pre-channelization period (Toth, 1990b). The KRHRP was designed to both meet this requirement and maintain the existing level of flood control within the Kissimmee Basin (USACE, 1996). The project involves Lakes Kissimmee, Hatchineha, Cypress and Tiger (**Figure 11-1**) and includes land acquisition, adjustment of the S-65 regulation schedule, and modifications to structures and canals. Together, the KRRP and KRHRP will restore ecological integrity to 40 mi^2 (104 km^2) of the river-floodplain system (USACE, 1991; USACE, 1996). Restoration success will be evaluated via a comprehensive ecological monitoring program.

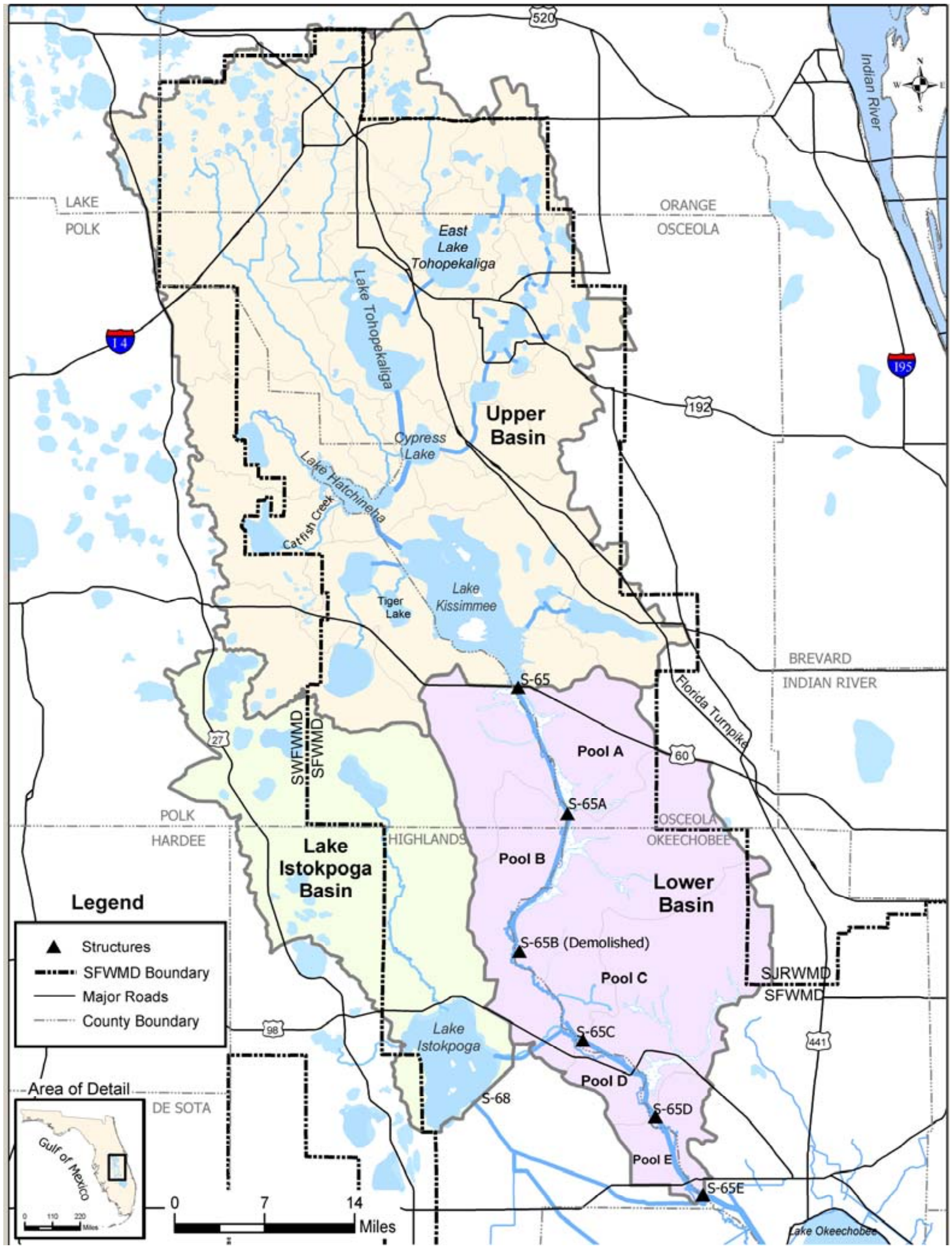

Figure 11-1. Geographic location of the Upper Basin, Lower Basin, and Lake Istokpoga Basin of the Kissimmee watershed.

In addition to the KRHRP, the Governing Board of the South Florida Water Management District (District or SFWMD) adopted a resolution (Resolution No. 2003-468) in April 2003, which directs the SFWMD to coordinate with the U.S. Army Corps of Engineers (USACE) and other stakeholders to develop the Long-Term Management Plan for the KCOL. 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.

Successful completion of the KRRP, KRHRP, and KCOL LTMP has critical implications for other ecosystem restoration projects in South Florida. For example, the restoration project should increase phosphorus retention within the Kissimmee River system through restoration of floodplain wetlands, thus removing a portion of phosphorus loads that would otherwise reach Lake Okeechobee. Additionally, the KRRP is a prerequisite for successful completion of the Comprehensive Everglades Restoration Program (CERP). According to the future-without-plan condition under CERP, it is assumed that the KRRP is in place and functioning (USACE and SFWMD, 1999). [See Chapter 2 of the *2005 South Florida Environmental Report – Volume II* (SFER) for additional details on CERP.]

Data collected for the comprehensive restoration evaluation program also are being used to support operational recommendations. Timely analyses of hydrologic conditions (i.e., stage and discharge) and associated physical, chemical, and biological responses are used to optimize the timing and quantity of water delivered to the Lower Basin in order to maximize ecological responses and benefits.

The objective of this chapter is to provide an overview and update of activities within the Kissimmee watershed; specifically, progress of the Kissimmee River Restoration Project, the Kissimmee River Headwaters Revitalization Project, and development of the Kissimmee Chain of Lakes Long-Term Management Plan. Information in this chapter focuses on the KRRP and includes (1) reference condition data that define the pre-channelized Kissimmee River; (2) baseline data that define the state of physical, chemical, biological, and functional components of the channelized Kissimmee River; and (3) initial response data collected after completion of Phase I construction and initiation of continuous flow.

KISSIMMEE WATERSHED BACKGROUND

HISTORICAL CONDITIONS

Historically, the Kissimmee Chain of Lake 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. Water levels within the KCOL fluctuated between 2 and 10 ft (0.6 and 3.0 m) annually (USACE, 1996). Lakes would rise in the wet season and overflow onto adjacent lands. The resulting 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). During the dry season, lakes generally became isolated from one another, allowing for oxidation of bottom sediments and preventing accumulation of organic matter within littoral zones (USACE, 1996).

The historical Kissimmee River meandered 103 mi (166 km) within a 1 to 2 mi (1.5 to 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) indicate that continuous flow and seasonal water level fluctuations were integral hydrologic characteristics of the unmodified system (Obeysekera and Loftin, 1990). Discharge exceeded 25 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 (Toth, 1993). Stage duration data and floodplain elevations adjacent to gauging stations indicate that 94 percent of the floodplain was inundated over 50 percent of the time (Koebel, 1995). When inundated, water depths were generally 1 to 2.3 ft (0.3 to 0.7 m), with depth greater than 3 ft (1 m) occurring over 40 percent of the floodplain (Koebel, 1995).

The historical Kissimmee River was atypical of North American river systems because of its prolonged floodplain hydroperiod and protracted floodplain recession rate (Koebel, 1995). The predictable annual flood-pulse brought on by seasonal rains and the near-continuous connectivity of the river and floodplain is thought to have been critical to the trophic structure and biological productivity of the system. The Kissimmee River ecosystem consisted of a mosaic of wetland habitats that supported, among other things, a renowned sport fishery (USFWS, 1959), 16 species of wading birds (Audubon Society, 1936–1987), at least 10 species of shorebirds (Audubon Society, 1936–1987), and 4,000 to 5,000 resident and over-wintering ducks (Perrin et al., 1982).

CENTRAL AND SOUTHERN FLORIDA PROJECT

Two major hurricanes in the late 1940s led to mass flooding and extensive property damage throughout the Upper Basin, 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. The Kissimmee Basin flood control works 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). The areas between water control structures, termed pools, function similarly to reservoirs and are named for the control structure at their southern terminus (e.g., Pool D lies between S56-C and S65-D; **Figure 11-1**). Upper Basin 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).

Impacts of the C&SF Project

Although the C&SF Project was extremely successful at achieving its flood control objective, it dramatically altered hydrologic conditions throughout the Kissimmee watershed (Obeysekera and Loftin, 1990). Water levels in the KCOL are now controlled by nine structures that regulate the amount and timing of discharges between lakes and to the Kissimmee River. Under regulation, the range of fluctuation has been reduced from 2 to 10 ft (0.6 to 3.0 m) to about 2 to 4 ft (0.6 to 1.2 m) annually (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 the ecosystem's health and that supported biological communities adapted to and dependent upon these fluctuations (Perin et al., 1982). Reducing the range of fluctuations has eliminated 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).

In addition to habitat loss, habitat has been degraded by dense growth of problematic, native and exotic plant species (USACE, 1996) Dense concentrations of undesirable vegetation along littoral zones not only cause accumulation of organic sediment, but also negatively impact organisms dependent upon healthy littoral communities (USACE, 1996). The end result is loss of desirable native species, and reduction in overall plant and animal diversity and abundance. Hydrilla also has become a problem in the regulated system. Hydrilla was first noted in KCOL during the 1980s (USACE, 1996). The species spread rapidly within each lake; however, by the late 1980s an active hydrilla (*Hydrilla verticillata*) treatment program on lakes Kissimmee, Cypress, and Hatchineha was in place (USACE, 1996).

Within the Kissimmee River valley, 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). Approximately 21,000 ac (8,500 ha) of floodplain wetlands were drained, covered with spoil material, or converted into canal (USACE, 1991). No-flow regimes in remnant channels encouraged extensive growth of floating vegetation, which impeded navigation (Toth, 1990a). 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). By the late 1970s, floodplain use by wintering waterfowl had decreased by greater than 90 percent compared to pre-channelization levels (Perin et al., 1982). 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 (Perin et al., 1982). The highly recognized largemouth bass (*Micropterus salmoides*) fishery was decimated, while fish species tolerant of low dissolved oxygen and reduced water quality, such as Florida gar (*Lepisosteus platyrhincus*), increased (Perin et al., 1982). Aquatic invertebrate taxa of the channelized system were typical of those found in lakes and reservoirs rather than riverine systems (Harris et al., 1995). 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).

Environmental degradation of the Kissimmee River, specifically the loss of fish and wildlife resources, and growing concerns over the contributions of channelization to eutrophication of Lake Okeechobee, was the impetus for a river restoration initiative. 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 "to construct the Kissimmee River headwaters revitalization project."

KISSIMMEE WATERSHED ACTIVITIES

KISSIMMEE RIVER RESTORATION PROJECT

Restoration Project Implementation

The Kissimmee River, Florida Project is comprised of the Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization projects. Currently, there are 31 project-related features. Fourteen of these have been completed, seven are in the planning stage, six are in the design phase, and four are under construction.

The purpose of the KRHRP is to provide the necessary water storage and regulations needed to approximate the historical flow characteristics for the Kissimmee River system, and to increase the quantity and quality of lake littoral zone habitat for the benefit of fish and wildlife (USACE, 1996; Section 1.3.2). These purposes will be accomplished by increasing the water storage capacity of lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 acre-feet, or ac-ft (12,340 hectare-meters, or ha-m) and by increasing the conveyance capacity of the canals and structures to accommodate these increased storage volumes. Meeting these objectives involves (1) acquisition of approximately 20,800 ac (8,400 ha) of land bordering these lakes, (2) widening the C-36 canal between lakes Cypress and Hatchineha and the C-37 canal between lakes Hatchineha and Kissimmee, (3) adding two gates to the S-65 water control structure to increase the outlet capacity from Lake Kissimmee, and (4) modifying the stage regulation schedule for the S-65 structure.

The headwaters revitalization regulation schedule is zoned to provide varying discharges based on season and water level (**Figure 11-2**). 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) National Geodetic Vertical Datum (NGVD). The new regulation schedule with increased maximum stage both provides for the reestablishment of pre-channelization seasonal outflow characteristics from Lake Kissimmee to the Lower Basin and benefits 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.

To date, the C-36 and S-65 modifications are complete. The majority of lands that will be inundated as a result of increased stage on lakes Kissimmee, Hatchineha, Cypress, and Tiger have been acquired. The widening of C-37 is expected to be completed in 2006. The headwaters revitalization operation schedule will be implemented upon completion of the C-37 modifications. In June 2001, an interim operation schedule was implemented for S-65. 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. Also, the interim schedule does not provide the benefits to littoral zone habitats in headwater lakes that will be realized with the headwaters revitalization schedule.

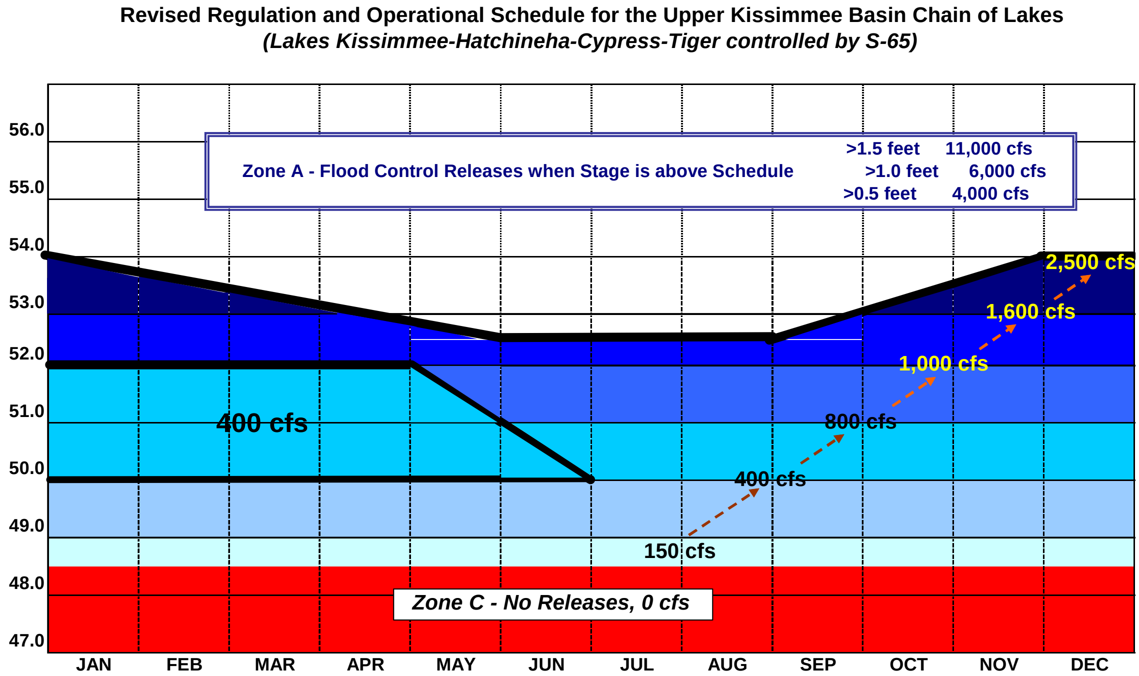

Figure 11-2. Revised regulation and operational schedule for the Upper Kissimmee Basin (UKB) Chain of lakes including lakes Kissimmee, Hatchineha, Cypress, and Tiger.

The river restoration component requires the acquisition of approximately 68,300 ac (27,640 ha) of land in the Lower Basin and involves a plan to (1) backfill an approximately 22 mi (35 km) section of C-38 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 to be completed in 2012; evaluation of restoration success will continue through 2017 (**Figure 11-3**). Ultimately, the project will result in restoration of approximately 104 km^2 of river-floodplain ecosystem, including 70 km 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 12,000 ac (4,900 ha) ha of floodplain.

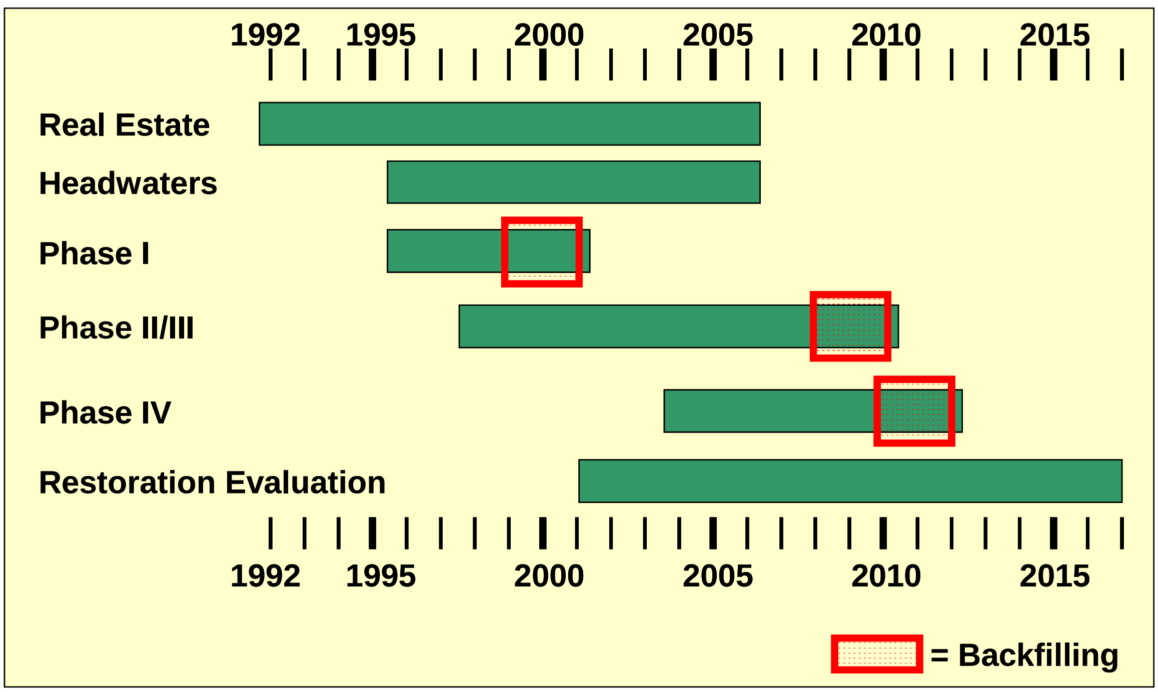

Figure 11-3. Implementation schedule for major project phases of the Kissimmee River Restoration Project (KRRP).

Restoration Evaluation Program Overview

A key element of the Kissimmee River Restoration Project is a comprehensive ecological evaluation program to (1) assess achievement of the ecological integrity goal, (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), which includes approximately $15.6 million (Fiscal Year 1991, or FY1991) for restoration evaluation. 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. Also, 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).

The KRRP is unusual among restoration projects for having a comprehensive monitoring program to evaluate project success. The success of many projects has not been determined (Bash and Ryan, 2002; DellaSala et al., 2003), in part because of the lack of a widely accepted, standardized approach for restoration evaluation (Anderson and Dugger, 1998). Restoration evaluation poses a number of challenges. First, it is difficult to make inferences about changes and causality for ecosystem restoration projects, such as the Kissimmee River, because, like other whole ecosystem manipulations, they lack treatment replication, randomization, and controls (e.g., Carpenter, 1998). Second, project goals have to be expressed as meaningful and measurable criteria that specify acceptable conditions. Third, success criteria should be based on reference conditions that represent the unimpacted or pristine system. Pre-impact data is frequently lacking, as are reference sites, because ecosystems selected for restoration tend to be rare or have unique functions on the landscape (NRC, 1992). These issues are addressed in the strategy for restoration evaluation described below for the KRRP.

To evaluate the goal of ecological integrity, the evaluation program 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 the KRRP's 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 (**Figure 11-4**). Information about observed changes in the system will be compared to anticipated changes described by individual restoration expectations (performance measures) to evaluate whether the expectation has been achieved. The results from evaluating all expectations will be integrated to determine success of the project. If an expectation is not achieved, then there will be an opportunity during the integration process to consider if adaptive management strategies should be implemented.

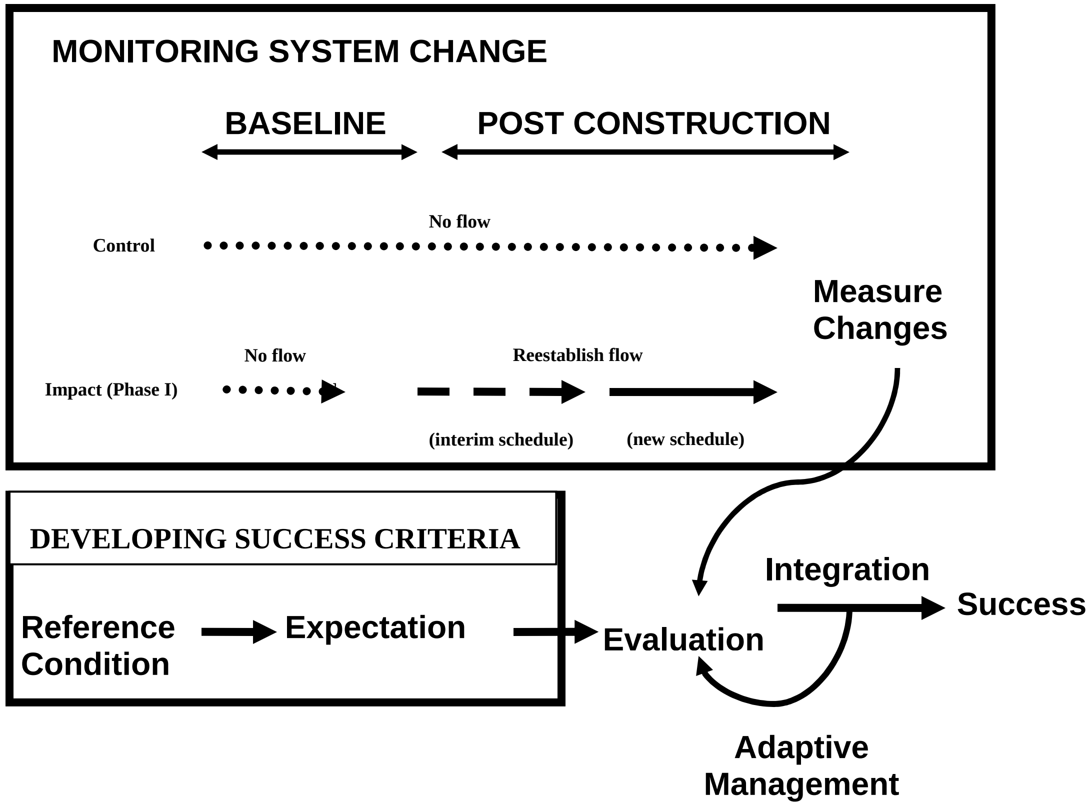

Figure 11-4. Strategy for evaluating the KRRP.

To detect system change, data were collected prior to the Phase I construction to establish a baseline for evaluating future responses. Baseline studies were conducted in Pool C, which included most of the area impacted by Phase I construction. Most studies also monitored 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). The BACI design does not require that the control and impact sites be identical, but they should be similar and should respond in a similar manner to environmental drivers such as climate. For most studies, the control site was Pool A, which is located upstream of the restoration project area and not scheduled for restoration. Baseline data will be compared to data collected after construction and restoration of pre-channelization hydrologic conditions.

A restoration expectation describes an aspect of ecological integrity for the Kissimmee River. It incorporates one or more metrics, is based on the best available reference condition data, and, if necessary, has been adjusted for constraints external to the restoration project. For this project, reference conditions were based on data from the pre-channelized river, where possible; however, such data were not available for all expectations. Reference conditions also were based on existing data from other rivers or wetland systems that were identified as appropriate reference sites for that expectation.

The District's Kissimmee Division is currently compiling and formatting two volumes of Kissimmee River restoration evaluation studies. The goal of these documents is to disseminate relevant and timely information regarding research and restoration evaluation efforts to the public and the scientific community. The first volume, *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, is a compendium of reports on baseline studies conducted for the restoration evaluation program. The reports present detailed background, data, and analyses related to baseline and reference conditions; selection of reference sites; responses to channelization as inferred from comparisons between baseline and estimated reference conditions; and development of the restoration expectations and ongoing monitoring programs. The second volume, *Defining Success: Expectations for Restoration of the Kissimmee River*, is a compendium of background information and documentation for the expectations and monitoring programs that will be used to evaluate success of the restoration project. A preliminary chapter describes ranking procedures that have been applied to the expectations for overall evaluation of the restoration, and describes methods for integrating the expectations to gauge the overall success of the project. A second chapter details selected monitoring programs that lack formal restoration expectations. The expectations will be presented in short summaries that describe project methods, baseline conditions, reference conditions, and the logic that guided expectation development. Together, these District publications will supplement journal publications by documenting and archiving development of the restoration expectations and monitoring programs, as well as pre-restoration evaluation studies.

Restoration Evaluation Program: Status and Results

The first phase of river reconstruction was completed in February 2001. An interim headwater regulation schedule (**Figure 11-5**) was implemented in June 2001, and has provided continuous flow through the reconnected river channel. Evaluation efforts to date include the (1) assessment of baseline conditions, (2) identification of reference conditions that represent the pre-channelization condition of the river, (3) monitoring for construction impacts during Phase I, and (4) monitoring initial responses to Phase I backfilling and implementation of the interim stage regulation schedule. Ongoing restoration evaluation efforts focus on the river channel affected by Phase I construction, with limited efforts to assess early recovery by select floodplain components (e.g., stage/hydroperiod, wetland vegetation, and wading birds/waterfowl). The following sections highlight construction impact assessments, as well as initial chemical, physical, biological, and functional responses documented under the interim regulation schedule.

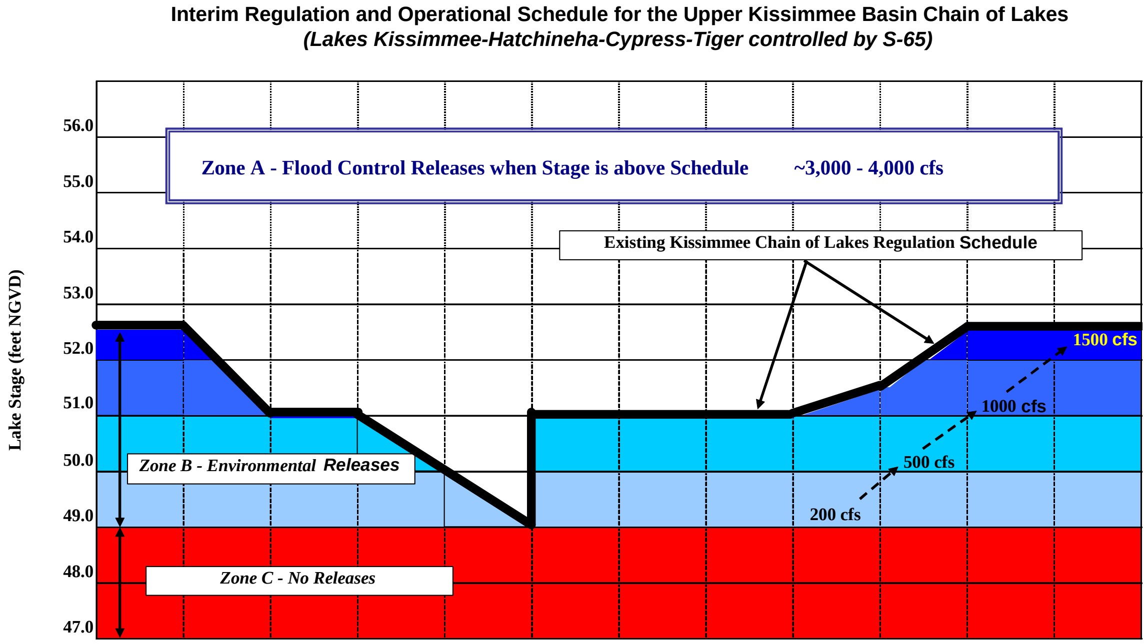

Figure 11-5. Interim regulation and operational schedule for the UKB Chain of Lakes.

CONSTRUCTION IMPACT ASSESSMENT

Construction impact assessment allows for the minimization or alleviation of any short-term or incidental environmental impacts occurring over the course of the construction phase. Phase I construction of the KRRP began in June 1999 and included backfilling of 7.5 mi (12 km) of canal and restoring flow through 15 mi (24 km) of continuous river channel. The impacts of construction on four water quality parameters [turbidity, total phosphorus (TP) flow-weighted concentration and load, and dissolved oxygen (DO) concentration] were quantified throughout the 18-month construction phase (Colangelo and Jones, 2004). Turbidity and DO data were collected weekly from water column profiles at one station upstream (S-65A) and one station downstream (S-65C) of the construction zone, and at four stations within the construction zone, using a multi-parameter water quality probe (**Figure 11-6**). TP flow-weighted concentration and load were calculated from samples collected daily at S-65A and S-65C. Data were analyzed to determine if canal backfilling and construction of a 1.25 mi (2 km) section of new river channel negatively impacted downstream water quality.

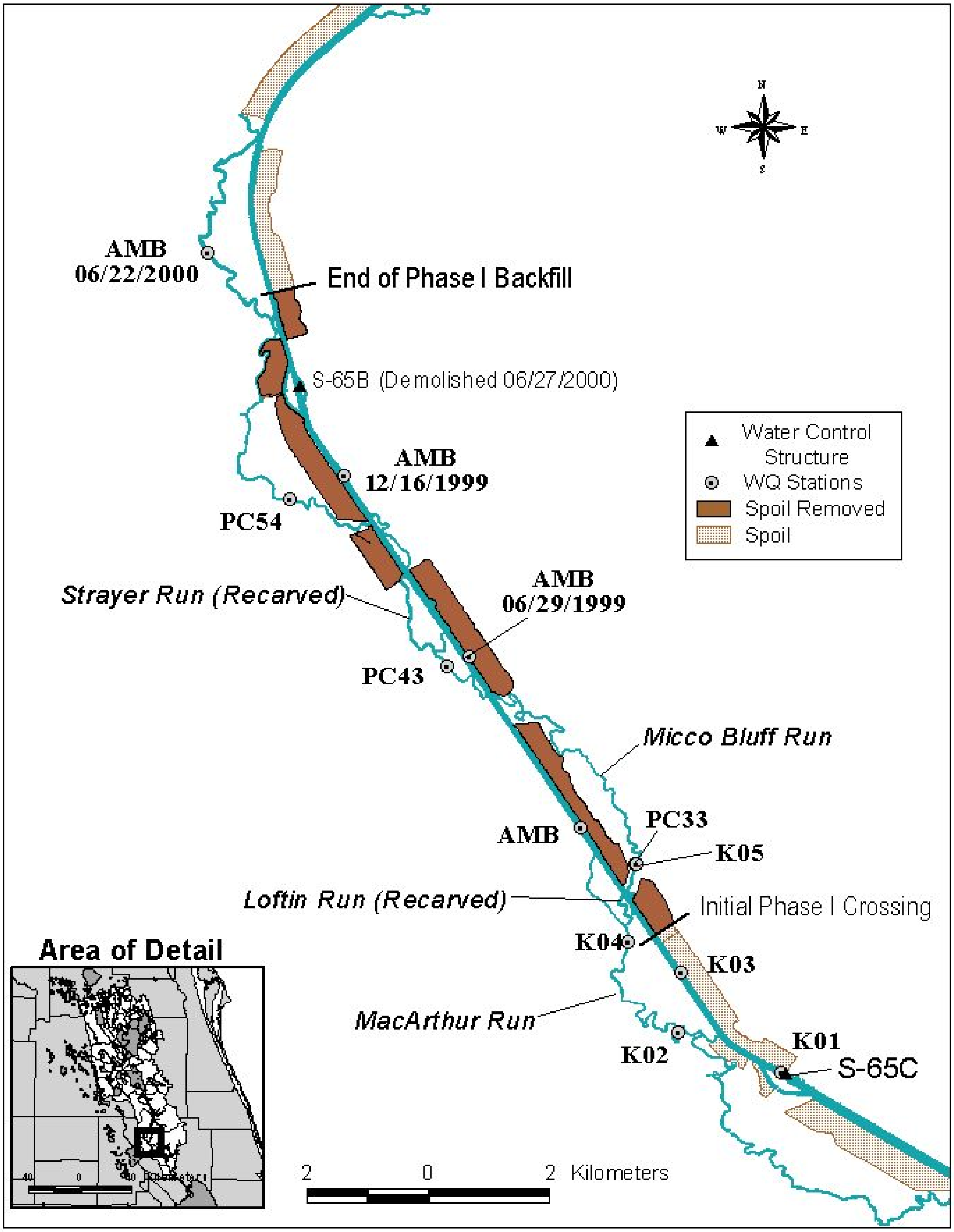

Figure 11-6. Monitoring stations for evaluating impacts to water quality and hydrologic responses during Phase I construction.

Turbidity levels at the downstream station were elevated for approximately two weeks during the construction period, but never exceeded the FDEP's construction permit criteria of 29 nephelometric turbidity units (NTU) above the background level. Turbidity levels at stations within the construction zone were occasionally high, primarily due to active construction; however, post-construction turbidity levels were similar to baseline levels (**Figure 11-7**). TP flow-weighted concentration at the downstream station was slightly higher than the upstream station during construction (**Figure 11-8**), but construction coincided with a period of low discharge through S-65C, limiting downstream transport of phosphorus. Long-term phosphorus loading to Lake Okeechobee was not significantly affected by construction (**Figure 11-9**). Upstream and downstream mean water column DO concentrations were similar during all sampling periods (Colangelo and Jones, 2004; **Figure 11-10**).

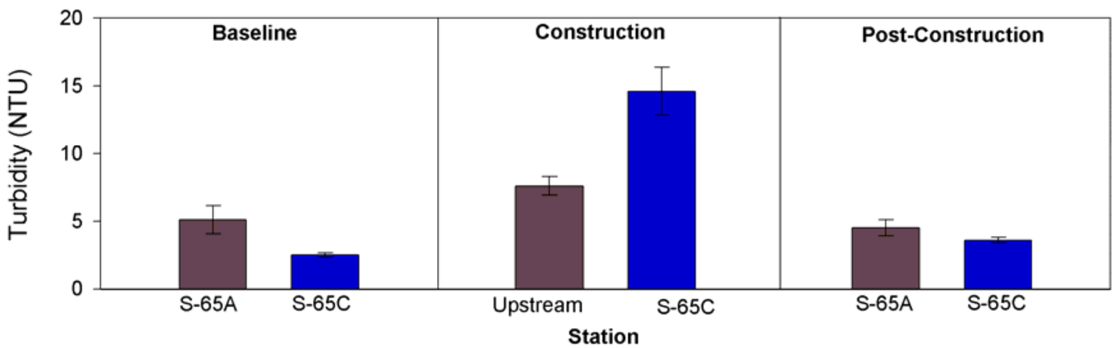

Figure 11-7. Mean baseline, construction and post-construction turbidity (NTU) at stations upstream and downstream of the construction area. Error bars represent ± one standard error of the mean.

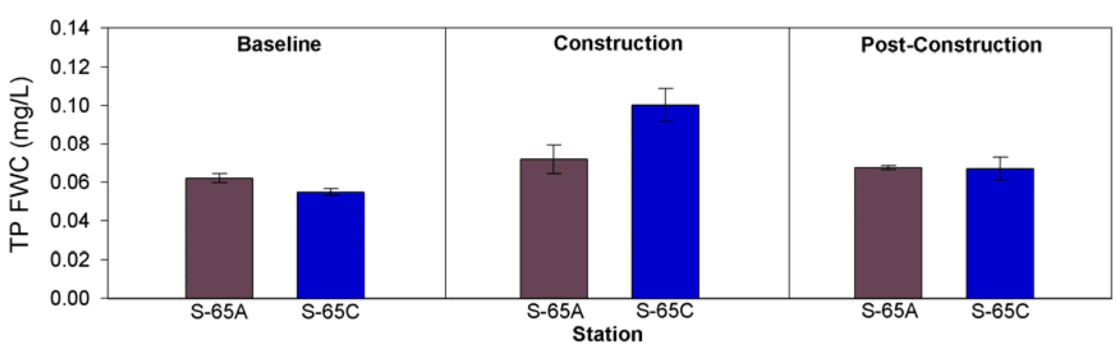

Figure 11-8. Total phosphorus (TP) flow-weighted concentration (mg/L) at upstream (S-65A) and downstream (S-65C) stations before, during, and after construction.

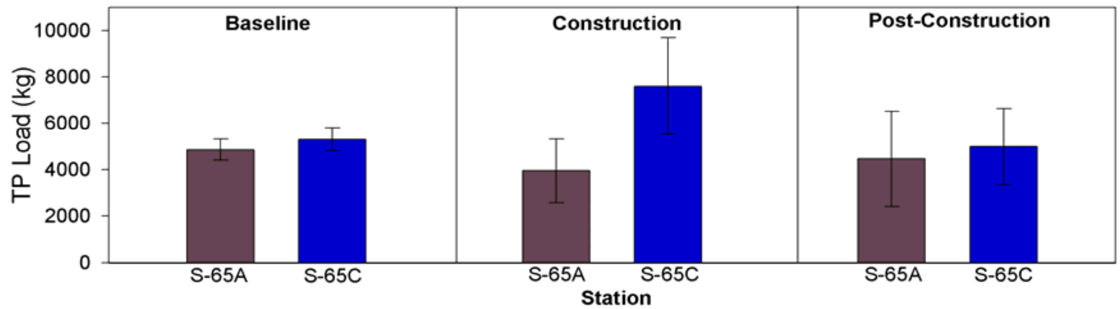

Figure 11-9. TP load (kg/mg) at upstream (S-65A) and downstream (S-65C) stations before, during, and after construction.

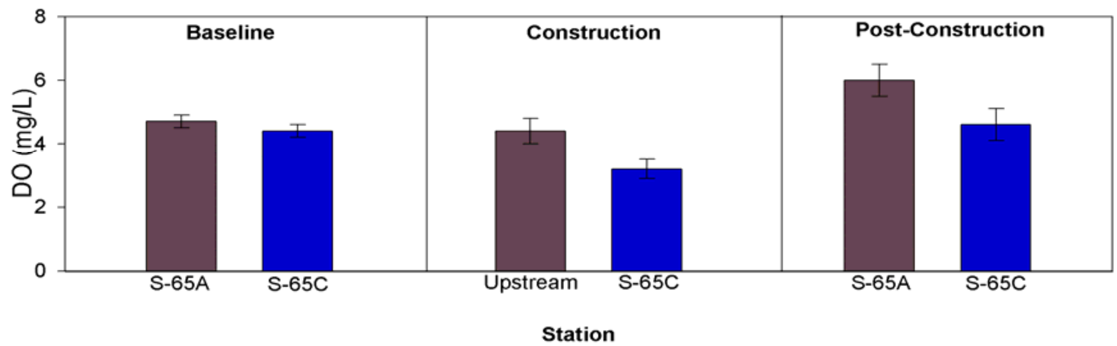

Figure 11-10. Raw means and standard errors of water column dissolved oxygen (DO) concentrations (mg/L) at upstream (S-65A), and downstream (S-65C) stations before, during and after Phase 1 construction. DO data were not normal and a square root transformation was employed prior to performing statistical tests. Results of Student's t-tests found no significant differences in DO concentrations at upstream and downstream stations during baseline, construction and post-construction periods after Phase I construction (Colangelo and Jones, 2004).

The successful completion of the first phase of restoration construction indicates that a project of this scale and scope can be accomplished without major long-term impacts to water quality or aquatic biota. However, water quality should continue to be monitored during future construction phases to minimize potential downstream impacts and localized impacts to fish and wildlife.

Hydrology

Flow is the defining characteristic of a river, and reestablishing attributes of the natural flow regime is critical for reestablishing ecological integrity to the Kissimmee River. Flow conditions contribute to river ecosystem integrity because the physical transport of materials and organisms by flow couples habitats within and between the river channel and floodplain. Aspects of flow, such as velocity profiles and hydroperiods, serve as important characteristics of habitat for many species. Key hydrologic features of the river prior to channelization were identified at the Kissimmee River Restoration Symposium (Toth, 1990b), and these features have been expressed as five hydrologic criteria for the KRRP (USACE, 1991) and include the following:

1. Continuous flow with duration and variability characteristics comparable to pre-channelization records.

2. A stage-discharge relationship that results in overbank flow along most of the floodplain when discharge exceeds 30 to 57 m^3/s (1,400 to 2,000 ft^3/s).

3. Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long-term variability characteristics.

4. Stage recession rates on the floodplain that do not typically exceed 0.3 m/month (1 ft/month).

5. Average flow velocities between 0.2 and 0.6 m/s (0.8 and 1.8 ft/s), when flows are contained within channel banks.

Reestablishing these hydrologic features in the restored river will depend on implementation of the new headwaters stage regulation schedule, which should occur in 2006. The reestablishment of these hydrologic features following Phase I of construction may be constrained by the presence of C-38 and the S-65C water control structure.

The next five subsections evaluate initial responses for the above hydrologic criteria using stage (NGVD 1929) and discharge data measured at different locations along the river. Stage was measured at three stations located in remnant reaches of the natural river channel that were reconstructed during Phase I of construction. From upstream to downstream, these stations were PC54, PC43, and PC33 (**Figure 11-6**). Discharge was measured at PC33 and at S-65, located at the outflow of Lake Kissimmee. Stage and discharge were measured continuously and expressed as mean daily values.

Continuous Flow

The first hydrologic criterion is that flow will be maintained continuously, and that it will exhibit a seasonal variability characteristic of the river prior to channelization. This criterion was evaluated by examining the time series of mean daily flow at PC33 and at S-65, following the completion of Phase I construction in February 2001, and examining the seasonal distribution of mean monthly flow.

Flow at PC33 in the reconnected river channel has been continuous since May 2001, and releases from S-65 have been continuous since July 2001 (**Figure 11-11**). Continuous flow in the reconnected river channel probably preceded releases from the Upper Basin because of local runoff. Flow conditions within the river channel depend in part on antecedent rainfall. At the conclusion of Phase I construction, the Kissimmee watershed was nearing the end of an extended drought, which was more severe in the Upper Basin than the Lower Basin. Except for a period of approximately five months during winter 1999–2000, the Upper Basin experienced severe drought (Palmer Drought Severity Index < -3) or extreme drought (PDSI < -4) from May 1998 through May 2001 (Abtew et al., 2002). During the same time period, the Lower Basin experienced moderate drought to normal conditions, except for two months of severe drought in January–February 2001.

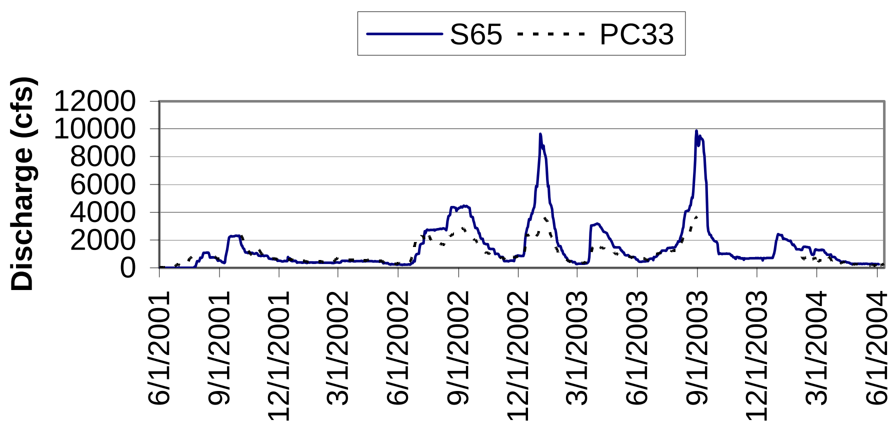

Figure 11-11. Post construction discharge at S-65 and PC33. Instrumentation at PC33 was lost during the high flow event at the end of August 2003, and was not replaced until February 2004.

The distribution of mean monthly flow at S-65 for the initial response period (May 2001–April 2003) tended to resemble that of the reference period (1933–1960) (**Figure 11-12**), although peak mean monthly flows occurred earlier (August–September) in the initial response period than the reference years (October–November). Additionally, the initial response value for January was more than twice that of the reference period.

These data suggest that even under the interim stage regulation schedule it is possible to maintain continuous flow except under extremely dry conditions, and to begin approximating the pre-channelization pattern of mean monthly flow. Some departures from the reference distribution may reflect the small number of years available for the initial response evaluation. With so few years, an unusual event or year can influence the distribution of monthly values. For example, the unusually high values for January probably reflect the increased releases resulting from El Niño rainfall in the winter 2003, and the Lake Tohopekaliga drawdown in 2004. Also, low averages in May and June 2001 may reflect the influence of low monthly flows during these months, as the watershed was recovering from drought.

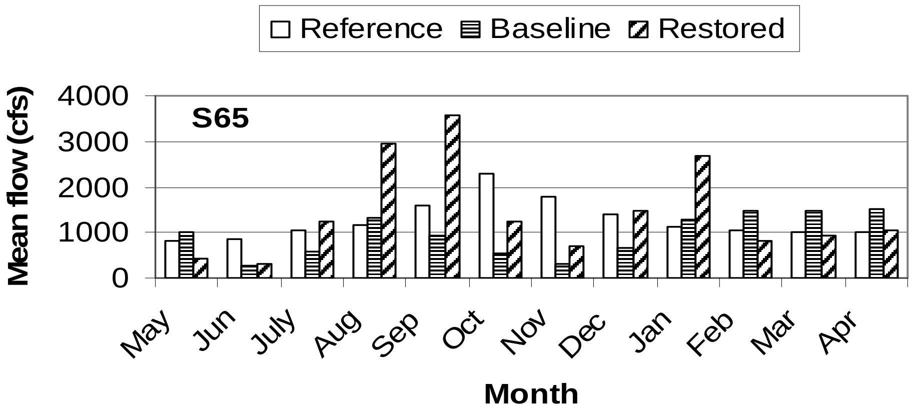

Figure 11-12. Mean monthly flow at S-65 for reference years (1933–1960), for the baseline years (1972–1999), and for the restored river (2001–2003).

Stage-Discharge Relationships

In rivers, discharge typically exhibits a positive, curvilinear relationship to river channel stage, and the shape of that curve is influenced by the stage at which discharge is no longer confined to the river channel. The stage discharge criterion can be evaluated by comparing the slopes for regressions of stage on discharge. An analysis of pre-channelization data for the Kissimmee River showed that stage at different locations along the river channel was positively related to the natural logarithm of discharge at S-65, and that all sites had the same slope of 0.76 (J. Chamberlain, unpublished data). During the baseline period, stage and discharge were not related. The stage discharge criterion was evaluated using mean daily stage data collected at three river channel sites (PC54, PC43, and PC33), and the natural logarithm of mean daily discharge at S-65 for the initial response period (July 2001–April 2004).

Mean daily discharge at S-65 ranged from 1.0 m^3/s (36 cfs) to 279.2 m^3/s (9,857 cfs) during the initial response period and overlapped the pre-channelization range from 10 m^3/s (350 cfs) to 255 m^3/s (9000 cfs). Stage tends to reflect ground elevation so that the most downstream station, PC33, had the lowest stages and the most upstream station, PC54, had the highest stages (**Figure 11-13**). At all three stations, the relationship of stage to the natural logarithm of S-65 discharge was statistically significant (**Table 11-1**). Discharge explained 73 to 82 percent of the variability in stage and regression models performed better at the two upstream sites, PC43 and PC54. This probably reflects the influence of the S-65C structure on stages at PC33.

The estimated slopes for the relationships ranged from 0.30 at PC33, to 0.56 at PC54 (**Table 11-1**). These estimates of the slope were precise with standard errors of 0.01. None of these values approached the desired slope of 0.76 for the reference data. The trend of increasing slope with increasing distance upstream of the S-65C structure suggested that the relationship may be influenced by the headwater stage at S-65C.

This initial analysis demonstrates that there has been improvement in the stage discharge relationships along the river channel. Achievement of this criterion will depend on removal of the S-65C structure and implementation of the revised headwaters regulation schedule.

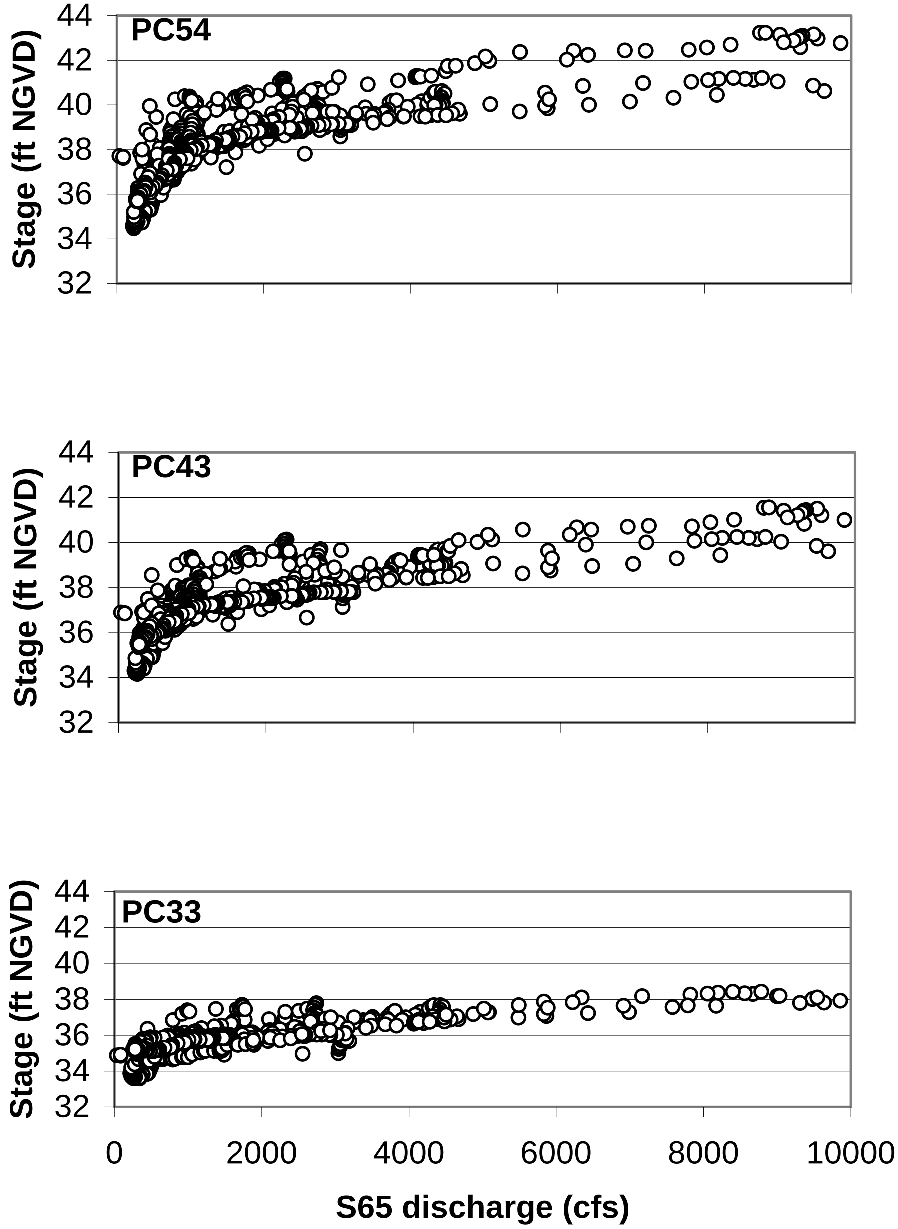

Figure 11-13. Stage at PC33, PC43, and PC54 versus discharge at S-65.

Table 11-1. Regression statistics for regression of stage at different stations along the river channel the discharge from S65. All regressions took the form: Stage = constant + slope ln Q. Stage (ft NGVD) was recorded for different stations along the river channel. Q was the discharge (ft^3/s) at S65.

Station	Constant	Slope (SE)	n	F	R^2
PC54	25.64	1.78 (0.03)	990	4440*	0.82
PC43	27.01	1.46 (0.02)	1012	4248*	0.81
PC33	29.02	0.96 (0.02)	854	2346*	0.74

*Denotes statistically significant relationship ($p < 0.01$).

Stage Hydrographs

The stage hydrograph criterion was evaluated by comparing stage frequency curves from a single river channel station (PC33) because data were available for baseline, and initial response periods as well as for a pre-channelization reference period. Stage frequency curves were constructed by summing the number of days that stage was at a given value, by converting the sum to a proportion of days for each stage value, and by plotting the cumulative proportion, which ranged from 0 to 1. Stage frequency curves were developed for PC33 using estimated stage for a reference period (June 1942 to May 1959), a baseline period (October 17, 1997 to May 31, 2001), and an initial response period (June 1, 2001 to June 11, 2004). Reference stage data at PC33 were estimated by interpolating between stages at the upstream Fort Kissimmee station and the downstream Fort Basinger station. Plotting as a cumulative frequency curve allowed curves based on different numbers of observations to be compared.

During the reference period, stage was free to fluctuate, and the estimated stages at PC33 ranged from 29.14 to 40.53 ft NGVD, and the cumulative frequency curve had a gradual slope (**Figure 11-14**). During the baseline period, the S-65C structure influenced the stage at PC33 because the headwater stage only fluctuated through a narrow range from 32.99 to 37.46 ft NGVD. Consequently, the cumulative frequency curve was nearly vertical because of the more narrow range of stages. During the initial response period, stage at PC33 was still constrained by the S-65C structure, but stage ranged from 32.99 to 38.42 ft NGVD. The cumulative frequency curve for the initial response period had a more gradual slope than the curve for the baseline period, with a greater proportion of time spent at higher stages than during the baseline; the initial response curve almost overlaid the curve for the reference period for stages greater than 36 ft.

Comparison of stage frequency curves for the reference, baseline, and initial response periods suggests that there have been major shifts in the frequency distribution of stages and floodplain inundation patterns. It is likely that the presence of the S-65C structure has constrained the lower limit for stage during the initial response period so that it cannot assume the shape of the reference period curve until S-65C is demolished during Phase II/III of construction.

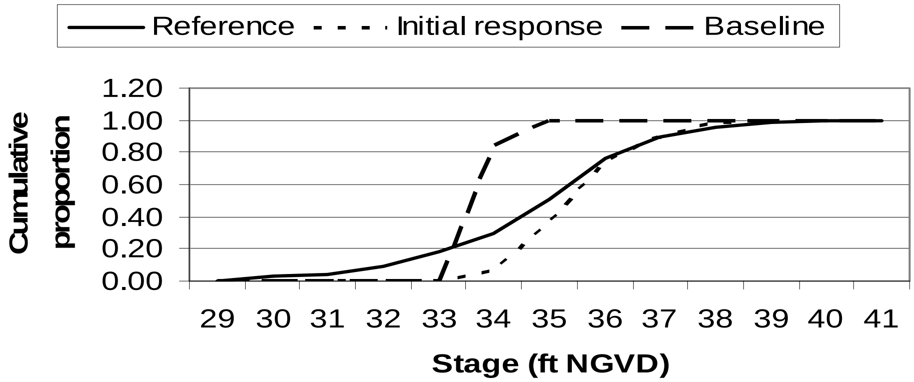

Figure 11-14. Stage frequency at PC33 for the reference period (1942–1959), initial response period (June 2001–June 2004), and the baseline period (October 17, 1997–May 31, 1999). Reference data are estimated stages at PC33.

Stage Recession Rates

The criterion for stage recession rate was evaluated with river channel stage data from PC54 (**Figure 11-15**). Stage followed similar patterns at other river channel stations, but data are only presented for PC54 because this station had the most complete record. Six recession events were identified at PC54 between June 1, 2001 and May 31, 2004 (**Table 11-2**). The duration of these events ranged from 27 to 260 days (d) and averaged 132 d. Recession rates for these events ranged from 0.22 m/30 d (0.72 ft/30 d) to 0.79 m/30 d (2.58 ft/30 d). Only two events exceeded 173 d in duration, and these began in September 2001 and 2003 and continued through to the following May of each year, respectively. These events had recession rates of 0.22 m/30 d (0.72 ft/30 d) and 0.23 m/30 d (0.77 ft/30 d), respectively.

While operating under the interim stage regulation schedule for S-65, some progress has been made in recreating stage recession patterns similar to those of the pre-channelized system. However, this criterion is not likely to be achieved until the headwaters revitalization stage regulation schedule has been implemented.

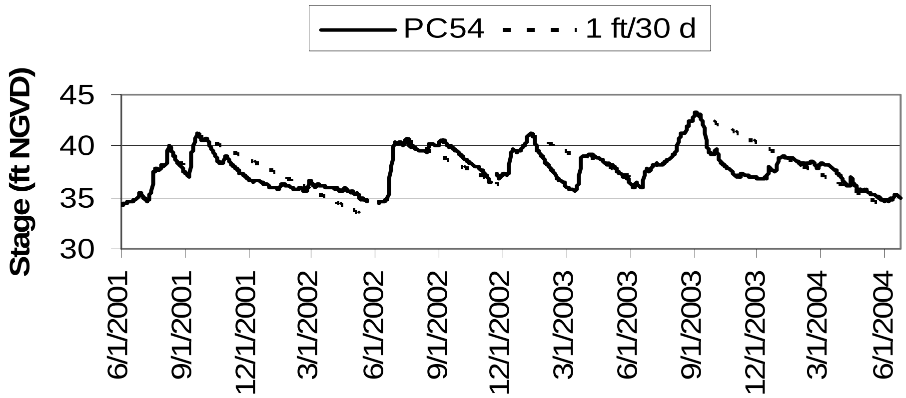

Figure 11-15. Stage at river channel station PC43 after Phase I of construction. Dotted line indicates the expected recession if it proceeded at a rate of 1 ft/30 d.

Table 11-2. Recession rates at station PC54 from June 1, 2001–May 31, 2004.

Event	Start	End	h_max	h_min	dh (ft)	dt (d)	ft/d)	(ft/30d)
1	8/9/2001	9/5/2001	38.89	36.57	2.32	27	0.09	2.58
2	9/18/2001	5/25/2002	40.13	34.19	5.94	249	0.02	0.72
3	7/15/2002	11/25/2002	39.71	36.21	3.5	133	0.03	0.79
4	1/9/2003	3/9/2003	40.25	35.47	4.78	59	0.08	2.43
5	3/30/2003	6/5/2003	37.79	35.54	2.25	67	0.03	1.01
6	9/3/2003	5/20/2004	41.55	34.84	6.71	260	0.03	0.77

River Channel Velocity

Mean channel velocity was estimated at approximately weekly intervals beginning in November 2001. Measurements were made at a permanent transect across the river channel approximately 150 m upstream of PC33, with either a 600 or 1200 kHz monostatic, broad-band four-transducer acoustic Doppler current profiler (ADCP). The ADCP was mounted on the bow of a boat that was moved along a cable stretched between the transect markers. Measurement protocol followed the U.S. Geological Survey (USGS) guidelines for obtaining measurements on four reciprocal transects with a coefficient of variation greater than or equal to 5 percent. Mean channel velocity was estimated by dividing an estimate of total discharge in the channel by the cross sectional area of water in the channel for each pass over the transect and averaging to obtain a mean for each date. Coefficient of variation for these means was greater than 3 percent, except for three dates (October 16, 2002; July 23, 2002; and May 29, 2002), and never exceeded 5 percent.

Mean channel velocity ranged from 0.113 m/s (0.371 ft/s) to 1.016 m/s (3.332 ft/s) (**Figure 11-16**). Of the 88 measurements, only 33 (43 percent) were in the desired range from 0.244 to 0.549 m/s (0.8 to 1.8 ft/s). While this range of mean channel velocities in the restored river channel does not yet meet the criterion, it does show substantial improvement over the baseline period, when the remnant channels are assumed to have had a mean channel velocity of zero most of the time.

Flow conditions within the river channel are partly dependent on antecedent rainfall. At the conclusion of Phase I construction, the Kissimmee watershed was nearing the end of an extended drought, which was more severe in the Upper Basin (north of S-65) than the Lower Basin. Except for a period of approximately five months during the winter 1999–2000, the Upper Basin experienced severe drought (Palmer Drought Severity Index < -3) or extreme drought (PDSI < -4) from May 1998–May 2001 (Abtew et al., 2002). During the same time period, the Lower Basin experienced moderate drought to normal conditions except for two months of severe drought in January–February 2001.

Following completion of Phase I, continuous flow began at PC33 in May 2001 and has continued through to present (**Figure 11-11**). Continuous releases at S-65 began in July 2001. While continuous flow has been maintained in the reconnected river channel for almost three years, it is premature to consider this expectation achieved because the means of evaluation requires that the assessment be based on five years of data.

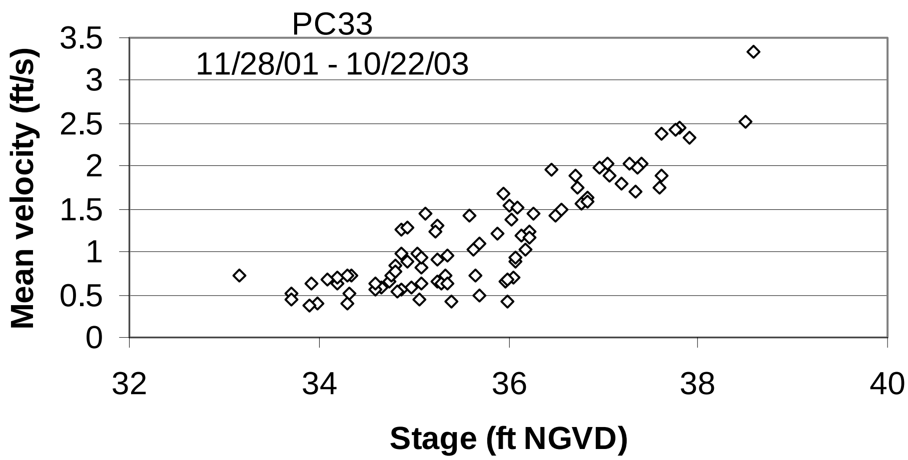

Figure 11-16. Mean channel velocity versus stage at PC33.

GEOMORPHOLOGY

Geomorphology interacts with hydrology to form a hydrogeomorphic habitat template on which the ecological integrity of the Kissimmee River will recover. Geomorphic monitoring for the restoration project focuses on two habitat characteristics: (1) the composition of river bed deposits, and (2) point sand bar formation. With the reestablishment of flow, the composition of river bed deposits should transition from being primarily organic/marl to primarily sand as the organic/marl deposits are eroded or buried in situ by sand deposition. Reestablishing flow will also lead to active point sand bar formation on meander bends. Achieving these responses will be an indication that natural sediment transport and depositional processes have been reestablished and that important habitat characteristics are being restored to the river channel.

To characterize river channel bed deposits, core samples were collected on transects across the river channel in spring 2002 after nine months of continuous flow and several high flow events. Transects were sampled by stretching a cable between permanent transect markers and collecting core (3.8 cm diameter) samples at 1.5 m intervals. For each core, the thickness of sediment layers was measured to the first appreciable sand layer. Organic and marl sediments located above this sand layer were assumed to represent post-channelization deposition. Three metrics were used to characterize each transect: (1) mean thickness of organic/marl deposits, (2) percent of samples lacking organic/marl deposits, and (3) thickness of organic/marl sediments at the thalweg (i.e., at the deepest point in the channel cross section). For the initial response period, 24 transects were sampled that were a random subset of the transects from each major run that had been established during the baseline period. Mean values for the initial response period were compared with mean values for 86 transects in the area of Phase I during the baseline period and with reference values averaged for 24 transects across remnant channels in Pool B that had experienced enhanced flow conditions for four years during the Pool B Demonstration Project.

Mean thickness of organic/marl deposits ranged from 0 to 11 cm. The highest values occurred at two transects located in MacArthur Run. Upstream of these two transects, a side channel was created during a high flow event that diverts most of the flow back to C-38. Mean thickness averaged 4 cm, which was a 71-percent decrease from the baseline value and was lower than the reference condition (**Figure 11-17**). Thicker deposits were usually associated with samples from littoral macrophyte beds. The percent of samples on a transect lacking organic/marl deposits ranged from 9 to 96 percent. The average value of 64 percent was an increase of greater than 2,000 percent over the baseline value of 3 percent. Thickness at the thalweg ranged from 0 to 34 cm and averaged 4 cm. This average value represents a decrease of 81 percent from the baseline value, and was less than the reference value of 9 cm. Despite the inclusion of two transects downstream of the flow diversion in MacArthur Run, all three metrics used to describe river bed deposits exceeded the response suggested by the reference values (**Figure 11-17**).

Point bar formation on meander bends was evaluated after nine months of continuous flow by reconnaissance from boat. In the area of Phase I, 63 meander bends were found with active point bar formation. This number is a substantial increase over the baseline period, where no evidence of active point bar formation on meander bends was found in aerial photography in the area of Phase I. However, the initial response value was not as high as the reference value of 80 meander bends with point bars that was determined from aerial photography of the same reach of the river collected at low water prior to channelization.

After only nine months of continuous flow, both indicators for the composition of river channel bed deposits and for point bar formation show responses to restoration of flow. The decrease in the amount and extent of coverage by organic/marl deposits on the river channel bed exceeded the response expected based on the reference condition. While this study shows a clear transition from river channel organic/marl deposits to sand, it did not distinguish between changes caused by erosion and those caused by in situ burial. While the increase in point bar activity has been substantial, it has not reached the level of the reference condition. These changes suggest that critical characteristics of flow are being reestablished under the interim stage regulation schedule, and these changes in habitat should promote responses by other components of the ecosystem.

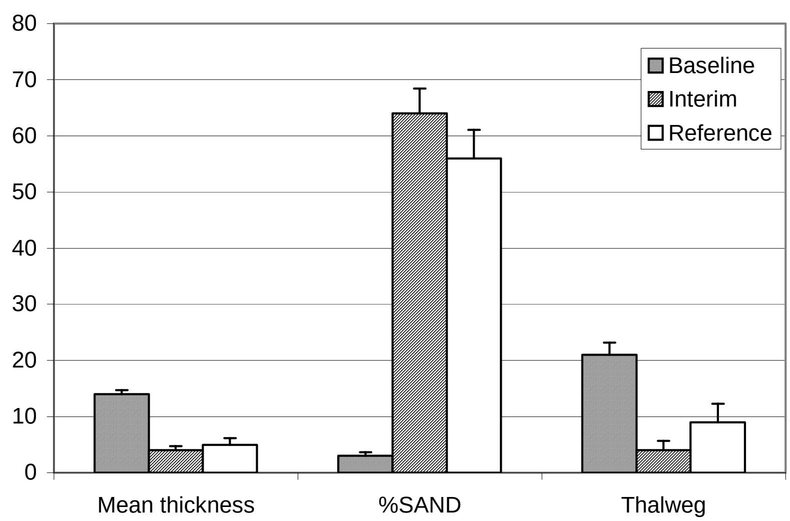

Figure 11-17. Mean (± SE) values for mean thickness of deposition on the channel bed, the percent of the channel bed that is bare sand, and the thickness of deposition on the channel bed at the thalweg. Values are presented for the baseline (n = 86), the values measured under flow (n = 24), and the values from the reference condition (n = 24).

WATER QUALITY

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 was identified as a key indicator of ecological integrity and essential component of the Kissimmee River restoration evaluation program. 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.

DO was monitored continuously at a depth of approximately 1 m in three remnant river run stations in Pools A and C. DO was also sampled monthly within seven remnant river runs and two canal stations in Pools A and C. Monitoring sites were selected to cover a large geographic area. Canal stations near water control structures S-65A and S-65C monitored DO concentrations of water flowing into and leaving the restoration project area.

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. Mean DO concentrations in the reference streams were 4.8 mg/L during the wet season, and 6.6 mg/L during the dry season (**Figure 11-18**). 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. 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 11-18**). 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 were 3.3 mg/L during the wet season and 6.1 mg/L during the dry season (**Figure 11-18**). Post-construction DO concentrations in the control area (Pool A) were 1.1 and 4.5 mg/L during the wet and dry seasons, respectively (**Figure 11-18**). Mean daily water column DO concentrations were > 2 mg/L for 85 percent of the time. Dissolved oxygen concentrations within one meter of the channel substrate were > 1 mg/L over 50 percent of the time.

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. Although the restoration expectation for dissolved oxygen concentrations in restored river channels is to be evaluated after implementation of the Kissimmee River Headwaters Revitalization Project regulation schedule, three of the four metrics used to evaluate DO response are being met under the interim regulation schedule.

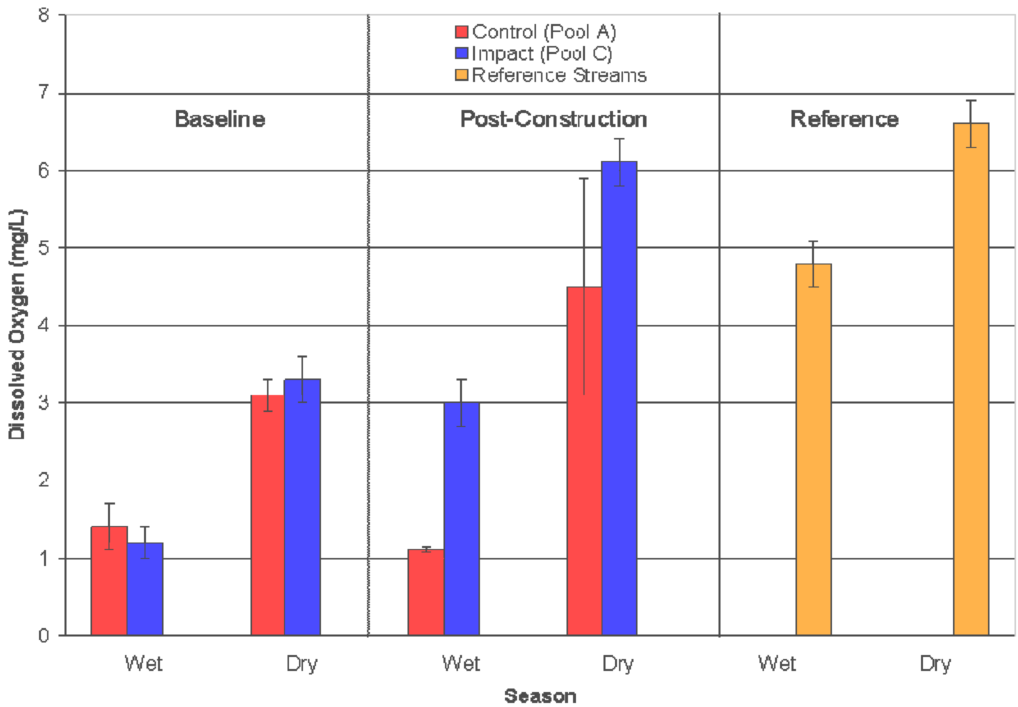

Figure 11-18. Mean (± standard error of the mean) DO concentrations (mg/L) in reference streams and the control and impact areas during the wet and dry season, before and after Phase I construction.

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 11-3**). Mean turbidity at these locations was very low, ranging from 1.3 to 3.5 NTU. Total suspended solids 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.

Table 11-3. Turbidity and total suspended solids (TSS) in remnant river runs of Pools A and C from March 19, 1996 to June 8, 1999 (Jones, 2003b).

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 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.

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, 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) under low as well as high discharge conditions. 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.

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 11-4**). 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.

Table 11-4. Turbidity and TSS data for Florida stream reference sites (Jones, 2003b).

	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
Rosalie Creek	11	3.8	4.8 ± 0.8	11.1	4	4.5	11.0

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

Following Phase I construction, turbidity remained low in the restored reach of the river during WY2002–WY2004. Turbidity averaged 3.6 to 6.3 NTU at the four stations in the restored reach (**Table 11-5**). The overall average was 5.3 NTU. Maximum values at these stations ranged up to 14.3 NTU. Turbidity levels were consistent between the three years. These data are not statistically different from data from the reference streams.

Total suspended solids have been slightly higher than expected. Median concentrations of TSS at the four stations within the restored reach ranged from 3.0 to 9.0 mg/L (**Table 11-5**). Nevertheless, the difference between these concentrations and concentrations in the reference streams is probably not ecologically significant.

Although Pool C river runs will be affected by mobilization of accumulated vegetation and organic deposits as discharge is diverted to these channels, turbidity and TSS are expected to return to reference levels after one full year of moderate flow (20–40 m^3 per second) through the restored river channel.

Table 11-5. Turbidity and total suspended solids in river runs of Pools A and C after Phase I construction (May 1, 2001 to April 30, 2004).

	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]	11	2.7	2.8 ±0.3	4.5	11	5.0	6.4
Rattlesnake Ham. Run--Pool A (KREA 91)[2]	23	2.1	2.4 ±0.3	5.7	23	< 3.0	18.8
Schoolhouse Run--Pool A (KREA 92)	34	1.9	2.2 ±0.2	5.0	36	< 3.0	9.8
Montsdeoca Run--Pool C (KREA 98)	33	4.9	5.3 ±0.4	13.7	33	7.0	13.2
Oxbow 13--Pool C (KREA 93)	34	5.7	5.9 ±0.4	14.3	34	8.0	17.2
Micco Bluff Run--Pool C (KREA 94)	34	5.8	6.3 ±0.4	13.2	35	9.0	19.1
MacArthur Run--Pool C (KREA 95)	33	3.2	3.6 ±0.4	10.7	34	< 3.0	16.8

[1] Many total suspended solids 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 WY2004.

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 phosphorus 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 reduce loading from these pools and also reduce loading from the headwater lakes. Restoration of sloughs and marshes along the river may increase retention of phosphorus from upland 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 may help lower phosphorus loads from tributaries.

Baseline and post-construction TP data have been obtained from routine monitoring at each C-38 water control structure. Concentrations of TP were determined from weekly to monthly grab samples and composite samples collected by autosamplers. 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 TP concentrations at each structure. Because TP loads can vary greatly between wet years and dry years, flow-weighted mean concentrations provide a more useful metric for evaluating trends.

The 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 11-19**). These amounts comprised 43 and 71 percent of the average load at S-65E, respectively. Annual flow-weighted mean concentrations averaged 53 parts per billion (ppb) at S-65C (range from 33 to 87 ppb), and 78 ppb at S-65D (range from 47 to 141 ppb) (**Figure 11-20**). Concentrations were greater during years of lowest flow (1981 and 1985). At S-65, upstream of the restoration project area, mean loading rate was 35 mt/y (**Figure 11-19**) and the flow-weighted mean concentration was 43 ppb (**Figure 11-20**).

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. The only phosphorus data from that period are from single samples collected at three locations along the river in 1952 (Odum, 1953). TP concentrations in these samples ranged from 2 to 60 ppb. Reference loads and concentrations may be estimated by making various assumptions about headwater concentrations and retention of phosphorus in the river's floodplain. Predictions of future loads and concentrations can be made using similar assumptions. Of course, estimated loads and concentrations will vary greatly depending on the assumptions used. Nevertheless, it is reasonable to suppose that concentrations were lower in the pre-channelized river. Also, restoration should tend to favor lower concentrations, but not until a natural river-floodplain hydroperiod and stable wetland ecosystem become established. These conditions will not be achieved until the new headwaters regulation schedule is implemented.

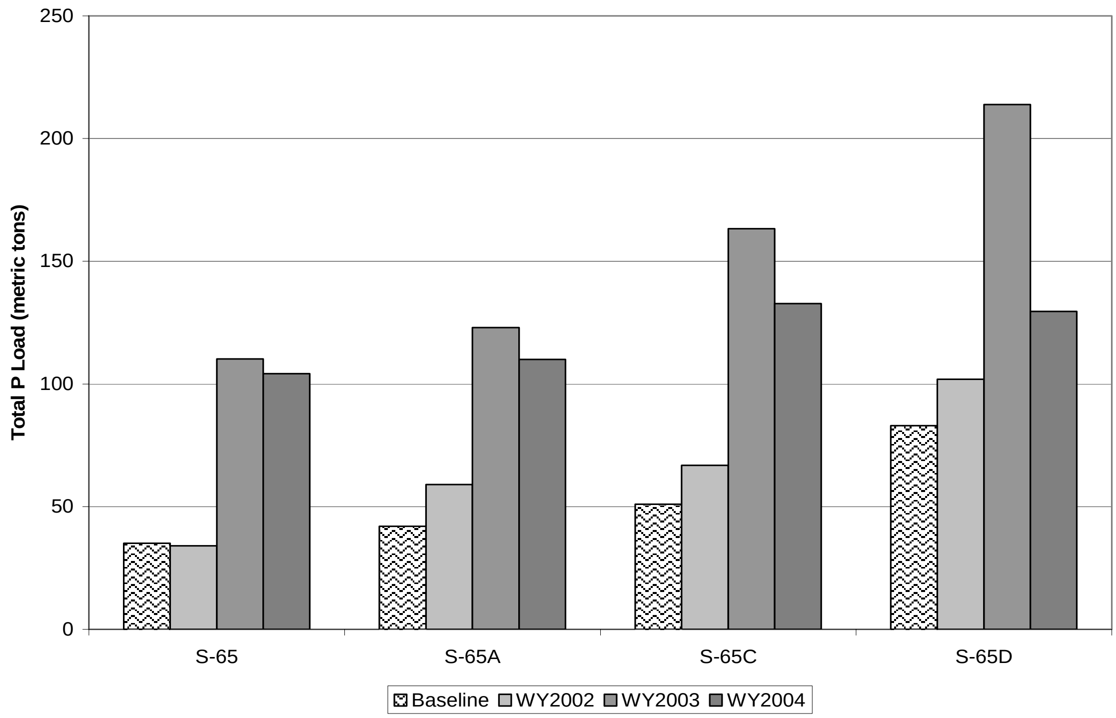

Figure 11-19. Annual TP loads (metric tons, or mt) from C-38 structures in comparison to baseline, reference, and expected loads.

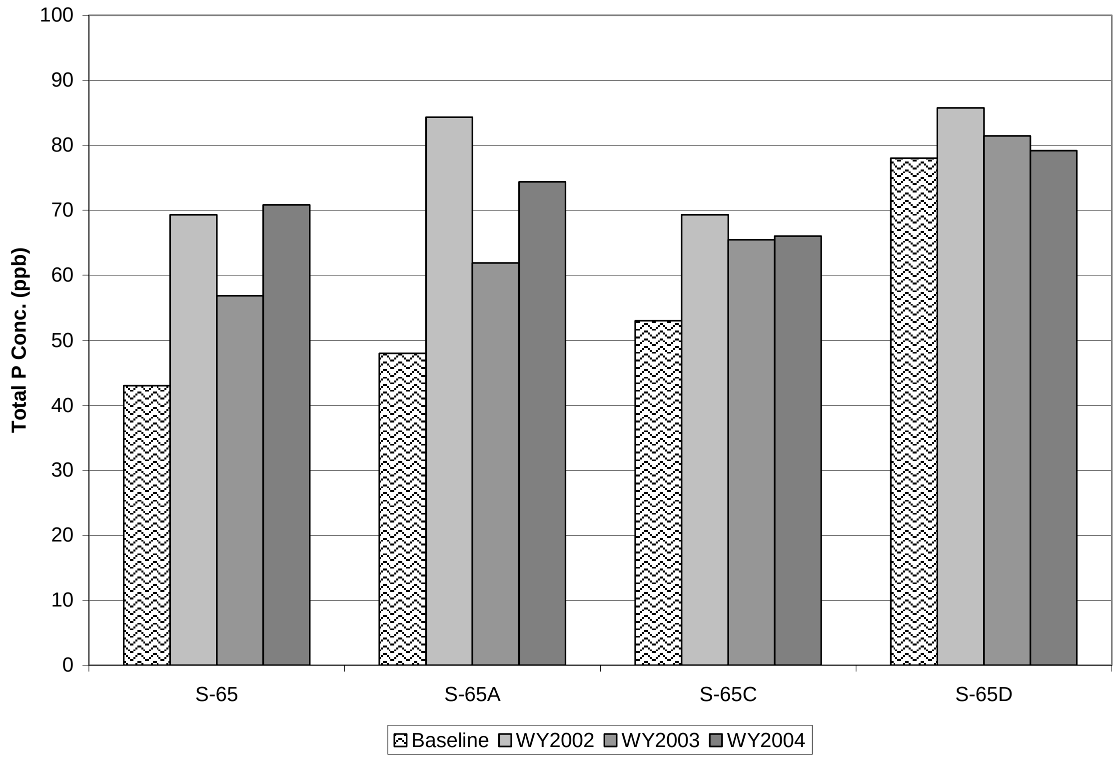

Figure 11-20. Annual flow-weighted mean TP concentrations (parts per billion, or ppb) at C-38 structures in comparison to baseline, reference, and expected concentrations.

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 loads nor concentrations of total phosphorus have declined at S-65C and S-65D since the baseline period. In fact, they have been higher (**Figures 11-19** and **11-20**). Annual flow-weighted mean TP concentrations at S-65C ranged from 65 to 69 ppb in WY2002–WY2004 and were similar to levels at S-65 and S-65A. Concentrations at S-65D were slightly higher.

Historically, TP concentrations in the upper reach of C-38 have reflected the trend in Lake Kissimmee. Higher concentrations have been measured at the lake's outlet (S-65) since the late 1990s. It is important to note that these elevated concentrations cannot be attributed to increases in Lake Kissimmee or other lakes in the Kissimmee Chain. The most recent data show that concentrations at S-65 were not always representative of concentrations in the middle of Lake Kissimmee, which averaged 37 ppb in WY2002, and 43 ppb in WY2003. (Sufficient data for averaging are not available yet for WY2004.) Therefore, evidence from the last several years points to sources at the southern end of Lake Kissimmee that are increasing concentrations at the lake's outlet. If sources of phosphorus at the lake's southern end can be identified and controlled, phosphorus inputs into the Kissimmee River and, ultimately, Lake Okeechobee could decrease.

RIVER CHANNEL VEGETATION

Elimination of flow in the Kissimmee River substantially modified the habitat of river channel plant communities, leading to changes in community composition and increases in the areal extent of aquatic plant cover. In flowing rivers, aquatic plant growth is constrained by channel depth and flow, and plants are typically limited to channel edges (Dawson, 1988). Physical changes associated with elimination of flow in the Kissimmee River included changes in channel substrate characteristics and channel depths.

Because of its sensitivity to flow and channel characteristics, littoral vegetation has been selected as an indicator of change resulting from restoration of flow in river channels. Based on reference and baseline data, several metrics were selected to monitor restoration-related changes in species composition and width of littoral vegetation beds. As a result of restored flow, it is expected that vegetation bed widths will decline substantially on inner channel bends and straight channel reaches. It is also expected that the community structure of vegetation beds will change from communities co-dominated by floating/mat-forming species and emergent species to communities heavily dominated by emergent species. These predictions are based on estimated pre-channelization conditions.

Plant species composition and vegetation bed width data were collected at transects located in remnant runs in Pools B and C (impact area) and in a control area in Pool A. Sampling was conducted twice annually (winter and summer) from 1998–2003. The 1-m-wide belt transects were located at bends and straight reaches of remnant river channels. Greater than 100 transect sections were measured per sample period in Pools B and C; approximately 40 transect sections were measured per sample period in Pool A. Sampling has been temporarily suspended in 2004 and is expected to be resumed in 2005.

Cover classes (Daubenmire, 1959) of all species present were recorded in contiguous 2 m x 1 m quadrats along each transect. Estimates were derived for both sides of the channel at each transect (two “transect sections” per transect). Relative cover of each species and growth-form (e.g., emergent, floating/mat-forming) in each bed was calculated as the sum of quadrat cover class midpoints for each species or growth-form, divided by the sum of midpoints of all species in the bed. Relative cover was averaged over all vegetated transect sections sampled for each species or growth-form for each of the sample periods. Grand means for the baseline period are the averages of the four 1998–1999 sample period means for each species or growth form (n = 4); grand means for the post-construction period are the averages of the six 2001–2003 sample period means (n = 6).

Vegetation bed widths were measured to the nearest 1 m along transects from the bank to the waterward edge of the bed. Beds were measured on both sides of the channel at each transect. Transect sections were classified by channel pattern (inner bend, outer bend, or straight reach). Widths were averaged for each sampling period over all sampled transect sections in each pattern category. Grand means of widths for the baseline period presented below are the averages of the four baseline sample period means (n = 4) for each pattern category; grand means for the post-construction period are the averages of the six post-construction sample period means (n = 6) for each pattern category.

Expectations were based on quantitative reference data to estimate pre-channelization littoral plant community structure and the width of vegetation beds. Data were obtained in June 1998 from a partially restored remnant channel in Pool B (River Run #1). The run had received intermittent flows and stage fluctuations since 1985 and continuous, moderate-to-high flow for 6 to 9 months prior to data collection. Weirs placed across the C-38 canal as part of the Pool B demonstration project (Toth, 1991) diverted water through the remnant channel.

Cover class (Daubenmire, 1959) data from a field survey of 13 transects in the partially restored channel (C. Hovey, unpublished data), and cover estimates from photointerpretation of 1998 aerial photography (C. Hovey, unpublished results) were used to derive estimates of relative cover of plant species under flowing conditions (i.e. prior to channelization). Relative cover means for the reference field survey are the averages of sampled vegetation beds (n = 26) that occurred at the 13 transects. Estimates of pre-channelization vegetation bed widths were obtained from data collected in a concurrent but separate survey of vegetation beds in the same channel. Data on widths of vegetation beds were collected at 42 beds at inner channel bends (n = 11), outer bends (n = 19), and straight reaches (n = 12) of river channel. Additional qualitative assessment of in-channel vegetation cover prior to channelization was based on June 1956 black and white aerial photography (1:12000).

Common floating and mat-forming species during the baseline period included *Salvinia minima*, a floating species; *Scirpus cubensis*, a non-native mat-forming species; and *Pistia stratiotes*, an invasive non-native floating species. *S. cubensis* forms dense floating mats of debris that may be colonized by emergent species and shrubs, and that may encroach on mid-channel areas under non-flowing conditions. Mean combined relative cover of floating and mat-forming species during the baseline period was 49.6 percent ± 4.0 percent in the impact area. Common emergent species were *Nuphar lutea*, an emergent with floating leaves; *Hydrocotyle umbellata*, and the grass *Sacciolepis striata*. Mean combined relative cover of emergent species was 43.3 percent ± 3.4 percent in the impact area (**Figure 11-21**). Vegetation covered a mean of 56.9 percent ± 5.0 percent (one standard error) of total channel width at transects in the impact area. Mean width of vegetation beds in the impact area was 12.4 m ± 0.7 m on inner bends, 6.0 m ± 1.0 m on outer bends, and 9.3 m ± 0.6 m on straight reaches (**Figure 11-22**).

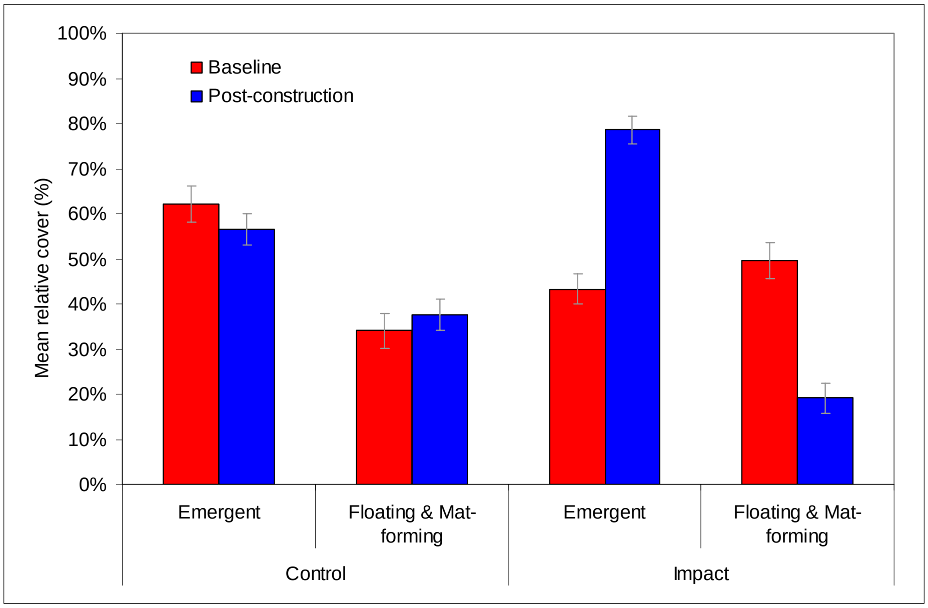

Figure 11-21. Mean (± one standard error) baseline and post-construction combined relative cover of emergent species and floating and mat-forming species in the control and impact areas.

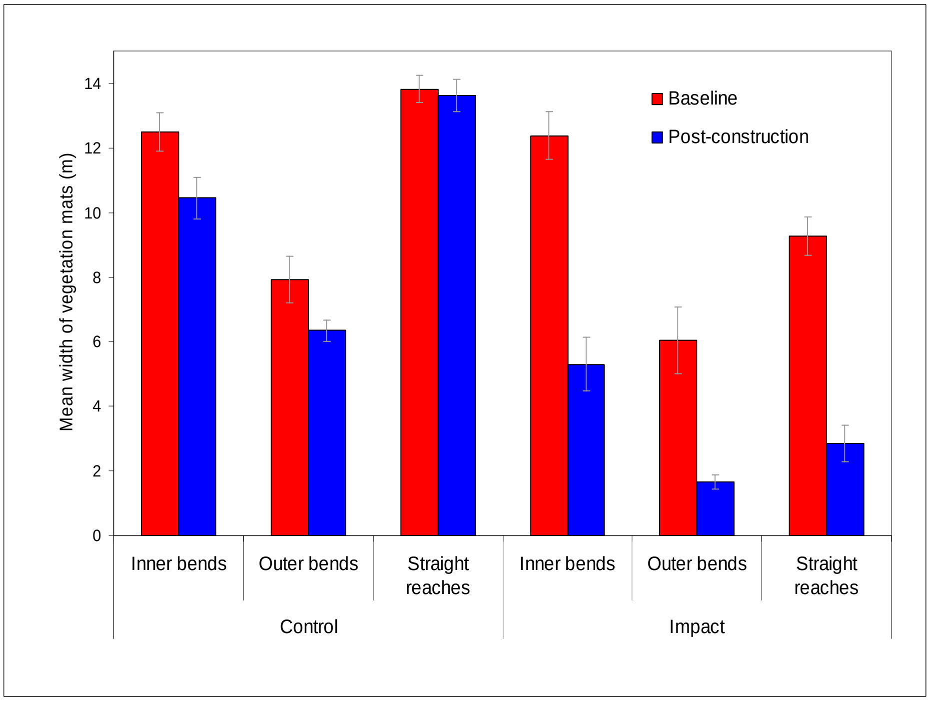

Figure 11-22. Mean (± one standard error) baseline and post-construction vegetation bed widths on three bend categories in the control and impact areas.

Emergent species, particularly *Polygonum densiflorum* and *Nuphar lutea*, dominated littoral zones in the 1998 reference survey. Based on the photointerpretation data, relative cover of emergent species was estimated at 97 percent. Based on the field survey data, mean combined relative cover of emergents was 87.8 percent ± 5.4 percent. The photointerpretation-based estimate of relative cover of floating and mat-forming species was 3 percent, while in the field survey data, mean combined relative cover of floating and mat-forming species (*P. stratiotes* and *Eichhornia crassipes*) was 4.5 percent ± 1.9 percent. *S. minima* (a common floating species in baseline surveys) and *S. cubensis* (a mat-forming species) were not found in either 1998 survey of the semi-restored channel.

Mean widths of vegetation beds in the reference survey were 5.0 m ± 0.4 m on inner channel bends (n = 11), 3.8 m ± 0.5 m on outer bends (n = 19), and 3.6 m ± 0.6 m on straight reaches (n = 12). These reference values were used to predict values for restored-condition littoral vegetation beds.

Post-construction (2001–2003) monitoring indicated substantial impact-area reductions in the widths of littoral beds on all bend categories (**Figure 11-22**) and a dramatic conversion from baseline-period communities that were slightly dominated by floating/mat-forming species in the impact area to post-construction communities that were dominated by emergents (78.6 % ± 6.0 %) (**Figure 11-21**). These results contrast with insignificant changes at control area transects, where restoration of flow did not take place.

The results suggest that, following channelization, littoral vegetation beds expanded toward mid-channel areas and cover of floating and mat-forming species increased relative to cover of emergent species. After restoration of flow, littoral areas converted from communities approximately co-dominated by floating/mat-forming species and emergent species to communities heavily dominated by emergent species. Mean vegetation bed widths on all channel bend categories and mean vegetated percentage of channel declined. Although the headwaters revitalization stage regulation schedule has not yet been implemented, the trajectories of monitored metrics have followed predicted trends.

FLOODPLAIN VEGETATION

Areal Coverage of Floodplain Plant Communities

Reestablishment of wetland plant communities will be the initial indicator of restoration of the biological integrity of the floodplain and an integral component of habitat characteristics that must be restored to reestablish the functional integrity of the system. Tracking and comparing landscape-scale vegetation changes from the pre-channelization environment through the baseline condition and recovering ecosystem is a primary method for assessing floodplain vegetation responses to restored hydrology. Several major plant community types including broadleaf marsh, wet prairie and wetland shrub dominated the floodplain prior to channelization. Changes in the quantity and distribution of these community types across the restored floodplain are indicative of ecosystem health and sustainability.

Expectations have been developed to evaluate areal coverage and distribution of floodplain wetland community types in response to Kissimmee River restoration in Pools B, C, and D. These expectations include an increase in total cover of all wetland vegetation communities, including broadleaf marsh and wet prairie. Vegetation survey data from 1978 indicate that approximately 4,352 ha of wetland plant communities were present in Pools B, C, and D after channelization (Milleson et al. 1980), of which 1,461 ha were in Pool C. These same surveys indicate that wetland communities in Pool A (control site) totaled 962 ha. More recent vegetation map data for Pool C were derived from photointerpretation of 1996 color infrared (CIR) aerial photography.

These data indicate that wetland plant communities comprised 1,657 ha within the Phase I project area (primarily Pool C). Because CIR aerial photography results in map data with greater detail and accuracy than that of Milleson et al. (1980), these data serve as the baseline for making comparisons following restoration. Baseline vegetation mapping for Phases II–III (primarily Pool D) and IV (Pool B) will be performed using CIR aerial photography acquired in late spring of 2003. The floodplain within the Phase I project area will be re-mapped using 2003 aerial photography to determine initial response of wetland plant communities to intermittent floodplain inundation under the interim regulation schedule. Pool A will be similarly mapped to monitor plant communities at the control site.

Expectations for recovery of floodplain plant communities were developed through photointerpretation of aerial photography and geographic information systems. Expectations were developed from reference condition data based on vegetation maps derived from 1950s aerial photography of the Kissimmee River valley (Pierce et al., 1982). Aerial overflights and subsequent photointerpretation and mapping of floodplain plant communities will be conducted every three years and will follow the current construction schedule for each phase of the project.

Aerial photography provides a "snapshot in time" and dramatic physical changes can be observed without technical processing or analytical mapping. **Figures 11-23** through **11-25** are aerial photos of water control structure S-65B and the associated tieback levee within the Phase I restoration project area. **Figure 11-23** was taken in 1995 using CIR film. C-38 canal and remnant river channels can be easily distinguished, and spoil material appears as white and gray-green areas adjacent to the canal. **Figures 11-24** and **11-25** were taken in 2003 using natural color digital and CIR film photography, respectively. The S-65B lock and dam structures were demolished in June 2000 during Phase I construction; however, their footprints are still distinguishable. Wetland vegetation colonizing the backfilled canal and degraded spoil mounds appear as wisps of bright green emerging from the water (**Figure 11-24**). **Figure 11-25**, taken two months later, indicates that the coverage and density of wetland vegetation has increased and appears light pink on the backfilled canal and degraded spoil mounds. The re-colonizing vegetation is comprised of wetland shrubs, wet prairie graminoid and forb species, broadleaf marsh species, and several aquatic taxa that are rarely found under channelized conditions.

Floodplain Plant Community Composition

Assessment of floodplain plant community composition will both document post-restoration plant community composition and capture successional changes in plant communities as they respond to restoration of historical floodplain hydroperiods. To estimate baseline conditions, species cover data were collected twice yearly, for at least one year, in one hundred different 100 m^2 (5 m by 20 m) plots established at representative floodplain locations. Prior to channelization, these locations supported examples of the dominant floodplain plant communities of the pre-channelization river. These communities include broadleaf marsh (dominated by *Sagittaria lancifolia* and/or *Pontederia cordata*), wet prairie, willow (*Salix caroliniana*), and buttonbush (*Cephalanthus occidentalis*).

Pre-channelization conditions were estimated using reference data (Toth, 1991; L. Toth, unpublished data), observational knowledge of the Kissimmee River ecosystem and best professional judgment. Comparisons with baseline data suggest that species composition in most floodplain vegetation plots has undergone substantial change since channelization. Because these sites were largely isolated from hydrologic influences of the Kissimmee River after channelization, most had developed upland plant communities. Upland pastures, usually dominated by combinations of seeded forage grasses, and wax myrtle (*Myrica cerifera*) shrublands were common communities in drained floodplains during the baseline period.

Because floodplain vegetation responses require restoration of historic floodplain hydroperiods, they have not yet been evaluated. Initiating the Headwaters Revitalization Project regulation schedule and reestablishing historic floodplain inundation characteristics are expected to drive predicted changes in floodplain plant community composition.

Kissimmee River C-38 and S65B Area 1995

Figure 11-23. Color infrared photography of the S-65B structure, tie back levee, C-38, and spoil mounds taken in 1995.

Kissimmee River Former S65B Area, the Backfilled C-38,
and Former Spoil Mounds 2003

Figure 11-24. Natural color digital aerial photography of the S-65B structure and tie back levee area taken in April 2003.

Figure 11-25. Color infrared aerial photography of the former S-65B structure and tie back levee area taken in late June 2003.

AQUATIC INVERTEBRATES

Aquatic invertebrates were identified as a critical biological component for assessing restoration of ecological integrity within the Kissimmee River ecosystem (Karr et al., 1991; Harris et al., 1995). Aquatic invertebrates can play an integral role in river ecosystem processes including nutrient cycling (Merritt et al., 1984), decomposition of detritus (Wallace and Webster, 1996), and energy flow to higher trophic levels (e.g., amphibians, reptiles, fishes, wading birds, and waterfowl) (Weller, 1995; Benke et al., 2001). Aquatic invertebrates also have a long history of use in biomonitoring (Plafkin et al., 1989; Rosenberg and Resh, 1993) and can serve as indicators of biotic integrity and ecological health (Karr, 1991).

In order to restore ecological integrity to the Kissimmee River and floodplain ecosystem, both structural and functional aspects of the ecosystem must be reestablished. Structural attributes can include species composition, guild structure, density, species richness and species diversity. Functional attributes may include measures of energy flux such as secondary production, and aquatic invertebrate drift. Restoration of the Kissimmee River is expected to reestablish critical habitat characteristics including current velocity, increased levels of dissolved oxygen, substrate composition and floodplain hydroperiods. These changes in habitat characteristics can significantly alter aquatic invertebrate community structure and lead to changes in invertebrate productivity. A conceptual model for invertebrate community structure in the restored system predicts an increase in the density, diversity and relative abundance of specific indicator taxa and functional feeding groups. This model also predicts an increase in secondary production of aquatic invertebrates within the restored system (Harris et al., 1995). Structural and functional shifts in aquatic invertebrate community characteristics along this predicted trajectory will ultimately be used as an indicator of restoration success.

In order to determine baseline (pre-restoration) conditions, multiple sampling techniques and metrics were used to characterize aquatic invertebrate community structure in mid-channel benthic, large woody debris and mid-channel water column (drift) habitats within remnant river channels. Samples were collected between August 1995 and May 1997 in Pools A and C. Samples were analyzed for density, species richness, species diversity, functional feeding group composition and functional habitat association. Secondary production of aquatic invertebrates also was calculated for each habitat type.

Within the river channel, baseline species richness and diversity were low in benthic habitats and on large woody debris. Functional feeding and functional habitat associations were dominated by taxa characteristic of lentic (non-flowing) water. Total annual production of aquatic invertebrates within both habitats was similar to other southeastern Coastal Plain rivers; however, the distribution of production among functional feeding groups within the Kissimmee River was highly skewed toward collector-gatherers and scrapers.

Lack of flow within remnant channels of the channelized Kissimmee River greatly altered aquatic macroinvertebrate community structure and drift composition. Downstream transport of aquatic invertebrates in the channelized system occurs via swimming or rafting, primarily on floating mats of water lettuce (*Pistia stratiotes*). Drift sample data indicate the presence of large numbers of cladocerans, copepods, benthic ostracods and oligochaetes. Lotic (flowing water) aquatic macroinvertebrate taxa were absent. No apparent seasonal trends in drift composition or density were observed.

Reference conditions for species composition of aquatic invertebrates in restored sand habitats (i.e, mid-channel benthic) are based on species richness of taxa within sandy benthic habitats of southeastern blackwater rivers (Benke et al., 1984; Smock et al., 1985; Stites, 1986;

Stites and Benke, 1989; Mason et al., 1994). Reference conditions for density, biomass, and production of passive filtering-collectors on river channel woody debris is derived from published data on functional feeding group composition, density, biomass and annual production of snag-dwelling invertebrates in two southeastern Coastal Plain river-floodplain systems; the Satilla River (Georgia), a sixth-order blackwater river with similar physical, chemical and hydrologic patterns as the historic Kissimmee River, and Cedar Creek (South Carolina), a second-order blackwater stream (Benke et al., 1984; Smock et al., 1985).

Reference conditions for macroinvertebrate drift density and biomass are based on invertebrate drift data from two unregulated, sixth-order southeastern Coastal Plain rivers, the Satilla and Ogeechee River, Georgia (Benke et al., 1986; 1991), and Blackwater Creek (Cowell and Carew, 1976), a tributary of the Hillsborough River in Florida. These studies indicate larval blackflies, mayflies, beetles, caddisflies, midges, and copepods were the major contributors to drift numbers and biomass.

Initial responses to restored flow and habitat structure under the interim regulation schedule have been positive for mid-channel benthic and snag-dwelling invertebrate communities. Within three years of restoring continuous flow (June 2001–June 2004), dominant benthic invertebrate taxa include native clams (*Musculium*/*Pisidium*/*Sphaerium* complex) and characteristic sand-dwelling chironomids including *Cryptochironomus* spp., *Tanytarsus* spp. and *Polypedilum* spp. and numerous microcrustaceans. Other native bivalves, including *Popenaias buckleyi* and *Anodonta* spp., also have been collected in low numbers. Although never collected during the baseline period, empty shells of *P. buckleyi* and *Anodonta* spp. were observed along the river margin in Pool C. It is unclear whether the individuals collected during post-construction sampling represent new colonists, or individuals that were present, but not sampled, during the baseline period. Although these taxa have long life cycles and mature slowly, it is expected that they will increase in numbers as restoration of the river continues. *Corbicula fluminea*, a non-native clam, has greatly increased in numbers since reestablishing flow. Aquatic invertebrate community structure and functional group associations on large woody debris (LWD) also have shifted since reestablishing flow. Taxa characteristic of enriched lentic habitats and tolerant of low levels of dissolved oxygen have been replaced by taxa characteristic of free-flowing blackwater streams of the southeastern U. S. Preliminary analyses indicate dominance by passive filtering-collectors including *Cheumatopsyche* spp. (Trichopetra: Hydropsychidae), *Cyrnellus* spp. (Trichoptera: Polycentropodidae) and *Rheotanytarsus* spp. (Chironomidae). Recolonization by hydropsychid caddisflies and other passive filtering-collector taxa are consistent with restoration of biological integrity and recovery of the food base. Passive filtering-collectors are expected to dominate density and biomass on LWD within the restored system and should account for the greatest proportion of secondary production in this habitat.

PERIPHYTON

Periphyton (algae attached to aquatic plants) are an integral part of the food web of aquatic systems and respond quickly to environmental change. Changes first detected in the algal community often signal changes for other trophic levels (Stevenson et al., 1996). While reference data for the pre-channelized Kissimmee River are unavailable, comparison of baseline and post-restoration periphyton communities should yield insights regarding the health of the restored system.

Baseline periphyton samples from river channels were collected monthly in Pools A and C from June through December 1999. Samples were collected using artificial substrates (clear acrylic rods) suspended from anchored floats. Three replicates were placed at weed bed margins and within weed beds at each of five stations to maximize the range of light conditions sampled in the river channel. Samples were collected at approximately 30-day intervals, and analyzed for species richness and relative abundance of cells of rheophilic (species with an affinity for, or that thrive in flowing water) taxa.

Mean species richness (± 1 S.E.) in remnant river channels of Pools A and C was 46.1 ± 1.9, and 38.1 ± 2.0 per sample (**Table 11-6**). One dominant (accounting for > 5 % of total numbers) algal species in Pool A was rheophilic, and two dominant species in Pool C were rheophilic. Mean relative abundance per sample of cells of rheophilic species was 22.6 ± 1.7 percent in Pool A, and 34.8 ± 3.3 percent in Pool C.

Post-construction periphyton sampling began in January 2004, and will continue through December 2004. Although no conclusions regarding periphyton response to restoration can be drawn until all data have been analyzed, large periphyton colonies have been observed growing on sand bars and emergent aquatic vegetation within the river channel. This, in association with increased levels of dissolved oxygen in the river channel, suggests that a healthy periphyton community has begun to develop.

Table 11-6. Dominant periphyton species (based on relative abundances of cells) within remnant channels of the Kissimmee River.

Pool	Species	Phylum	Relative abundance of cells (%)	Rheophilic *
A	*Oscillatoria spp. #1*	Cyanophyta	7.6	X
A	*Gomphonema gracilis*	Bascillariophyta	6.7	
A	*Nitzchia amphibia*	Bascillariophyta	8.2	
A	*Coelast spp.*	Chlorophyta	5.1	
A	*Kirchneriella spp.*	Chlorophyta	6.8	
C	*Oscillatoria spp. #1*	Cyanophyta	8.0	X
C	*Oscillatoria spp. #2*	Cyanophyta	9.4	X
C	*Schizothrix spp.*	Cyanophyta	12.2	
C	*Navicula conservacea*	Bascillariophyta	7.2	
C	*Nitzchia palea*	Bascillariophyta	6.5	

*Lowe (1974); Palmer (1977).

HERPETOFAUNA

Amphibians and reptiles were identified as important biological components for assessing restoration of ecological integrity within the Kissimmee River ecosystem. Adult and larval herpetofauna play an integral role in food web dynamics and energy flow through aquatic and terrestrial ecosystems. They are major consumers of invertebrates and algae (Blaustein and Wake, 1990) and, in turn, are consumed by a variety of invertebrates (Travis et al., 1985; Roth and Jackson, 1987), fishes (Azevedo-Ramos et al., 1999), birds (Ogden et al., 1976; Collopy and Jelks, 1989; Beissinger, 1990), and other amphibians and reptiles (Morin, 1983; Wilbur et al., 1983; Ashton and Ashton, 1988).

Amphibians also serve as indicators of ecosystem health. Because of their complex life cycle, obligate association of larvae with water, and terrestrial or semi-terrestrial adult stage, environmental conditions within aquatic and terrestrial habitats must be favorable for reproduction, development, and survival (Zug et al., 2001). Additionally, the permeable skin of most amphibians makes them susceptible to air-borne, aquatic, and terrestrial contaminants (Zug et al., 2001). Adult and larval amphibians are vulnerable to low temperature, drought, and anthropogenic shifts in wetland hydrology (Pechmann et al., 1989; Stebbins and Cohen, 1995).

In order to establish a baseline for comparisons following restoration of floodplain wetlands, multiple sampling techniques, including visual encounter surveys and throwtraps, were used to survey herpetofaunal species richness, species diversity, community evenness, community similarity, and relative abundance within several altered floodplain habitats of the channelized Kissimmee River ecosystem. Surveys were conducted monthly in Pools A and C for a period of 30 months, beginning in August 1997.

The conversion of broadleaf marsh habitat to pasture, combined with shortened and unpredictable hydroperiods in remnant wetlands following channelization, dramatically altered herpetofaunal community structure, distributions, and temporal patterns of amphibian reproduction. Most herpetofaunal taxa characteristic of wetland habitats of Central Florida are absent from remnant marshes of the channelized Kissimmee River. Amphibian reproduction within remnant broadleaf marshes of the channelized system is generally limited to short periods when summer rains temporarily inundate floodplain habitats.

Reference conditions for herpetofaunal community structure in broadleaf marsh were developed based on a comprehensive review of amphibian and reptile distributions and habitat preferences throughout Florida (Carr, 1940; Carr and Goin, 1955; Auffenberg, 1981). Reference conditions for amphibian reproduction in broadleaf marsh were based on the fact that, in the tropics, amphibian breeding activity often is continuous, with some species in breeding readiness at all times (Stebbins and Cohen, 1995). Due to the subtropical climate of the Kissimmee River ecosystem, and its historical long-term floodplain inundation frequencies, it is likely that some larval amphibians were present in floodplain marshes throughout much of the year.

Restoration of pre-channelization hydrology, including long-term floodplain inundation frequencies, is expected to reestablish historic floodplain wetland communities in the central portion of the Kissimmee river/floodplain ecosystem. Because hydrology and habitat quality are critical factors influencing species composition, distribution, and reproduction in herpetofaunal communities (Skelly, 1997; Adams, 1999; Bodie and Semlitsch, 2000), restoration is expected to provide for colonization, reproduction, and persistence of a herpetofaunal community characteristic of natural wetlands of Central Florida (Tennant, 1997; Bartlett and Bartlett, 1999; Franz et al., 2000).

Because discharge regimes under the interim regulation schedule have not been adequate to provide for reestablishment of natural hydroperiods and associated restoration of ecological integrity of the floodplain, evaluation of herpetofaunal response will commence following initiation of the Headwaters Revitalization Project regulation schedule. Appendix 11-1, Table 1 lists potential indicator species for assessing restoration of amphibian and reptile community structure in reestablished broadleaf marsh habitats. **Table 11-7** lists amphibians known to use remnant floodplain habitats for reproduction and their breeding periods.

Table 11-7. Florida breeding periods of amphibian species known to occur in the channelized Kissimmee River ecosystem. Breeding periods are from Mount (1975) and Conant and Collins (1991).

Indicator Species	Spring	Summer	Autumn	Winter
Acris gryllus dorsalis (Florida Cricket Frog)	X	X	X	X
Gastrophryne carolinensis (Narrow-mouthed Toad)	X	X	X	
Hyla cinerea (Green Tree Frog)	X	X	X	
Hyla femoralis (Pine Woods Tree Frog)	X	X	X	
Hyla squirella (Squirrel Tree Frog)	X	X	X	
Pseudacris nigrita (Florida Chorus Frog)	X	X	X	
Pseudacris ocularis (Little Grass Frog)	X	X	X	X
Rana catesbeiana (Bullfrog)	X	X	X	
Rana grylio (Pig Frog)	X	X	X	X
Rana sphenocephala (Southern Leopard Frog)	X	X	X	
Eurycea quadridigitata (Dwarf Salamander)	X		X	X

FISHES

Floodplain Community

Fishes are ecologically important components of large river-floodplain ecosystems (Welcomme, 1979). Fish species representing a range of trophic levels (herbivore, piscivore, omnivore, invertevore, planktivore, detritivore) consume foods originating from aquatic and terrestrial environments (Karr et al., 1986) and serve as a critical link in the energy pathway between primary producers and higher trophic level consumers, including amphibians, reptiles, and birds (Karr et al., 1991; Gerking, 1994). Because freshwater fishes are relatively long-lived (Carlander, 1977; Lee et al., 1980) and can travel considerable distances within their watershed (Gent et al., 1995; Furse et al., 1996), they integrate aspects of aquatic ecosystems across broad temporal and spatial scales (Karr et al., 1986). Fishes also are often used as bioassays for contaminants within aquatic environments (USEPA, 1977). For these reasons, fishes are excellent indicators of aquatic ecosystem health or integrity (Karr et al., 1986; Ohio EPA, 1987; Gammon and Simon, 2000), and were identified as an essential component of the Kissimmee River restoration evaluation plan.

Two types of remnant impounded wetlands, broadleaf marsh (BLM) and woody shrub (WS), were sampled within Pools A, C, and D between August 1996 and January 1999, to determine the effects of channelization on floodplain fish communities and provide a baseline for post-restoration comparison. BLM in Pool A and WS in Pool D served as control sites, while both habitats in Pool C served as impact sites. Ten random samples were collected during each sampling event using a 1-m^2 throw trap. First year sampling was conducted quarterly, with monthly sampling beginning in August 1997 and continuing through January 1999. Pasture habitat also was sampled because it is expected to revert to broadleaf marsh following restoration. Pasture in Pools A (control site) and C (impact site) was sampled for 11 months between March 1998 and January 1999. For BLM and WS, each sampling year is based on a complete wet (June–November) and dry (December–May) season.

Mean annual fish density, averaged for the three baseline study years, was 1.7 ± 1.1 fish/$m^{2,}$ and 1.5 ± 1.1 fish/m^2 at BLM control and impact sites, respectively. Mean annual fish density in WS was greater than BLM density; within WS densities were slightly higher at WS impact sites (5.4 ± 1.1 fish/m^2) than at WS control sites (3.9 ± 2.5 fish/m^2). Mean monthly fish density did not exceed 0.3 fish/m^2 at pasture sites.

Small-bodied fishes comprised 99 percent of the 3,159 fishes collected in all floodplain habitats (Appendix 11-1, Table 2). Only one young-of-year (YOY) large-bodied centrarchid, *Lepomis macrochirus*, was collected during baseline sampling. All other centrarchids were small-bodied taxa typical of shallow, ephemeral marsh habitats (Lee et al., 1980).

Mean (± SE) annual relative abundance at the BLM control site in Pool A was dominated by elassomatids (66.2 % ± 19.8 %). Poeciliids, small-bodied centrarchids, and fundulids comprised 33.0 percent ± 5.1 percent, 0.7 percent ± 0.7 percent, and 0.1 percent ± 0.1 percent, respectively, of collected fishes. Community composition at the BLM impact site in Pool C also was dominated by elassomatids (68.9 % ± 12.4 %). Poeciliids (30.5 % ± 12.7 %), small-bodied centrarchids (0.2 % ± 0.2), and a single clariid species (0.4 % ± 0.4 %) also were found (Appendix 11-1, Table 2).

Poeciliids (89.4 % ± 4.6 %) were dominant at WS impact sites, which also included elassomatids (8.5 % ± 5.1 %) and fundulids (2.0 % ± 1.3 %). The only YOY large-bodied centrarchid (0.1% ± 0.1%) was collected at a WS impact site. Community composition was more evenly distributed among elassomatids (51.0 % ± 13.2 %) and poeciliids (48.4 % ± 12.9 %) at WS control sites, where fundulids were uncommon (0.6 % ± 0.3 %) (Appendix 11-1, Table 2).

Relative abundance at the pasture control (Pool A) site was evenly distributed between elassomatids (52.2 %) and poeciliids (47.7 %). However, the impact site was dominated by elassomatids (72.7 %), with poeciliids accounting for the remaining 27.3 percent of sampled fishes (Appendix 11-1, Table 2).

Reference data on floodplain fish community structure of the Kissimmee River are limited to a single sample (FGFWFC, 1957). Consequently, reference conditions were derived from relevant data from the FGFWFC (1957) report, and comparable river/floodplain (lower Mississippi River) and marsh (Florida Everglades) ecosystems. Jordan et al. (1997) found Everglades' marshes supported an average fish density of 23.4 fish/m^2 (± 0.9 fish/m^2), with a range between 4 and 109 fish/m^2. Average fish density was derived from data pooled across independent studies and years, thus it does not reflect mean annual density. However, because samples were collected during different years, it is likely they represent fish density over a range of hydrologic conditions.

The FGFWFC (1957) collected 922 individual fish representing 24 species, and 11 families in Kissimmee River BLM prior to channelization (Appendix 11-1, Table 2). Fish collected included both large (adults > 80 mm SL) and small-bodied individuals. The assemblage was dominated in abundance by small-bodied species (62.9 percent), especially golden shiner *Notemigonus crysoleucas* (39 percent). The remainder of the assemblage was comprised of large-bodied centrarchids and esocids (35.7 percent) and a single catostomid (1.4 percent). Of the 329 centrarchids and esocids collected, 98 percent were juveniles or young of the year.

Guillory (1979) found 62 taxa utilized inundated floodplain habitats of the lower Mississippi River. Ten large-bodied taxa (*Esox americanus, L. gulosis, L. macrochirus, L. microlophus, L. punctatus, M. salmoides, Pomoxis nigromaculatus Amia calva*, *Dorosoma cepedianum*, *Lepisosteus platyrhincus*), which also occurred in the historic Kissimmee River, comprised 12.2 percent of the total number of fishes collected. Seven of these ten taxa (*E. americanus, L. gulosis, L. macrochirus, L. microlophus, P. nigromaculatus*, *A. calva, D. cepedianum*) were YOY or adults in spawning condition, indicating inundated floodplain habitats of the lower Mississippi River serve as spawning and nursery areas.

Trexler et al. (in press) found that seven species of centrarchids and esocids (*E. americanus, E. niger, L. gulosis, L. macrochirus, L. microlophus, L. punctatus, M. salmoides*) accounted for 27 percent of the total number of fishes sampled in the Florida Everglades. Three other large-bodied taxa (*A. calva*, *Erimyzon sucetta*, *Lepisosteus platyrhincus*) comprised approximately 60 percent of all large-bodied fishes sampled (n = 583). Jordan et al. (1997) found 29 taxa of fishes utilizing wet prairie habitats within Water Conservation Area 3 of the Florida Everglades, 17 of which occurred within the historic Kissimmee River floodplain. Poeciliids (*Gambusia affinis*, *Heterandria formosa*) and Fundulids (*Lucania goodei*) accounted for 86 percent of the total number of fishes collected. Jordan et al. (1999) found small-bodied fish composition within backwater ponds of the Florida Everglades declined from 40 to 60 percent during stage recession periods due to an influx of large-bodied piscivorous fishes seeking deep water refuge (Loftus and Eklund, 1994), and an associated increase in predation (Kushlan, 1976; 1980; Loftus and Eklund, 1994).

Multiple metrics are being used to evaluate response of the floodplain fish community to restoration. Mean annual density of small bodied fishes (fishes < 10 cm total length) within restored broadleaf marsh will increase significantly and resemble values estimated from reference sites. Mean annual relative abundance of small fishes is expected to shift dramatically from dominance by poeciliids and elassomatids, to include cyprinids, cyprinodontids, fundulids, percids, and immature centrarchids in proportions similar to reference conditions.

Reestablishing the timing and duration of floodplain inundation in a way that mimics historic hydrologic conditions is essential in structuring floodplain fish assemblages. Therefore, floodplain fish assemblages will not be sampled until implementation of the Headwaters Revitalization Project regulation schedule. However, anecdotal information indicates fish use of inundated floodplain habitats since completion of Phase I backfilling. Abandoned pit nests have been noted on restored portions of the floodplain and adults of large-bodied species including Florida gar, chain pickerel, and bluegill have been observed during periods of moderate to high inundation.

River Channel Community

Channelization of the Kissimmee River altered hydrologic, geomorphic, and dissolved oxygen characteristics of the river. Dissolved oxygen regimes of unrestored, remnant river channels persist at the tolerance threshold (2.0 ppm) for many fish species (Moss and Scott, 1961; Davis, 1975; Smale and Rabeni, 1995; Matthew, 1998) and periodically reach critically low levels (< 0.5 ppm) during summer months (Toth, 1993; Koebel, 1995), allowing tolerant species (i.e., *L. platyrhincus, A. calva*) to displace less tolerant species (Matthews, 1998).

Baseline annual electrofishing was conducted within remnant river channels from June 1992 to 1994 by the Florida Game and Freshwater Fish Commission (currently known as the Florida Game and Freshwater Fish Conservation Commission, or FWC). Dominant species (greater than 5 percent of mean annual relative abundance) at control sites in Pool A included *L. platyrhincus* (36.8 %), *L. macrochirus* (19.9 %), *A. calva* (8.4 %), and *Micropterus salmoides* (7.9 %). Community composition at impact sites (Pool C) was similarly dominated by *L. platyrhincus* (19.6 %), *L. macrochirus* (16.5 %), and *M. salmoides* (9.5 %), but also included *G. holbrooki* (16.9 %) and *Notemigonus crysoleucas* (11.7 %). Centrarchids accounted for only 31.8 and 38.3 percent of the fish communities in Pools A and C, respectively.

Electrofishing data from the St. Johns, Withlacoochee, and Oklawaha rivers were collected annually during the autumn low water period from 1983 to 1990, and serve as reference condition data for the Kissimmee River. All three rivers are either located entirely within or have headwaters originating in peninsular Florida below the Suwannee and St. Johns drainages, the demarcation between peninsular and northern fish assemblages (Swift et al., 1986; Gilbert, 1987). All rivers have undergone varying degrees of anthropogenic alteration that include channelization, impoundment, and point sources of pollution (Bass, 1991; Estevez et al., 1991; Livingston, 1991; Livingston and Fernald, 1991) and therefore are not pristine reference sites for the historic Kissimmee. However, data from these rivers provide representative information on the composition of riverine fish communities within peninsular Florida.

Lepomis auritus and *L. macrochirus* were dominant in each peninsular river with mean annual relative abundance exceeding 18 percent (range from 18.7 to 23.2 percent) and 14 percent (range from 14.8 to 35.0 percent), respectively (**Table 11-8**). Other centrarchids contributing greater than 5 percent mean annual relative abundance included *L. punctatus, L. microlophus, L. gulosus*, and *M. salmoides*. *Gambusia holbrooki* and *Notropis petersoni* were the remaining dominant species in the Withlacoochee River, while *N. crysoleucas* and *Fundulus seminolis* contributed greater than 5 percent in the St. Johns River. Centrarchids collectively comprised greater than or equal to 70 percent of the river channel fish community in all peninsular Florida rivers.

Comparisons of relative abundance show strong differences between baseline and reference conditions. Relative abundances of *L. platyrhincus* and *A. calva* are typically higher in altered river systems with degraded water quality (Champeau, 1990; Bass, 1991). Additionally, these taxa prefer systems with little to no flow and abundant aquatic vegetation (Lee et al., 1980; Mettee et al., 1996). The reestablishment of flow is expected to decrease coverage of emergent littoral vegetation and ameliorate degraded water quality, leading to an expected decrease in abundance of both taxa. Relative abundance of *L. auritus* and *Lepomis punctatus* is positively correlated with increased flow (Aho and Terrell, 1986), and is expected to increase following reestablishment of historic flow patterns. Conversely, abundance of *Notemigonus crysoleucas* is typically limited in lotic (flowing) systems (Lee et al., 1980; Mettee et al., 1996), and is expected to decrease in restored river sections. Reestablishment of historic sand substrate and sandbars will increase availability of spawning habitat for *L. auritus*, *L. macrochirus*, *L. punctatus*, and remaining centrarchids (Carlander, 1977; Struber et al., 1982, Aho and Terrell, 1986), with increased recruitment resulting from reestablishment of the river channel-floodplain linkage that historically provided floodplain habitat as refugia for juveniles (FGFWFC, 1957). Reestablishment of these functional attributes in the restored system is expected to result in increased relative abundance of centrarchid taxa.

River channel fish assemblages will not be sampled again until initiation of the Headwaters Revitalization Project regulation schedule. Several physical and biotic components of the ecosystem that influence fish assemblages must be restored prior to large-scale change in fish assemblage structure, including river channel geomorphology, in-channel flow characteristics, dissolved oxygen conditions, and timing and duration of floodplain inundation. However, recent informal creel data from the Phase I restoration area indicate angler success for centrarchid (bass and sunfishes) species is high, suggesting that these groups have already begun to respond positively to restoration-related changes in habitat. Angler success for largemouth bass has been as high as 7 fish per hour, with many quality fish of 3 to 4 pounds being caught.

Table 11-8. Percent contribution by centrarchids collected via electrofishing within three peninsular Florida Rivers between 1983 and 1990 and in Pool C of the Kissimmee River between 1992 and 1994 (Kissimmee River (KIS), St. Johns River (STJ), Oklawaha River (OKL), and Withlacoochee River (WIT).

Species	KIS	STJ	OKL	WIT
Centrarchus macropterus	--	0.01 ±0.01	--	--
Ennecanthus gloriosus	0.5 ±0.2	0.03 ±0.02	0.02 ±0.01	0.5 ±0.2
Lepomis auritus	--	18.7 ±1.2	23.2 ±1.6	19.2 ±2.9
Lepomis gulosus	4.8 ±1.6	1.3 ±0.2	4.9 ±0.5	6.1 ±0.4
Lepomis macrochirus	16.5 ±4.0	35.0 ±1.1	27.7 ±2.4	14.8 ±2.8
Lepomis marginatus	0.3 ±0.1	0.03 ±0.03	0.1 ±0.04	2.5 ±0.7
Lepomis microlophus	4.4 ±0.9	8.1 ±1.1	9.3 ±0.6	6.7 ±1.8
Lepomis punctatus	1.5 ±0.7	3.4 ±0.3	10.7 ±1.5	18.5 ±2.1
Micropterus salmoides	9.4 ±0.7	4.8 ±0.2	5.3 ±0.4	5.8 ±2.3
Pomoxis nigromaculatus	0.9 ±0.02	2.1 ±0.3	0.5 ±0.1	0.3 ±0.2
TOTAL	38.3	73.4	81.7	74.4

AVIAN COMMUNITY

Birds are both integral to the Kissimmee River/floodplain ecosystem and highly valued by its human users. Pre-channelization data indicate that the system once supported an abundant and diverse bird community (Audubon Society, 1936–1987). Restoration is expected to reproduce the necessary conditions to once again support such a community. Further, since many bird groups (e.g., wading birds, waterfowl, shorebirds, raptors) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller, 1995).

Avian responses to the restoration project are assessed using two primary methods: airboat and aerial surveys. However, casual observations by Kissimmee scientists and harvest data from hunting also are used to document species of birds using the river and floodplain. Airboat and aerial surveys have been conducted monthly during the baseline (pre-restoration) period and following the completion of Phase I backfilling. Airboat surveys are used to measure the species and numbers of wading birds, shorebirds, and other aquatic species (hereafter referred to as waterbirds) utilizing river channel habitats. During each monthly airboat survey, waterbirds are counted in three river channel sections each in Pool A (will not be restored) and Pool C (part of the area to be restored). The airboat is driven at a constant speed while a single observer counts all waterbirds within the river channel. Waterbird numbers are tallied separately for Pools A and C. Following restoration, the relative abundance of waterbird species using river channels is expected to change: anhingas, white ibis, and great egrets are expected to increase relative to total numbers, while common moorhens are expected to decrease. Shorebirds also are expected to respond to restoration through increases in both abundance and species richness.

Aerial surveys are used to measure the densities of cattle egrets, wading birds, waterfowl, and raptors on the 100-year floodplain, as well as to search for rookeries of nesting wading birds on or near the floodplain. Restoration is expected to bring increased use of the floodplain by all of these groups except cattle egrets, whose relative abundance is expected to decline relative to aquatic wading bird species. Furthermore, mixed species wading bird rookeries are expected 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 birds on the floodplain, east-west aerial transects (n = 218) were established at 200 m intervals beginning at the S-65 structure and ending at the S-65D structure (**Figure 11-26**). Thus, aerial surveys include areas that have and have not been restored. Each month, a minimum of 15 percent of the 100-year floodplain in Pools A–D is surveyed via helicopter flying at constant altitude and speed. A single observer counts all wading birds, waterfowl, and raptors within 200 m of one side of the transect line. Densities are calculated separately for restored and unrestored areas. Aerial searches for wading bird colonies are flown monthly 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.

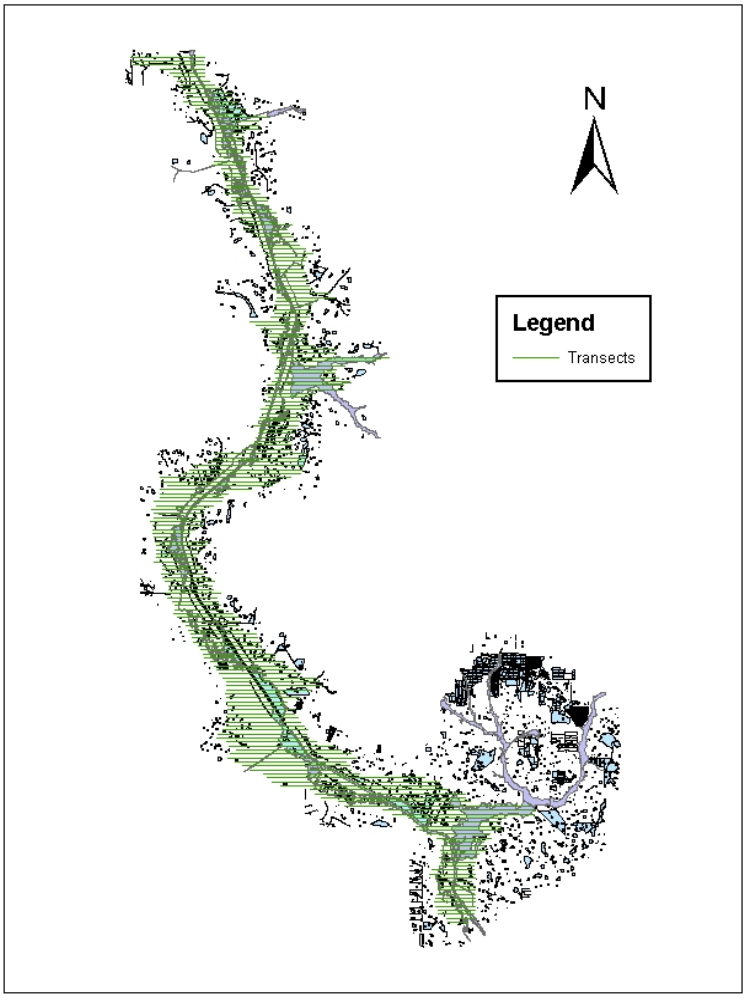

Figure 11-26. Aerial transects used to evaluate densities of wading birds, waterfowl, and raptors on the Kissimmee River floodplain. A total of 217 transects were established in Pools A–D at 200 m intervals. Each transect is oriented east-west and extends to the 100-year floodplain line on both sides of the river.

Use of river channels by waterbirds has changed following restoration (**Table 11-9**). For example, prior to backfilling in Pool C, anhingas accounted for 6 percent of all river channel waterbird observations; following backfilling, anhingas averaged 15 percent of observations in 2001–2002, and 31 percent in 2003–2004. The total (as opposed to relative) number of anhingas using restored river channels also has increased. Laterally flattened fish such as sunfishes and bass are important food items for anhingas in Florida (Frederick and Siegel-Causey, 2000); increased use of restored river channels by anhingas may signal increases in the availability of centrarchid prey. In contrast to the anhinga, the relative abundance of the common moorhen has declined following Phase I backfilling. Given the species' preference for slow- or non-moving waters, it is not surprising that it has declined with reestablishment of flow to restored river channels. Neither the great egret nor the white ibis have increased their use of river channels following restoration; with inundated floodplain wetlands available adjacent to river channels, it is possible that these two depth-limited foragers simply prefer that habitat over river channels.

Table 11-9. Percentage of total waterbird counts during river channel surveys represented by anhinga, common moorhen, great egret, and white ibis. The period 1996–1998 encompasses Baseline surveys, while 2001–2004 surveys occurred after Phase 1 backfilling.

Year	Anhinga		Common Moorhen		Great Egret		White Ibis	
	Pool C	Pool A	Pool C	Pool A	Pool C	Pool A	Pool C	Pool A
1996-97	5.42	7.69	33.43	52.91	8.80	1.41	2.08	1.23
1997-98	5.99	3.90	44.04	55.72	6.47	1.31	4.37	3.25
2001-02	15.13	1.53	12.47	57.45	5.41	0.00	5.21	0.00
2003-04	30.75	25.76	9.45	27.82	5.57	1.99	3.47	1.04

Quantifying shorebird responses to restoration via airboat surveys of river channels has proven to be problematic for two reasons. First, although shorebirds make extensive use of river channel habitats, especially sandbars, they also use and, in the case of some species, prefer shallow floodplain wetlands. Thus, river channel surveys alone are inadequate to document shorebird responses to restoration. Second, most shorebird species that are expected to use the restored river/floodplain system are small and cryptically colored. Species with these characteristics are often difficult to detect during airboat surveys. For these reasons, shorebird survey methods are being modified in 2005. The combination of current survey methods with casual observations has yielded insights into early responses of shorebirds to restoration, however. During the baseline period, only two species of shorebird were recorded; following the first backfilling phase, an additional eight species returned to the river/floodplain, including breeding black-necked stilts (**Table 11-10**).

Table 11-10. Species of shorebirds observed in Pool C during the baseline period and after Phase 1 backfilling.

Species	Baseline	After Backfilling
American Avocet	No	Yes
Black-necked Stilt	No	Yes
Common Snipe	Yes	Yes
Dowitcher sp.	No	Yes
Greater Yellowlegs	No	Yes
Killdeer	Yes	Yes
Least Sandpiper	No	Yes
Semi-palmated Plover	No	Yes
Spotted Sandpiper	No	Yes
Western Sandpiper	No	Yes

As a group, wading birds (excluding cattle egrets) have exhibited a strong numerical response to newly restored habitats on the Pool C floodplain (**Figure 11-27**). While annual densities of wading birds in Pool A have never exceeded 6 birds/km^2 during the years following Phase I backfilling, densities in restored areas have averaged 20 and 24 birds/km^2 during 2002 and 2003, respectively. Monthly densities of wading birds in the restored area have been as high as 57 birds/km^2 and have exceeded 20 birds/km^2 in 10 out of 21 post-Phase I surveys. The white ibis, which likely was the most common Kissimmee River wading bird species prior to channelization (Audubon Society, 1936–1987), had the highest counts in 12 out of 21 post-Phase I surveys. The primarily terrestrial cattle egret, which flourished after the majority of floodplain wetlands were converted to cattle pastures in the channelized system, has declined relative to aquatic wading birds on the restored floodplain. This species outnumbered all other wading bird species combined during baseline surveys, but averaged only 24 and 14 percent of total wading bird counts in 2001–2002 and 2003–2004, respectively.

Surveys conducted prior to channelization suggest that the floodplain of the Kissimmee River, especially wet prairies on the outer margins, supported large numbers and a high species richness of waterfowl (Audubon Society, 1936–1987; reviewed in Perrin et al., 1982). During eight years of winter waterfowl surveys in the 1950s, a minimum of 12 and as many as 18 species were documented each year (USFWS, 1959). Surveys conducted during 1978–1980 documented a 92-percent decrease in duck numbers following channelization (Perrin et al., 1982). During the baseline period, only five duck species were recorded and winter population estimates remained low, ranging from 0.7 ducks/km^2 in Pool A to 3.4 ducks/km^2 in the areas slated for restoration. Duck species richness in the restored area has doubled following restoration. The American wigeon, northern pintail, northern shoveler, ring-necked duck, and fulvous whistling duck were not seen during baseline surveys, but have been present following restoration. Winter densities of ducks in the restored area were 9.5 ducks/km^2 in 2001–2002, and 3.1 ducks/km^2 in 2003–2004; duck densities in Pool A during these years were 2.9 ducks/km^2 and 1.0 ducks/km^2, respectively.

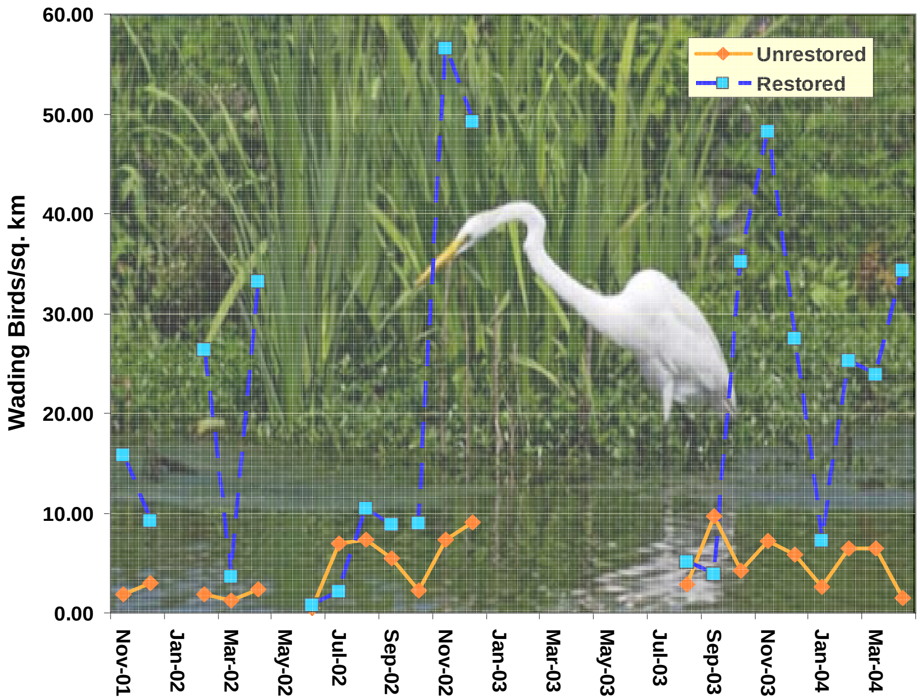

Figure 11-27. Densities of wading birds (excluding cattle egrets) using restored and unrestored portions of the Kissimmee River floodplain following Phase 1 backfilling.

Aquatic wading birds regularly formed rookeries on the historic Kissimmee River/floodplain and surrounding sloughs and wetlands (Audubon Society, 1936–1987). Reproductive effort declined following channelization and baseline surveys noted only two small colonies during three years. During 2003, a single rookery of cattle egrets (approximately 20 nests) formed on the restored floodplain, but no aquatic wading birds rookeries formed that year. No active colonies were found in Pools A–D during 2004 aerial surveys. A number of 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. Also, 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 2006 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 rookeries.

THREATENED AND ENDANGERED SPECIES

The pre-channelized Kissimmee River and floodplain provided habitat for a diverse assemblage of birds, including four species that are currently listed as threatened or endangered by the U.S. Fish & Wildlife Service. Of these species, three are wetland specialists (wood stork, endangered; snail kite, endangered; bald eagle, threatened), while the fourth, Audubon's crested caracara (threatened), utilizes a matrix of terrestrial and wetland habitats (Sykes et al., 1995; Morrison, 1996; Coulter et al., 1999; Buehler, 2000). Both wood storks and bald eagles are expected to benefit from the restoration project; densities of wood storks on the floodplain and number of bald eagle nesting territories in the vicinity of the river/floodplain are expected to increase. Conversely, current Audubon's crested caracara territories within the channelized floodplain may become less suitable with restoration. While snail kites may benefit from the restoration-related increases in floodplain wetlands, few data exist on the extent of their use of the pre-channelized system.

Bald eagles were once common breeders within the Lower Basin. While data on the pristine system are unavailable, the Lower Basin had an average of 23 active nesting territories during the 1962–1971 construction of the C38 canal (Shapiro et al., 1982). Post-channelization surveys conducted from 1976–1978 found that the number of Lower Basin nesting territories had decreased to an average of six territories per year (Shapiro et al., 1982). Although the Lower Basin contains numerous ponds, sloughs, and other potential foraging habitats outside the 100-year floodplain, the precipitous drop in eagle territories following channelization implies that most were at least partially dependent on the pre-channelized Kissimmee River/floodplain. The FWC has conducted annual, state wide nesting season surveys of bald eagles since 1973 (Nesbitt, 2002), and these data are the primary information source for evaluation of baseline and post-restoration nesting effort. During the baseline period, an average of three bald eagle pairs nested within or immediately adjacent to the 100-year floodplain, including one pair within the area designated for restoration**.** During the 2002–2003 nesting season, a new territory was established adjacent to the Phase I restoration area, bringing the total within the area designated for restoration to two. Further increases in eagle nesting territories within the restoration area will likely depend on dispersal of juvenile/displaced eagles from other areas and increases in available habitat following Phase II/III and Phase IV backfilling.

Wood stork densities on the floodplain are assessed using the aerial survey methodology described in the previous section. Monthly densities are tallied separately for restored and un-restored portions of the floodplain. Wood storks were apparently common in the pre-channelized system. Audubon wardens regularly documented large foraging flocks, as well as some nesting, along the river and floodplain (National Audubon Society, 1936–1987). Following channelization and the concomitant loss of wetlands, wood stork use of the floodplain was low. Toland (1990) reported densities of 0.2 storks/km^2 from 1987–1988 surveys, while baseline (1996–1998) densities were less than 0.1 storks/km^2. Toland (1990) also reported densities of 0.6 storks/km^2 in an area of partially restored marsh in Pool B that was used for the Kissimmee River Demonstration Project, suggesting that the species would respond positively to the restoration project. Following completion of Phase I, monthly wood stork densities on the Pool C floodplain have been quite variable, ranging from 0.0 to 6.2 birds/km^2 following restoration, with a mean density of 0.4. Wood storks are tactile foragers that require shallow, somewhat sparsely vegetated water with concentrated prey densities for foraging (Coulter et al., 1999). During periods of high water levels, the restored floodplain may be nearly uniformly inappropriate for foraging. During drying events, however, the numerous floodplain depressions and sloughs may provide excellent foraging conditions. Thus, the variability in wood stork numbers may simply reflect the species' ability to utilize appropriate foraging habitat on the floodplain, when available, or to search in other areas when this habitat is not readily available.

Audubon's crested caracara is a species that likely realized a net gain in available habitat in response to channelization. The Lower Basin falls within the heart of the species' range and the grassland/palm/wetland complex that replaced floodplain wetlands following channelization is typical of its preferred habitat (Morrison, 1996). While caracaras will forage in wetlands, the restoration project was likely to make the floodplain less suitable as caracara habitat according to the U.S. Fish and Wildlife's Biological Opinion (USFWS, 1991). This opinion went on to conclude that while the restoration project might affect individual caracaras, it would not jeopardize the continued existence of the species. During the baseline period, there were fifteen known caracara territories within the 100-year floodplain and successful nests produced an average of 2.1 young each (Morrison, 1998). Post-construction surveys of territories and reproductive output were conducted during 2001–2003 following completion of Phase I backfilling (Johnson Engineering, 2004). The post-construction surveys located birds on 12, 13, and 12 territories during 2001, 2002, and 2003, respectively. Successful nests fledged an average of 1.5 young each. In areas of restored floodplain, data suggested that pairs were shifting upland or moving out of the area, as predicted by the 1991 Biological Opinion. Caracara monitoring will continue prior to, during, and after each upcoming backfilling phase.

WATERSHED HYDROLOGY AND OPERATIONS

Hydrologic conditions within the Kissimmee watershed are a function of natural hydrologic inputs (e.g., rainfall) and management decisions. The watershed receives an average of approximately 50 inches of rainfall per year with most falling during a distinct wet season (SFWMD, 2000). Much of the surface water runoff from the watershed is conveyed through a network of canals that interconnects the KCOL and terminates with Lake Kissimmee. The outflow from Lake Kissimmee flows into the channelized Kissimmee River south to Lake Okeechobee (**Figure 11-1**). The movement of water through this network is regulated by thirteen water control structures managed by the SFWMD in accordance with regulations prescribed by the Secretary of the Army. Seven regulation schedules maintain lake and canal stages in the Kissimmee Chain of Lakes. Four schedules manage stages along the Kissimmee River. A fifth structure, S-65B, was demolished in 2000 as part of the restoration project.

Operation of structures is determined by a stage regulation schedule that specifies discharges that can be made through the structure depending on the headwater stage and time of year. The canals and structures are part of the C&SF Project that provides flood control and water supply to the region. The system also is operated to protect environmental values, especially ecological integrity in the Kissimmee River. Thus, hydrologic conditions in the Kissimmee watershed are a function of variable rainfall and management decisions that balance multiple needs.

During Water Year 2004 (WY2004) (May 1, 2003 – April 30, 2004), the observed lake stage tended to track the stage regulation schedule for most of the KCOL lakes, with two noteworthy exceptions (as further described below). First, unusually heavy rainfall during the summer 2003 raised lake stage above the regulation schedule in August and September 2003 for lakes Kissimmee, Hatchineha, and Cypress, which are regulated by the S-65 structure (**Figure 11-28**). Because lakes Kissimmee, Hatchineha, and Cypress were well above the stage regulation schedule and several tropical systems had the potential to cause even more rainfall, discharges through S-65 were increased to lower lake stage. Discharge at S-65 peaked at 279 m^3/s at the end of August 2003, which was one of the highest discharges measured at this location. As lake stage fell below the regulation schedule, the discharge was rapidly reduced to maintain some water

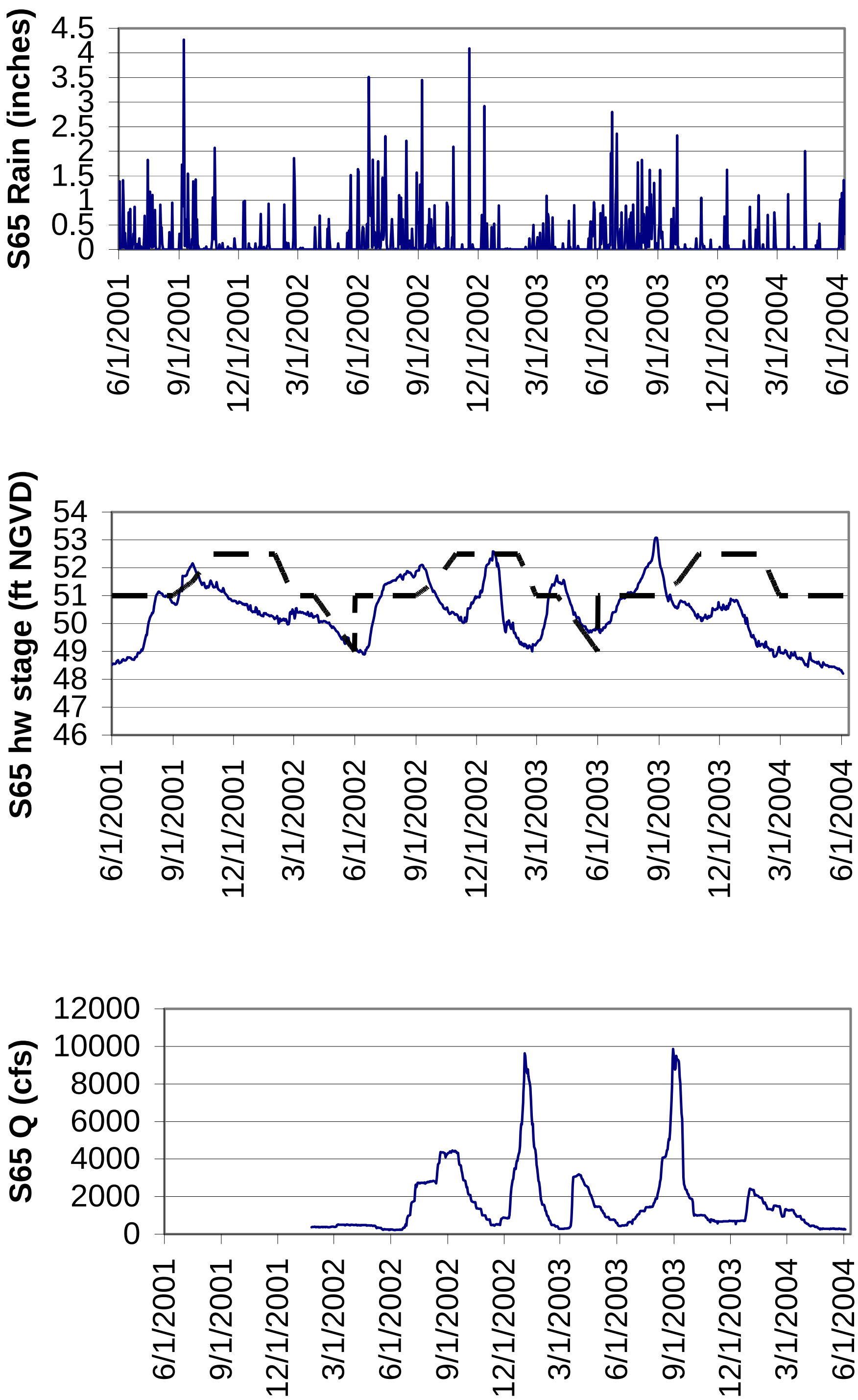

Figure 11-28. Rainfall, headwater stage (solid line) and interim stage regulation schedule (dashed line), and discharge at the S-65 outflow of Lake Kissimmee for WY2004.

storage within the lake. As discharge from Lake Kissimmee increased during this event, dissolved oxygen concentrations in the section of river channel restored during Phase I dropped to very low levels (< 1.0 milligrams per liter, or mg/L) throughout the channel for several weeks. While oxygen concentrations within the channel were low, concentrations along the outside edge of the floodplain were much higher (David Colangelo, SFWMD, unpublished data). Fish appeared to be using the floodplain as a refuge from hypoxic conditions in the river channel.

Second, the Florida Freshwater Fish and Wildlife Commission (FWC) requested a deviation to the stage regulation schedule for S-61 and S-65 to allow the extreme drawdown of Lake Tohopekaliga. The purpose of the drawdown is to allow the removal of both organic material that has accumulated on the bottom of the lake and floating plant tussocks from the littoral zone of the lake. The anticipated benefits of the project include enhancement of native aquatic vegetation, improved fish habitat, and improved recreational opportunities. The deviation modified the regulation schedule for S-61 to allow the stage in Lake Tohopekaliga to drop to 14.8 m NGVD and the schedule for S-65 to lower the stage in lakes Cypress, Hatchineha, and Kissimmee to 14.6 m NGVD by mid February 2003.

Following deviation approval, the drawdown schedule was modified to take into account a recent analysis of population data for the endangered snail kite (*Rostrhamus sociabilis*) that provided evidence for a recent, precipitous decline in total numbers and reproductive success and further indicated that Lakes Kissimmee and Toho currently function as key breeding areas for the species. Based on recommendations from a Snail Kite Issue Team, the FWC recommended that the schedule be altered to reach 14.94 m NGVD by March 1, 2003, and hold Lake Kissimmee at 14.87 ft NGVD. Delaying the drawdown by two weeks and keeping Lake Kissimmee stage higher was expected to lessen impacts on the Florida apple snail (*Pomacea paludosa*), which is a critical food item for the snail kite.

Discharge from Lake Tohopekaliga was increased in November 2003 to begin lowering lake stage for the drawdown. Discharge from Lake Kissimmee was increased in December 2003 to begin lowering the stage in lakes Kissimmee, Cypress, and Hatchineha. Approximately 62 hm^3 of water were diverted to storage on private, tribal, and public lands as an alternative to storage in Lake Okeechobee and to minimize downstream impacts. This estimate is slightly larger than the additional volume that was discharged for the extreme drawdown. Despite modifications to the schedule, the FWC was able to complete muck removal at nine out of eleven sites in the lake. Preliminary estimates indicate 6 million m3 of muck were either removed from lake or consolidated into spoil islands within the lake. Measures to protect apple snails in Lake Kissimmee appeared to be successful as well. By April 20, 2004, observations in Lake Kissimmee suggested that apple snails had been able to oviposit on emergent marsh plant stems still over water, and there was little evidence of stranding of snails (Duke Hammond, FWC, personal communication).

KISSIMMEE CHAIN OF LAKES LONG-TERM MANAGEMENT PLAN

The Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP) was initiated in April 2003 through a SFWMD Governing Board resolution (Resolution No. 2003-468). The purpose of this plan is to improve and sustain the ecosystem health of the regulated lakes in the KCOL while minimizing adverse impacts to downstream ecosystems. The SFWMD is the lead agency responsible for coordinating KCOL LTMP interagency activities and producing the plan. Other cooperating agencies include the Florida Fish and Wildlife Conservation Commission (FWC), Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), U.S. Environmental Protection Agency (USEPA), local governments and community leaders, and other stakeholders.

The KCOL LTMP is intended to pick up where the KRHRP leaves off. The KRHRP provides greater and more natural lake level fluctuations, expands the lake littoral zone habitat for fish and wildlife, and provides operational flexibility to incorporate management strategies to meet the needs of the river restoration project (USACE, 1996). The project only includes lakes Kissimmee, Hatchineha, Cypress and Tiger, however, and does not address lake level regulation in the 16 lakes north of Lake Cypress. Further, KRHRP does not consider requirements for treatment of hydrilla or lake habitat restoration and enhancement projects.

In the last year, multiple interagency meetings were convened to establish partnerships and build consensus among the federal and state agencies with mandated activities within the watershed. Two discrete work efforts have emerged from these meetings. The first is an effort to define and assess ecosystem health within the KCOL. The second, separate initiative will model and evaluate alternative water regulation schedules within the Kissimmee watershed. This second effort spans the entire watershed and will focus on how to regulate the KCOL and Kissimmee River in accordance with one another while meeting flood control, water supply, aquatic plant management, and natural resource operations objectives for these systems and Lake Okeechobee. The second initiative will be coordinated throughout the SFWMD to ensure the resulting regulation schedules consider the needs of a number of other activities including those associated with aquatic plant management, land management, and water supply planning (see the *Integrated Operations for the Kissimmee Watershed* section for additional details).

The primary purpose of the KCOL LTMP is to create a coordinated, multidisciplinary framework for addressing and resolving water management issues. As a starting point for KCOL LTMP development, water resource issues were identified through interagency meetings. These issues were later synthesized into five goals. The scope of these goals was constrained by the direction given in Resolution No. 2003-468, other mandates of the participating agencies, and planning and management activities already established or in progress. The five goals are as follows:

1. **Hydrologic management:** Manage water levels in the Kissimmee Chain of Lakes for flood protection, aquatic habitat enhancement, recreational use (navigation), water supply, aquatic weed control, and protection of downstream water resources

2. **Habitat preservation and enhancement:** Manage the Kissimmee Chain of Lakes and adjacent state lands to preserve and enhance habitat, maintain or restore fish and wildlife resources, maintain healthy sport fish populations, and protect threatened and endangered wildlife species

3. **Aquatic plant managemen**t: Control aquatic plants in the KCOL to maintain navigation, reduce risk of damage to in-lake structures, and improve aquatic habitat and ecological integrity

4. **Water quality improvement:** Achieve state water quality standards

5. **Recreation and public use:** Manage public lakes and state lands for multiple recreational purposes and maintain healthy fish and wildlife communities

The KCOL LTMP will develop performance measures that define ecosystem health and compile baseline conditions describing the current state of the ecosystem. The final document will identify unmet performance measures through the evaluation of baseline conditions. Additionally, the plan will identify where data and/or literature did not exist to establish either performance measures and/or baseline conditions for critical ecosystem functions. In addition, each participating agency will be asked to identify mandated activities that can be used to address conditions that do not meet performance measures. Agencies and their associated mandates will be identified as potential resources to address these issues. The KCOL LTMP will provide a definition of health, an assessment of status, and listed agency mandates that could potentially be used to address conditions that do not meet performance measures.

During the last year, major accomplishments include (1) identifying project goals and producing of a draft document outlining project goals and scope, (2) developing a conceptual lake ecosystem model, and (3) establishing guidelines for the development of performance measures.

INTEGRATED OPERATIONS FOR THE KISSIMMEE WATERSHED

The initiative to model and evaluate alternative water regulations within the Kissimmee watershed will develop interim and long-term operating plans for the Kissimmee watershed portion of the C&SF Project. These operating plans will be designed to meet flood control, water supply, aquatic plant management, and natural resource operations objectives while also preserving and/or enhancing the ecological values of the Kissimmee Chain of Lakes, Kissimmee River, and Lake Okeechobee. The interim plan will be constrained by water management infrastructure and land interests that will exist from 2007 through completion of the KRRP. The long-term plan will be constrained by future water management and land interests that will exist when KRRP construction is complete in 2012. The analyses and modeling performed in support of operations plan development will provide estimated water levels and flows for lands previously identified for the KRRP and provide the supporting water management information to allow operation of the C&SF system in accordance with the acquired land interests and the strategic goals of the SFWMD.

A surficial groundwater monitoring network is being established for the Lower Basin to characterize the surficial aquifer system. This initiative will enhance understanding of the behavior and mechanics of the regional hydrologic system and support development of an integrated groundwater-surface water model for the Kissimmee watershed. There is a general lack of information regarding the hydrogeologic properties on the unconfined surficial aquifer in the Lower Basin. Of specific interest is the base flow this aquifer provides to the river through floodplain tributaries. This work is being undertaken on a collaborative basis with the USACE as part of the KRRP. The USACE will perform the drilling, testing, and surveying of the new wells. The SFWMD will instrument, fence, and maintain the wells. Wells will be drilled along the floodplain edge and throughout the contributing watershed. Completion of the monitoring well network is expected by the end of FY2005.

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, dissolved oxygen, 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. Approximately 23 water bodies in the Kissimmee Basin are currently listed for TMDL development for several parameters including dissolved oxygen, nutrients, ionized ammonia, turbidity, mercury, cadmium, and others. The timeline for the TMDL development is 2005 through 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 Class III water quality standards. Class III is a designated use for waters, which means surface waters for recreation, 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 that are currently listed for TMDL development are expected to experience improvement in water quality due to reestablishment of natural filtration, reaeration, and biological processes.

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 Florida Department of Agriculture and Consumer Services (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 Kissimmee Basin is approximately $5 million. These BMPs are planned to be implemented beginning in 2009. (Additional details on the LOPP can be found in Chapter 10 of the 2005 SFER – Volume I and Chapter 3 of the 2005 SFER – Volume II).

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.

The KCOL LTMP will contribute significantly to development of a watershed plan for the region by providing a scientifically based, water quality management strategy for the Kissimmee Chain of Lakes. It will be important for addressing specific water quality needs that are not included in the LOPP or TMDL programs.

KISSIMMEE UPPER BASIN LOCAL GOVERNMENT PARTNERSHIPS

Much of the water flowing to the KCOL and Kissimmee River originates in four headwaters basins north of the KCOL. This area is one of the most rapidly urbanizing areas in Florida. The quality and quantity of water flowing through these basins influence the health of all downstream systems. The SFWMD works with local governments throughout the Kissimmee Upper Basin to fund water resource projects to improve water quality, water supply, natural resources and flood control levels of service. Over the past year the SFWMD Orlando Service Center has worked with Orange and Osceola counties to fund a number of stormwater master plan, improvement, and retrofit projects. It also has obtained state appropriations to fund environmental enhancement projects for Lake Tohopekaliga.

TRIBUTARY RESTORATION PROJECTS

Restoration of Packingham and Buttermilk Sloughs

The KICCO Wildlife Management Area (WMA) is an approximate 7,400-ac (3000-ha) property in Polk County. The property is managed by the Land Stewardship Division of the South Florida Water Management District 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 this project is to restore historical floodplain hydrology to Packingham and Buttermilk Sloughs.

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 both impoundments will depend upon the degree of flooding to the west, both on and off District-owned lands, and 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. Modeling is currently underway to determine backwater effects and placement of containment levees and water control structures.

Rolling Meadows Wetland Restoration

Rolling Meadows Ranch lies on the south shore of Lake Hatchineha (**Figure 11-1**). The 2,260-acre property was recently purchased by the District and the FDEP as part of the Kissimmee River Restoration Plan. 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, fed by water from Lake Hatchineha when lake stage exceeds a certain elevation and from Catfish Creek which historically entered Lake Hatchineha 2000 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 will likely 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 C37 by the USACE as part of the Kissimmee River Restoration Plan. 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. It is expected that additional land surveying will be completed in order to determine which alternative is most appropriate. The details of this restoration plan are still under development, but significant progress has been made by the District, FDEP and the Nature Conservancy through a Memorandum of Understanding with the FDEP.

CONCLUSIONS

Phase I of the KRRP was completed in February 2001, and involved filling approximately 7.5 mi (12 km) of the C-38 canal and demolishing the S-65B structure to reconnect 15 mi (24 km) of continuous river channel. Restoration of the channel form in this reach has allowed the intermittent inundation of approximately 12,000 ac (4,900 ha) of floodplain. Although the headwaters revitalization stage regulation schedule has not yet been implemented, the changes in channel form associated with construction and the implementation of an interim stage regulation schedule have significantly altered the physical habitat template to which other components of the ecosystem are beginning to respond. Where appropriate, these initial responses to Phase I of the project have been measured. These initial responses include the following:

- Maintenance of continuous flow for over three years in the reconnected river channel
- The replacement of organic/marl deposits on the river channel bed with sandy deposits
- An increase in the number of meander bends with active formation of point sand bars
- An increase in the mean concentration of dissolved oxygen from 1.2 to 3.3 mg/L during the wet season and from 3.3 to 6.1 mg/L during the dry season in the river channel
- A reduction in the mean width of littoral vegetation beds within reconnected river channels and a shift in vegetation communities from a slight dominance by floating/mat forming species to heavy dominance by emergent species
- Colonization by natural wetland vegetation of floodplain where the C-38 was filled and spoil mounds were degraded
- Colonization of mid-channel benthos by invertebrate species indicative of reestablished sand channel habitats and dominance of woody snag invertebrate communities by passive filter-feeding insects, which require flowing water
- Increased mean density of aquatic wading birds on the restored floodplain relative to control areas
- Decreased representation of cattle egrets relative to aquatic wading bird species on the restored floodplain
- Establishment of a new bald eagle nesting territory adjacent to the area of Phase I

The KCOL LTMP resulted from a Governing Board resolution and has the purpose of improving and sustaining lake ecosystem health in the Kissimmee Chain of Lakes. In the last year, a number of interagency meetings have taken place to establish partnerships and build consensus for this project. Major accomplishments during the last year include identifying project goals and producing of a draft document outlining the project goals and scope, developing a conceptual lake ecosystem model, and establishing guidelines for the development of performance measures.

LITERATURE CITED

Abtew, W., R.S. Huebner and S. Sunderland. 2002. Part I: Hydrologic Analysis of the 2000–2001 Drought in South Florida. South Florida Water Management District, West Palm Beach, FL.

Adams, M.J. 1999. Correlated Factors in Amphibian Decline: Exotic Species and Habitat Change in Western Washington. *Journal of Wildlife Management*, 63(4): 1162-1171.

Aho, J.M. and J.W. Terrell. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Redbreast Sunfish. *U. S. Fish Wildl. Serv. Biol. Rep.*, 82(10.119).

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.

Ashton, R.A., Jr. and P.S. Ashton. 1988. *Handbook of Reptiles and Amphibians of Florida. Part One: The Snakes*. Windward Publishing, Inc. Miami, FL.

Auffenberg, W. 1981. Florida Environments and their Herpetofaunas. Part I: Environmental Characteristics. *Florida Herpetologist*, 2: 1-36.

Azevedo-Ramos, C., W.E. Magnusson and P. Bayliss. 1999. Predation as the Key Factor Structuring Tadpole Assemblages in a Savanna Area in Central Amazonia. *Copeia*, 1: 22-33.

Bartlett, R.D. and P.P. Bartlett. 1999. *A Field Guide to Florida Reptiles and Amphibians*. Gulf Publishing Company. Houston, TX.

Bash, J.S., and C.M. Ryan. 2002. Stream Restoration and Enhancement Projects: Is Anyone Monitoring. *Environmental Management*, 29: 877-885.

Bass, D.G., Jr. 1991. Riverine Fishes of Florida. R.J. Livingston, ed. pp. 65-83. In: *The Rivers of Florida*. Springer-Verlag, New York, NY.

Beissinger, S.R. 1990. Alternative Foods of a Diet Specialist, the Snail Kite. *The Auk*, 107: 327-333.

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.

Benke, A.C., T.C. Van Arsdall, Jr., D.M. Gillespie and F.K. Parrish. 1984. Invertebrate Productivity in a Subtropical Blackwater River: The Importance of Habitat and Life History. *Ecological Monographs*, 54: 25-63.

Benke, A.C., R.J. Hunter and F.K. Parrish. 1986. Invertebrate Drift Dynamics in a Subtropical Blackwater River. *Journal of the North American Benthological Society*, 5: 173-190.

Benke, A.C., K.A. Parsons and S.M. Dhar. 1991. Population and community patterns of invertebrate drift in an unregulated Coastal Plain river. *Canadian Journal of Fisheries and Aquatic Sciences*, 48: 811-823.

Benke, A.C., J.B. Wallace, J.W. Harrison and J.W. Koebel. 2001. Food Web Quantification Using Secondary Production Analysis: Predaceous Invertebrates of the Snag Habitat in a Subtropical River. *Freshwater Biology*, 46: 329-346.

Blaustein, A.R. and D.B. Wake. 1990. Declining Amphibian Populations. A Global Phenomenon? *Trends in Ecological Evolution*, 5: 203-204.

Bodie, J.R. and R.D. Semlitsch. 2000. Spatial and Temporal Use of Floodplain Habitats by Lentic and Lotic Species of Aquatic Turtles. *Oecologia*, 122: 138-148.

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

Buehler, D.A. 2000. Bald Eagle. A. Poole and F. Gill, eds. In: *The Birds or North America, No. 506*. The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Carlander, K.D. 1977. *Handbook of Freshwater Fishery Biology, Volume 2*. Iowa State University Press, Ames, IO.

Carpenter, S.R. 1998. The Need for Large-Scale Experiments to Assess and Predict the Response of Ecosystems to Perturbation. pp. 287-312 M.L. Pace and P.M. Groffman, eds. In: *Successes, Limitations, and Frontiers in Ecosystem Science*. Springer-Verlag, New York. NY.

Carr, Jr., A.F. 1940. A Contribution to the Herpetology of Florida. University of Florida Publication. Volume 3. No. 1.

Carr, A. and C.J. Goin. 1955. Guide to the Reptiles, Amphibians, and Freshwater Fishes of Florida. University of Florida Press. Gainesville, FL.

Champeau, T.R. 1990. Icthyofaunal Evaluation of the Peace River, Florida. *Fla. Sci.*, 53(4): 302-311.

Colangelo, D.J. and B.L. Jones. 2004. Phase I of the Kissimmee River Restoration Project, Florida, USA: Impacts of Construction on Water Quality. *Environmental Monitoring and Assessment*, In press.

Collopy, M.W. and H.L. Jelks. 1989. Distribution of Foraging Wading Birds in Relation to the Biological Characteristics of Freshwater Wetlands in Southwest Florida. Florida Game and Fresh Water Fish Commission. Nongame Wildlife Program Final Report. 120 pp.

Conant, R. and J.T. Collins. 1991. *A Field Guide to Reptiles and Amphibians – Eastern and Central North America*. Houghton Mifflin Company. New York, NY.

Coulter, M.C., Rodgers, J.A., Ogden, J.C. and F.C. Depkin. 1999. Wood Stork. A. Poole and F. Gill, eds. In: *The Birds or North America, No. 409.* The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Cowell, B.C. and W.C. Carew. 1976. Seasonal and Diel Periodicity in the Drift of Aquatic Insects in a Subtropical Florida Stream. *Freshwater Biology*, 6: 587-594.

Daubenmire, R. 1959. A Canopy Coverage Method of Vegetational Analysis. *Northwest Science*, 33: 42-64.

Davis, J.C. 1975. Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review. *J. Fish. Res. Board. Can.,* 32(12): 2295-2332.

Dawson, F.H. 1988. Water Flow and the Vegetation of Running Waters. J.J. Symoens, ed. pp. 283-309. In: *Vegetation of Inland Waters*. Kluwer Academic Publishers, New York, NY.

DellaSala, D. A., A. Martin, R. Spivak, T. Schulke, B. Bird, M. Criley, C. van Daalen, J. Kreilick, R. Brown and G. Aplet. 2003. A Citizen's Call for Ecological Forest Restoration: Forest Restoration Principles and Criteria. *Ecological Restoration*, 21: 14-23.

Estevez, E.D., L.K. Dixon and M.S. Flannery. 1991. West-Coastal Rivers of Peninsular Florida. R.J. Livingston, ed. pp. 187-221. In: *The Rivers of Florida*. Springer-Verlag, New York, NY.

Franz, R., D. Maehr, A. Kinlaw, C. O'Brien and R.D. Owen. 2000. Amphibians and Reptiles of the Bombing Range Ridge, Avon Park Air Force Range, Highlands and Polk Counties, Florida. Florida Museum of Natural History. Gainesville, FL.

Frederick, P.C. and D. Siegel-Causey. 2000. Anhinga (*Anhinga anhinga*). A. Poole and F. Gill, eds. In: *The Birds or North America, No. 522*. The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Furse, J.B., L.J. Davis and L.A. Bull. 1996. Habitat Use and Movements of Largemouth Bass Associated with Changes in Dissolved Oxygen and Hydrology in Kissimmee River, Florida. *Proc. Ann. Conf. Southeast. Assoc Fish and Wildl. Agencies*, 50: 12-25.

Gammon, J.R. and T.P. Simon. 2000. Variation in a Great River Index of Biotic Integrity over a 20-Year Period. *Hydrobiologia*, 422-423: 291-304.

Gent, R., J. Pitlo, Jr. and T. Boland. 1995. Largemouth Bass Response to Habitat and Water Quality Rehabilitation in a Backwater of the Upper Mississippi River. *North American Journal of Fisheries Management*, 15: 784-793.

Gerking, S.D. 1994. *Feeding Ecology of Fish*. Academic Press, New York, NY.

Gilbert, C.R. 1987. Zoogeography of the Freshwater Fish Sauna of Southern Georgia and Peninsular Florida. *Brimleyana*, 13: 25-54.

Guillory, V. 1979. Utilization of an Inundated Floodplain by Mississippi River Fishes. *Florida Scientist*, 42(4): 222-228.

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.

Johnson Engineering, Inc. 2004. Post-Restoration Monitoring of Audubon's Crested Caracara within the Kissimmee River Restoration Project Area. Final Report to South Florida Water Management District, West Palm Beach, FL.

Jordan, F., H.L. Jelks and W.M. Kitchens. 1997. Habitat Structure and Plant Community Composition in a Northern Everglades Wetland. *Wetlands*, 17: 275-283.

Jordan, F., S. Coyne and J.C. Trexler. 1999. Fish and Macroinvertebrate Population Studies in the Water Conservation Areas. Final Report (Contract No. C-E6636) submitted to South Florida Water Management District, West Palm Beach, FL.

Karr, J.R. 1991. Biological Integrity: A Long-Neglected Aspect of Water Resource Management. *Ecological Applications*, 1: 66-84.

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

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant and I.J. Schlosser. 1986. Assessing Biological Integrity in Running Waters: A Method and its Rationale. Illinois Natural History Survey Special Publication 5. 28 pp.

Karr, J.R., H. Stephen, A.C. Benke, R.E. Sparks, M.W. Weller, J.V. McArthur and J.H. Zar. 1991. Design of a Restoration Evaluation Program. Report by the American Fisheries Society, Bethesda, MD submitted to the South Florida Water Management District, West Palm Beach, FL.

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.

Kushlan, J.A. 1976. Environmental Stability and Fish Community Diversity. *Ecology*, 57: 821-825.

Lee, D.S., C.R. Carter, C.H. Hocutt, R.E. Jenkins, D.E. McAllister and J.R. Staufffer, Jr. 1980. Atlas of North American Fishes. Publication No. 1980-12 North Carolina Biological Survey. pp. 1-867.

Livingston, R.J. 1991. The Oklawaha River. R.J. Livingston, ed. pp. 85-95. In: *The Rivers of Florida*. Springer-Verlag, New York, NY.

Livingston, R.J. and E.A. Fernald. 1991. Chapter 1: Introduction. R.J. Livingston, ed. pp. 1-15. In: *The River of Florida*. Springer-Verlag, New York, NY.

Loftus, W.F. and A.M. Ekland. 1994. Long-Term Dynamics of an Everglades Small-Fish Assemblage. S.M. Davis and J.C. Ogden, eds. pp. 461-483 In: *Everglades: The Ecosystem and its Restoration*. St. Lucie Press, Delray Beach, FL.

Lowe, R.L. 1974. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. *Environ. Monit. Ser.*, 670/4-74-005.

Matthews, W.J. 1998. *Patterns in Freshwater Fish Ecology*. Chapman and Hall, London, England.

Merritt, R.W., K.W. Cummins and T.M. Burton. 1984. The Role of Aquatic Insects in the Processing and Cycling of Nutrients. V.H. Resh and D.M. Rosenberg, eds. pp. 134-163. In: *The Ecology of Aquatic Insects*. Praeger Publishers, New York, NY.

Mason, W.T., Jr., R.A. Mattson and J.H. Epler. 1994. Benthic Invertebrates and Allied Macrofauna in the Suwannee River and Estuary Ecosystem, Florida. *Florida Scientist*, 57: 141-160.

Mettee, M.F., P.E. O'Neil and J.M. Pierson. 1996. *Fishes of Alabama*. Oxmoor House, Birmingham, AL.

Milleson, J.F., R.L. Goodrick and J.A. Van Arman. 1980. Plant Communities of the Kissimmee River Valley. Technical Publication 80-7. South Florida Water Management District, West Palm Beach, FL.

Morin, P.J. 1983. Predation, Competition, and the Composition of Larval Amphibian Guilds. *Ecological Monographs*, 53: 119-138.

Morrison, J.L. 1996. Crested Caracara (*Caracara plancus*). A. Poole and F. Gill, eds. In: *The Birds of North America, No. 249.* The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Morrison, J.L. 1998. Baseline Data on Audubon's Crested Caracara in the Kissimmee River Restoration Project Area. Unpublished Final Report to the South Florida Water Management District, West Palm Beach, FL.

Moss, D.D. and D.C. Scott. 1961. Dissolved Oxygen Requirements of Three Species of Fish. *Trans. Am. Fish. Soc.*, 90(4): 377-393.

Mount, R.H. 1975. The Reptiles and Amphibians of Alabama. Agricultural Experiment Station. Auburn University. Auburn, AL.

National Audubon Society. 1936–1987. Audubon Warden Field Reports. National Audubon Society, Tavernier, FL.

NRC. 1992. Restoration of Aquatic Ecosystems. National Research Council. National Academy Press, Washington, D.C.

Nesbitt, S.A. 2002. Bald Eagle Population Monitoring: Annual Study Progress Report. Florida Fish and Wildlife Conservation Commission, Gainesville, FL.

Obeysekera, J. and K. Loftin. 1990. Hydrology of the Kissimmee River Basin – influence of man-made and natural changes. K. Loftin, L. Toth, and J. Obeysekera, eds. pp. 211-222. In: *Kissimmee River Restoration Symposium*. South Florida Water Management District, West Palm Beach, FL.

Odum, H.T. 1953. Dissolved Phosphorus in Florida Waters. pp. 1-40 In: *Report of Investigations, No. 9: Miscellaneous Studies*. Florida Geological Survey, Tallahassee, FL.

Ogden, J.C., J.A. Kushlan and J.T. Tilmant. 1976. Prey Selectivity by the Wood Stork. *Condor,* 78: 324-330.

Ohio EPA. 1987. Biological Criteria for the Protection of Aquatic Life, Volume II. Ohio Environmental Protection Agency, Columbus, OH.

Pechmann, J.H.K., D.E. Scott, J.W. Gibbons and R.D. Semlitsch. 1989. Influence of Wetland Hydroperiod on Diversity and Abundance of Metamorphosing Juvenile Amphibians. *Wetlands Ecology and Management*, 1: 3-11.

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.

Pierce, G.J., A.B. Amerson and L.R. Becker Jr. 1982. Pre-1960 Floodplain Vegetation of the Lower Kissimmee River Valley, Florida. Biological Services Report 82-3. Final Report prepared by Environ. Consult., Inc. Dallas, TX.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA-444/4-89/001. U.S. Environmental Protection Agency, Washington, D.C.

Rosenberg, D.M. and V.H. Resh (eds.). 1993. *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, New York, NY.

Roth, A.H. and J.F. Jackson. 1987. The Effect of Pool Size on Recruitment of Predatory Insects and on Mortality in Larval Anurans. *Herpetologica*, 43: 224-232.

SFWMD. 2000. Kissimmee Basin Water Supply Plan. South Florida Water Management District, West Palm Beach, 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. Florida Forever Work Plan 2004 Annual Update. South Florida Water Management District, West Palm Beach, FL.

Shapiro, A.E., F. Montalbano, III and D. Mager. 1982. Implications of Construction of a Flood Control Project upon Bald Eagle Nesting Activity. L.S. Perrin, M.J. Allen, L.A. Rowse, F. Montalbano, III, K.J. Foote and M.W. Olinde, eds. pp. 106-118. In: *A Report on Fish and Wildlife Studies in the Kissimmee River Basin and Recommendations for Restoration.* Florida Game and Freshwater Fish Commission, Okeechobee, FL.

Skelly, D.K. 1997. Tadpole Communities. *American Scientist*, 85: 36-45.

Smale, M.A. and C.F. Rabeni. 1995. Hypoxia and Hyperthermia Tolerances of Headwater Stream Fishes. *Trans. Am. Fish. Soc.*, 124: 698-710.

Smock, L.A., E. Gilinsky and D.L. Stoneburner. 1985. Macroinvertebrate Production in a Southeastern United States Blackwater Stream. *Ecology*, 66: 1491-1503.

Stebbins, R.C. and N.W. Cohen. 1995. *A Natural History of Amphibians*. Princeton University Press. Princeton, NJ.

Stevenson, R.J., M.L. Blothwell and R.L. Lowe. 1996. *Algal Ecology: Freshwater Benthic Ecosystems*. Academic Press, San Diego, CA.

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

Stites, D.L. 1986. Secondary Production and Productivity in the Sediments of Blackwater River. Ph.D. Dissertation. Emory University, Atlanta, GA.

Stites, D.L. and A.C. Benke. 1989. Rapid Growth Rates of Chironomids in Three Habitats of a Subtropical Blackwater River and their Implications for P:B Ratios. *Limnology and Oceanography*, 34: 1278-1289.

Struber, R.J., G. Gebhart and O.E. Maughan. 1982. Habitat Suitability Index Models: Bluegill. U.S. Department of the Interior, U.S. Fish and Wildlife Service. FWS/OBS-82/10.8.

Swift, C.C., C.R. Gilbert, S.A. Bortone, G.H. Burgess and R.W. Yerger. 1986. Zoogeography of the Freshwater Fishes of the Southeastern United States: Savannah River to Lake Pontchartrain. pp. 213-266. In: *The Zoogeography of North America Freshwater Fishes*. Wiley & Sons, New York, NY.

Sykes, P.W., Jr., J. A. Rodgers, Jr. and R. E. Bennetts. 1995. Snail Kite. A. Poole and F. Gill, eds. In: *The Birds of North America, No. 171* The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Tennant, A. 1997. *A Field Guide to Snakes of Florida*. Gulf Publishing Company. Houston, TX.

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

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

Toth, L.A. 1990b. An Ecosystem Approach to Kissimmee River Restoration. pp. 125-133. M.K. Loftin, L. Toth and J. 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.

Travis, J., H.W. Keen and J. Julianna. 1985. The Role of Relative Body Size in a Predator-Prey Relationship between Dragonfly Naiads and Larval Anurans. *Oikos*, 45: 59-65.

Trexler, J.C., W.F. Loftus, C.F. Jordan, J.H. Chick, K.L. Kandl and O.L. Bass. In press. Ecological Scale and its Implications for Freshwater Fishes in the Florida Everglades. J.W. Porter and K. G. Porter, eds. In: *Linkages Between Ecosystems in the South Florida Hydroscape*. CRC Press.

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

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL.

USEPA. 1977. Interagency 316a Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impacts Statements. U. S. Environmental Protection Agency, Washington, D. C.

USFWS. 1959. A detailed report of the fish and wildlife resources in relation to the Corps of Engineers' plan of development, Kissimmee River Basin, Florida. Appendix A 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.

USFWS. 1991. Kissimmee River Restoration Project: Fish and Wildlife Coordination Act Report. Annex E in Final Integrated Feasibility Report and Environmental Impact Statement, Environmental Restoration, Kissimmee River, Florida. U.S. Army Corps of Engineers, Jacksonville, FL.

Wallace, J.B. and J.R. Webster. 1996. The Role of Macroinvertebrates in Stream Ecosystem Function. *Annual Review of Entomology*, 41: 115-139.

Welcomme, R.L. 1979. *Fisheries Ecology of Floodplain Rivers*. Longman Group Limited. London, England.

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.

Wilbur, H.M., J.P. Morin and R.N. Harris. 1983. Salamander Predation and the Structure of Experimental Communities: Anuran Responses. *Ecology*, 64: 1423-1429.

Zug, G.R., Vitt, L.J., and J.P. Caldwell. 2001. *Herpetology*. Academic Press, New York, NY.