Chapter 9: Kissimmee River Restoration and Basin Initiatives

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SUMMARY

The South Florida Water Management District (SFWMD or District) continues to coordinate with the United States Army Corps of Engineers (USACE) on the Kissimmee River Restoration Project (KRRP). In addition, the SFWMD is integrating the KRRP with management activities throughout the Kissimmee Basin and the Northern Everglades region. The primary goals of these efforts are to (1) restore ecological integrity to the Kissimmee River and its floodplain, (2) collect ecological data to evaluate river restoration and support water management decision making, (3) enhance and sustain natural resource values in the Kissimmee Chain of Lakes (KCOL), and (4) retain the flood reduction benefits of the Central and Southern Florida Flood Control Project (C&SF Project) in the Kissimmee Basin. In addition to projects under the KRRP, the SFWMD also manages the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project.

The KRRP's goal of restoring ecological integrity to approximately one-third of the river and its floodplain depends largely on reestablishing the physical form of the river–floodplain system (i.e., the physical habitat template) and then applying hydrologic conditions similar to those that existed before the river was channelized in the 1960s. Achieving these conditions involves acquiring more than 102,000 acres of land in the river's floodplain and headwaters, backfilling 22 miles of the C-38 flood control canal, reconnecting remnant sections of the original river channel, removing two water control structures, and modifying portions of the river's headwaters to meet hydrologic criteria for river restoration. The first three construction phases of restoration, completed between 2001 and 2009, have reestablished flow to 24 miles of river channel and allowed intermittent inundation of 7,710 acres of floodplain. Work on remaining restoration construction (backfilling of C-38) for Phases II and III was on hold in Water Year 2014 (WY2014) (May 1, 2013–April 30, 2014) due to real estate and cost crediting issues, although construction on non-backfill contracts continued. However, all remaining land acquisition in the Lower Kissimmee Basin has either been completed or will be complete by the end of 2014, cost credit issues have been resolved, and a decision was made to implement the authorized Headwaters Revitalization Schedule (HRS) upon completion of KRRP. As a result of these successes, the USACE has accelerated the KRRP construction schedule; the new projected completion date for KRRP is January 2019.

The KRRP's success is being evaluated through the Kissimmee River Restoration Evaluation Program (KRREP). Evaluation of restoration success was recognized as a crucial aspect of the project in the Final Integrated Feasibility Report and Environmental Impact Statement for the

Restoration of the Kissimmee River, Florida (USACE, 1991) and was identified as a SFWMD responsibility in its cost-share agreement with the USACE (Department of the Army and SFWMD, 1994). Success is being tracked, in part, using 25 performance measures to evaluate how well the project meets its ecological integrity goal. Targets for these performance measures, called restoration expectations, are based on reference conditions derived from information on the pre-channelized river or similar systems. A final evaluation of KRRP success will follow completion of all project components. Many of the restoration expectations, particularly those related to floodplain responses, depend on the removal of water control structure S-65C during upcoming phases of restoration construction and implementation of a new HRS after construction is complete. This regulation schedule will allow additional storage capacity in the headwater lakes, thereby allowing more flexible operations that can more closely approximate the prechannelized river's flow regime, including discharges with more natural timing, magnitude, and rates of change, and is anticipated to drive the expected biological and physical changes in the system.

This year's update on KRREP evaluations includes analyses of newly available data from studies of hydrology, dissolved oxygen (DO), nutrients, floodplain vegetation, herpetefauna, wading birds, and waterfowl. This subset of restoration evaluation studies assesses the level of response of critical ecosystem components to physical restoration under the interim hydrologic conditions that are currently in place. Results from these studies provide information for sound water management decision making as the KRRP progresses and for guiding water management after the project is complete. Key WY2014 highlights of this chapter include the following:

- **Hydrologic conditions.** The Kissimmee Basin had above average rainfall in WY2014; the upper and lower basins were above average by 4.8 inches and 8.6 inches, respectively. Discharge from the upper basin to the Kissimmee River was increased to limit the rise in lake stage and reached a maximum in late July of 6,500 cubic feet per second at S-65. Increases in discharge in early June were associated with decreases in the concentration of DO in the Kissimmee River. DO decreased below 2 milligrams per liter (mg/L), beginning an hypoxic event, as has happened every year since completion of backfilling for Phase I of the restoration project. The WY2014 event lasted for 73 days, during which DO decreased to less than 0.5 mg/L. The onset of the hypoxic event was associated with a fish kill.
- **River channel hydrology.** Flow was effectively continuous (Expectation 1) in the Phase I area throughout WY2014, as it has been in 10 of the last 13 years of the interim period; however, the target of being achieved in all years is not being met. The expected seasonal flow pattern (Expectation 2) was not achieved in WY2014. Neither the maximum nor the minimum of mean monthly discharge occurred in the target window, and the target window for maximum discharge had almost the lowest value of mean monthly discharge. Over the entire interim period, neither the maximum nor the minimum of mean monthly discharge is being met at reference period target frequencies.
- **Floodplain hydrology.** Floodplain stage met the amplitude of stage fluctuation and hydroperiod components of Expectation 3 at only two sites in WY2014; over the interim period, these components are being met less often than in the reference period. A new criterion was introduced in WY2014 which describes the hydroperiod and depth requirements of broadleaf marsh (BLM), the dominant and most characteristic wetland plant community of the pre-channelization floodplain. The BLM Criterion specifies water depth greater than or equal to 0.3 meters for at least 210 days per water year. It was met in WY2014 only at sites in the southern floodplain, which are influenced by the backwater effect of S-65C; northern floodplain sites did not meet the BLM Criterion in WY2014 and have only rarely met

it in the interim period. In WY2014; two floodplain monitoring sites had multiple recession events (Expectation 4), and only two sites had events that met the duration (greater than 173 days duration) and recession rate (less than or equal to 0.3 meters per 30 days) criteria. On average, the duration and recession rate criteria for this expectation are being met less often in the interim period than during the reference period. Therefore, this expectation is not being met in the interim period.

- **Dissolved oxygen.** Concentrations of DO in the river channel of the Phase I restoration area continued to be higher than pre-restoration levels. Of the three metrics used to evaluate DO response in WY2014, one was met. Mean DO concentrations fell just short of the wet season (June–October) target range but exceeded the dry season (December–May) target range in WY2014. The third metric, frequency of concentrations greater than 2.0 mg/L, fell 10 percent short of its 90 percent target; this reflects periods of anoxic conditions in the river channel that are likely impacting recovery of fish populations (see the *Hypoxia in the Kissimmee River: Consequences, Causes, and Water Management* section for additional information on DO sags). The final determination of restoration success with respect to DO will be made after the restoration project is completed.
- **Nutrient loads and concentrations.** Relative to the 13 years since Phase I construction was completed, nutrient loads at C-38 structures in WY2014 were near-average. However, total phosphorus (TP) loads and concentrations have been significantly higher during the post-Phase I period at S-65, S-65A, S-65C, and S-65D in comparison to a pre-construction baseline period (WY1975–WY1995). Total nitrogen loads and concentrations did not increase. Higher TP concentrations at S-65 appear to be responsible for the increased TP at the lower structures. These increases are not due to higher concentrations in Lake Kissimmee, which did not increase significantly between the two periods. Instead, local watershed runoff into the extreme south end of the lake appears to be influencing TP at S-65.
- **Floodplain vegetation.** A vegetation map of the Phase I construction area, based on 2011 aerial imagery, was completed and compared to previous maps dating back to 1952. Total wetland plant coverage has remained steady in the Phase I floodplain area between 2008 and 2011. Beyond small changes in abundance of different wetland classes, the biggest change was an increase in the Miscellaneous Wetland vegetation type in the central Phase I floodplain. Broadleaf and Buttonbush Marsh and Wetland Shrub vegetation increased slightly between the two maps, while Wet Prairie vegetation declined by almost 10 percent.
- **Wading bird nesting.** Ten previously undocumented wading bird colonies were located this season as the result of an expanded survey effort. The total number of nests this season was slightly above the long-term average due to increased white ibis nesting on Lake Mary Jane and nests observed at the newly detected colonies. All colonies this season were dominated by aquatic species as of late May, with the exception of Bumblebee Island (Lake Istokpoga), which was dominated by cattle egrets. Most nesting of both aquatic wading bird species and cattle egrets continued to occur on islands in the KCOL and Lake Istokpoga, with the largest colony forming on Lake Mary Jane. The lack of significant colonies of aquatic wading birds near the Kissimmee River restoration area suggests that prey availability on the floodplain is not yet sufficient to support the completion of breeding. Hydrologic conditions more suitable for foraging and nesting are expected when the restoration project is finished.
- **Wading bird abundance.** Since 2001, the abundance of foraging wading birds within the restored portions of the river has met the restoration expectation in all but two years. Although mean monthly abundance during the 2013–2014 season was

lower than the previous season, the three-year running average remained above the restoration target. Wading bird numbers were below the long-term monthly means during five of the six months surveyed. Bird use fluctuated as water levels on the floodplain rose and receded following three significant water level reversals.

- **Waterfowl abundance.** Waterfowl abundance has consistently exceeded the restoration expectation since 2001. Although waterfowl abundance during 2013–2014 was lower than the previous season, the three-year running average stayed well above the restoration target. Waterfowl numbers were below the long-term monthly means during three of the five months surveyed. The restoration target for waterfowl species richness has not yet been reached.

As part of the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project, water and nutrient budgets were developed for East Lake Tohopekaliga and Lake Tohopekaliga. These budgets indicated that minor tributaries contributed a significant amount of flow and load. To evaluate these contributions, the Watershed Assessment Model (WAM), a component of the PN-Budget tool (JGH Engineering, 2013), was used to estimate flow and loads from both major and minor tributaries as part of a land use-based nutrient budget study. WAM is a process-based model that can be used to perform hydrological and water quality analysis based on land use, soil, weather, and land management conditions (SWET, 2011a). The estimates generated by WAM were similar to estimates from water and nutrient budget analysis for total flow for both lakes and TP loads for Lake Tohopekaliga. Future efforts to measure flow at some key minor tributaries should improve these estimates.

INTRODUCTION

The Kissimmee Basin includes more than two dozen lakes in the Kissimmee Chain of Lakes (KCOL), their tributary streams and associated marshes, and the Kissimmee River and floodplain (**Figures 9-1** and **9-2**). The basin forms the headwaters of Lake Okeechobee and the Everglades; together they comprise the Kissimmee–Okeechobee–Everglades system. In the 1960s, the Central and Southern Florida Flood Control Project (C&SF Project) modified the Kissimmee Basin's water resources extensively by constructing canals and installing water control structures to achieve flood control. In the Lower Kissimmee Basin, construction of a 56-mile-long canal through the Kissimmee River resulted in profound ecological consequences caused by elimination of flow in the original river channel and prevention of seasonal floodplain inundation. In the Upper Kissimmee Basin, C&SF Project modifications did not allow lake stages to rise as high or drop as low as they did when they were unregulated. The reduced ranges of fluctuation altered or eliminated much of the formerly extensive littoral zones around the lakes and the marshes between them. These and other environmental losses led to legislation authorizing the federal–state Kissimmee River Restoration Project (KRRP). The South Florida Water Management District (SFWMD or District) has been working since the 1990s to coordinate and evaluate the KRRP, which is being done through the Kissimmee River Restoration Evaluation Program (KRREP).

The KRRP is integrated with other management activities in the Kissimmee Basin and the Northern Everglades region. The primary goals of these efforts are to (1) restore ecological integrity to the Kissimmee River and its floodplain, (2) collect ecological data to evaluate river restoration and support management decision making, (3) enhance and sustain natural resource values in the KCOL, and (4) retain the C&SF Project's flood reduction benefits in the Kissimmee Basin. The geographic scopes of projects in the Kissimmee Basin are shown in **Figure 9-3**. Other ongoing activities of regional importance, such as water reservation development, water management operations, nutrient control efforts, and invasive species management, have been discussed in detail in Chapter 11 of the *2010* and *2011 South Florida Environmental Reports* (SFER) – *Volume I* (Jones et al., 2010, 2011).

This chapter is an update to Chapter 9 of the 2014 SFER – Volume I (Jones et al., 2014). It focuses on progress of Kissimmee Basin projects during Water Year 2014 (WY2014) (May 1, 2013–April 30, 2014). The chapter also summarizes hydrologic conditions during WY2014 and presents newly available data from the evaluation of the river restoration project and water and phosphorus budgets from certain lakes in the KCOL. Detailed studies examining a suite of ecological responses to Phase I of restoration can be found in a recent special edition of the international journal Restoration Ecology dedicated solely to the KRRP (see the *Kissimmee River Restoration Project Special Section Published in May 2014* section below).

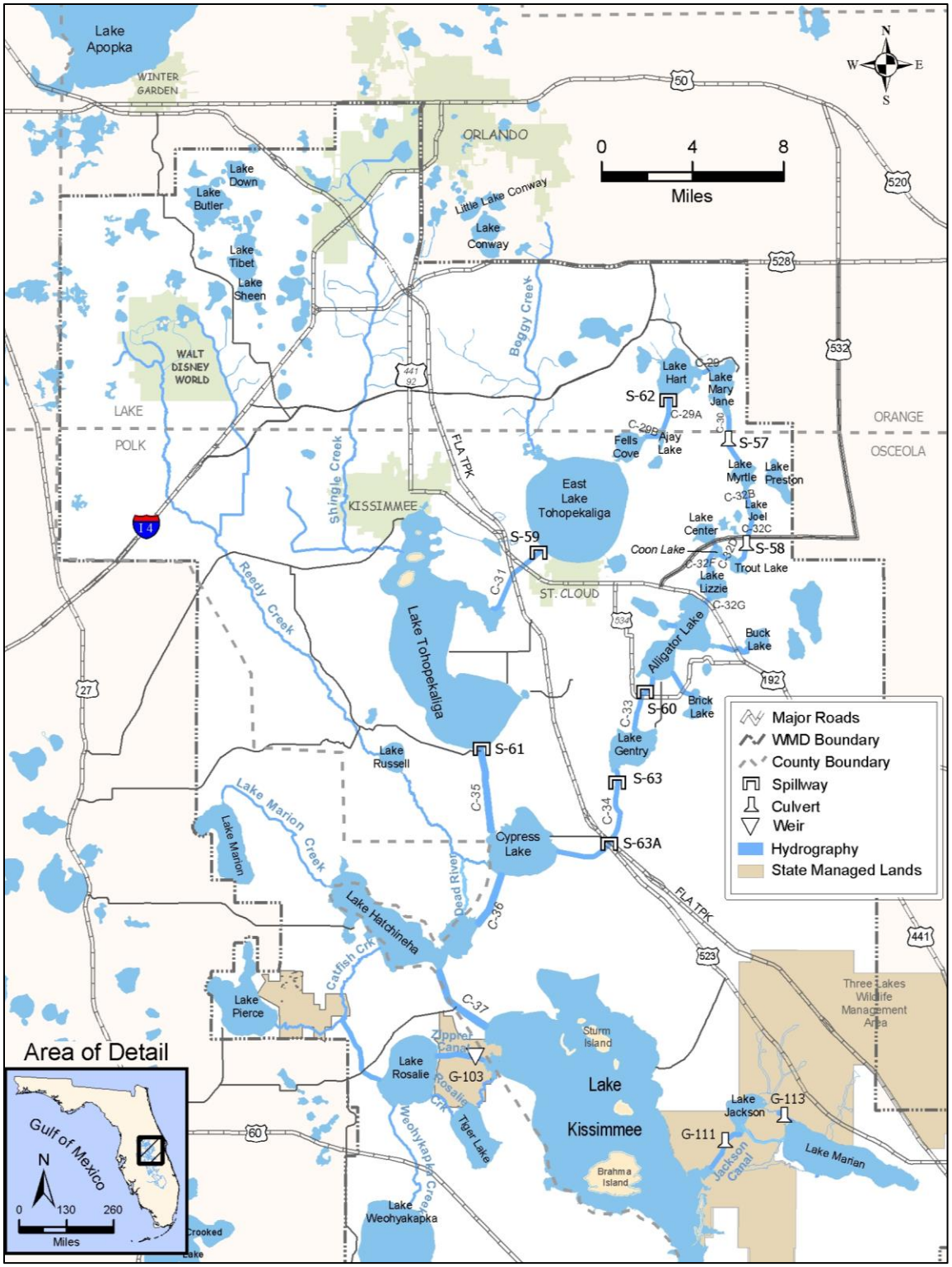

Figure 9-1. Upper Kissimmee Basin.
[Note: WMD – South Florida Water Management District.]

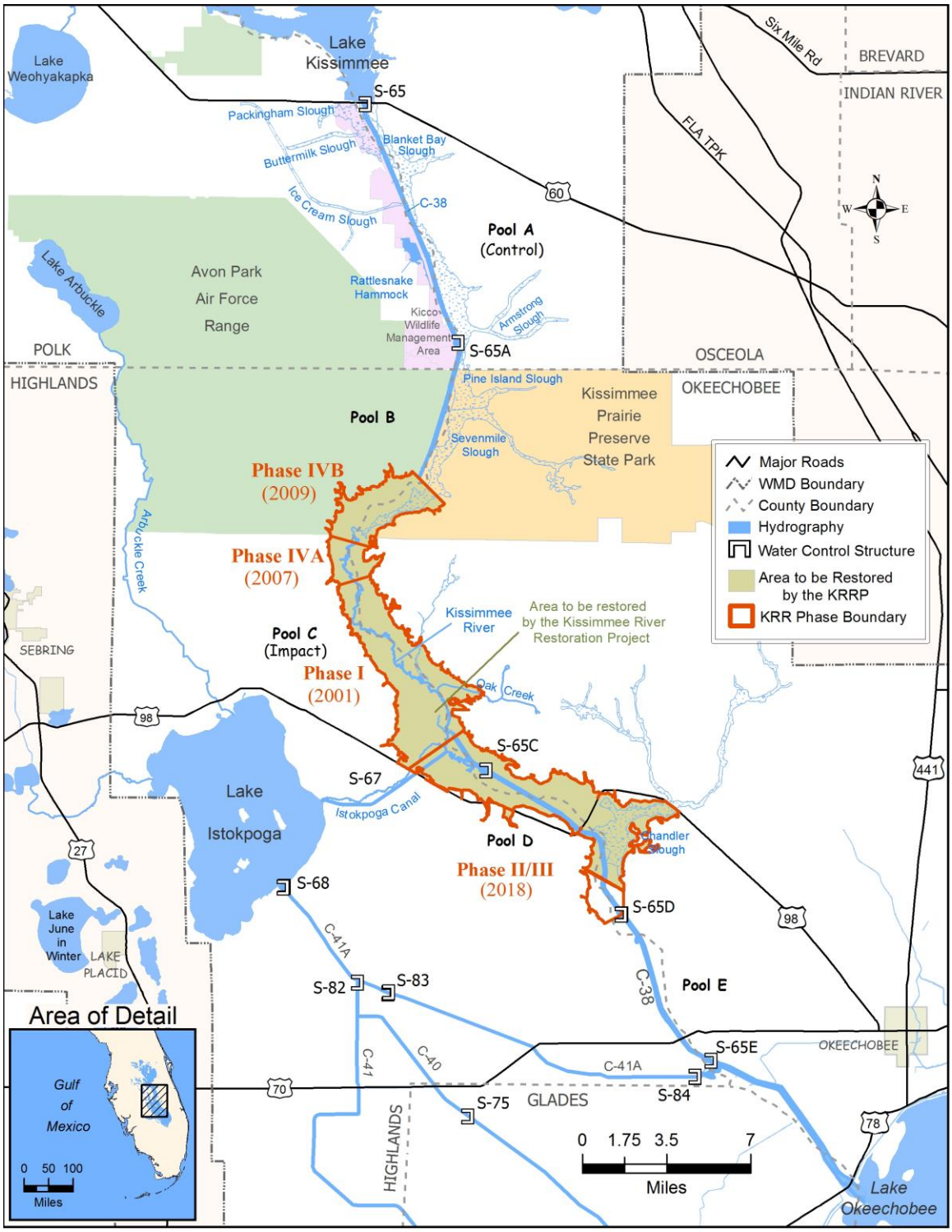

Figure 9-2. Lower Kissimmee Basin. [Note: KRRP – Kissimmee River Restoration Project and KRR – Kissimmee River Restoration.]

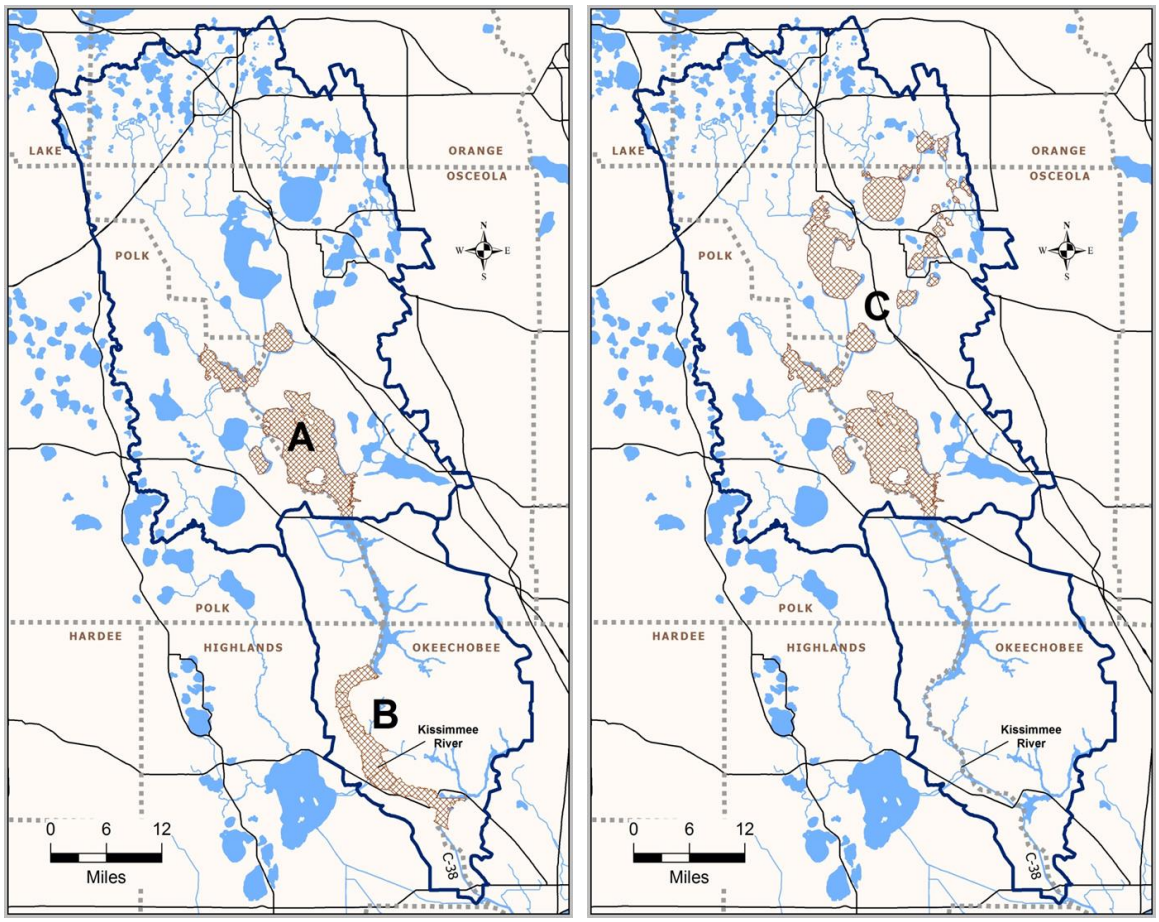

Figure 9-3. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) headwater lakes components of the KRRP, (B) KRRP, and (C) Kissimmee Chain of Lakes (KCOL) and Kissimmee Upper Basin Monitoring and Assessment Project.

KISSIMMEE RIVER RESTORATION PROJECT

OVERVIEW

Concerns about environmental degradation and habitat loss in the Kissimmee River Valley and the potential contribution of the channelized river to eutrophication in Lake Okeechobee were the impetus for the KRRP. The goal of this project is to restore ecological integrity to the Kissimmee River and its floodplain. Successful restoration depends largely on reestablishing hydrologic conditions similar to the prechannelization period (Toth, 1990). A headwaters component of the project is designed to allow additional storage capacity in the headwater lakes, providing more flexible operations that can more closely approximate the prechannelized river's flow regime, including discharges with more natural timing, magnitude, and rates of change. Increasing storage in the headwater lakes by allowing higher stages for longer periods of time is expected to have the additional benefit of improving the quantity and quality of lake littoral zone habitat in Lakes Kissimmee, Hatchineha, Tiger, and Cypress (USACE, 1996). Restoration is to occur without jeopardizing existing flood reduction benefits provided by the C&SF Project in the Kissimmee Basin.

In the Lower Kissimmee Basin, the KRRP is expected to restore ecological integrity to approximately one-third of the river and floodplain, modifying a contiguous area of floodplain-

river ecosystem of over 39 square miles (sq mi). More than 20 sq mi of new wetlands will be reestablished in areas that were drained by the canal, and 40 miles (mi) of reconnected river channel will receive reestablished flow. In the Upper Kissimmee Basin, over 7,000 acres (ac) of littoral marsh are expected to develop on the periphery of the four lakes regulated by water control structure S-65 (USACE, 1996). The KRRP is funded under a 50-50 cost-share agreement between the SFWMD and the United States Army Corps of Engineers (USACE). Engineering, construction, and water control manual modification components of the project are the responsibility of the USACE, while the SFWMD's purview is land acquisition, hydrologic modeling, and ecological evaluation of the restoration project.

RESTORATION CONSTRUCTION COMPONENTS

Restoration components include (1) acquiring 65,603 ac of land in the Lower Kissimmee Basin, of which 99 percent has been acquired to date, (2) backfilling approximately 22 mi of the C-38 canal (over one-third of the canal's length) from the lower end of Pool D north to the middle of Pool B, (3) reconnecting the original river channel across backfilled sections of the canal, (4) recarving sections of river channel destroyed during C-38 canal construction, (5) removing the S-65B and S-65C water control structures and associated tieback levees, and (6) modifying portions of the river's headwaters to meet hydrologic criteria for river restoration. The material used for backfilling is the same that was dredged during construction of the C-38 canal. Composed primarily of sand and coarse shell, this material was deposited in large spoil mounds adjacent to the canal.

Reconstruction of the river–floodplain's physical template is being implemented in four phases (**Figure 9-2**), currently projected for completion in 2019 (**Table 9-1**). Phase I construction was completed in February 2001. This phase was followed by Phase IVA/IVB, which extends north from the Phase I project area and was completed in December 2009. Phases II and III, the last major phases of construction, are scheduled to begin in 2015–2016. While the restoration phases were named in the order of expected completion, the sequence has changed over time for logistical reasons (i.e., budgetary considerations, coordination with land acquisition, and ease of access).

Table 9-1. Sequence of backfilling construction phases of the Kissimmee River Restoration Project (KRRP) with selected benefits.

Construction Sequence	Name of Construction Phase	Timeline	Backfilled Canal (miles)	River Channel Recarved (miles)	River Channel to Receive Reestablished Flow (miles)	Total Area (acres)	Wetland Gained (acres)	Location and Other Notes
1	Phase I Project Area	1999–2001 (complete)	8	1	14	9,506	5,792	Most of Pool C, small section of lower Pool B
2	Phase IVA Project Area	2006–2007 (complete)	2	1	4	1,352	512	Upstream of Phase I in Pool B to Weir #1
3	Phase IVB Project Area	2008–2009 (complete)	4	4	6	4,183	1,406	Upstream of Phase IVA in Pool B (upper limit near location of Weir #3)
4	Phase II/III Project Area	2015–2019 (projected)	9	4	16	9,921	4,688	Downstream of Phase I (lower Pool C and Pool D south to CSX Railroad bridge)
Restoration Project Totals			**22**	**10**	**40**	**24,963**	**12,398**	

The construction phases completed so far have backfilled 14 mi of flood control canal, recarved 6 mi of river channel that had been obliterated during canal dredging, and demolished a water control structure (S-65B). These efforts reestablished flow to 24 mi of continuous river channel and allowed intermittent inundation of 7,710 ac of floodplain (**Table 9-1**).

The KRRP will culminate with modification of the Kissimmee Basin water control structure operations including the implementation of a new stage regulation schedule, called the Headwaters Revitalization Schedule (HRS), to operate the S-65 water control structure. The HRS will allow lake water levels to rise 1.5 feet (ft) higher than the current S-65 schedule and will increase the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 acre-feet (ac-ft). Ninety-nine percent of the 36,612 ac of lands that will be affected by the higher water levels have been acquired, and all projects needed to increase the conveyance capacity of Upper Kissimmee Basin canals and structures are in place to accommodate the larger storage volume. The last of these upper basin projects, the C-37 Canal Widening Project, was completed in 2012.

Because of the time lag between completion of the earliest phases of the construction project and the implementation of the HRS, the USACE authorized an interim regulation schedule that allows the SFWMD to make releases from S-65 when its headwater stage is within a certain range (termed "Zone B") below the maximum regulated stage. Zone B allows releases from S-65 for environmental purposes when flood control releases are not needed. It is used to maintain flow in the reach of the restored river channel throughout the year and to allow seasonal variability. Environmental releases according to this interim schedule began in July 2001 after the Phase I construction was completed and lake levels began to rise following the 2000–2001 drought. Zone B releases have allowed continuous flow to the river since that time except for a 252-day dry period in 2006–2007. While the use of Zone B releases has been beneficial, it does not provide the full benefits that the HRS is expected to provide.

CONSTRUCTION STATUS

In WY2014, construction activities consisted of completion of the CSX Railroad Bridge, and ongoing construction of the S-65EX1 spillway. **Table 9-2** provides brief descriptions of current activities along with a chronological list of all the KRRP construction activities.

In recent years, the final backfilling contracts (Phase II and Phase III) have been on hold due to real estate and cost crediting issues. All remaining real estate in the Lower Kissimmee Basin has been or will be acquired by the end of 2014. Additionally, cost credit issues, such as authorization of credit for large acquisitions in the Lower Kissimmee Basin have been resolved. As a result of these successes, the USACE has accelerated the construction schedule. The new estimated completion date is January 2019.

Table 9-2. Chronology of KRRP construction.
[Note: **Bold** text indicates C-38 canal backfilling contracts.]

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
1	Test Backfilling – A short section of the C-38 canal was backfilled as a test to evaluate engineering and design construction methods.	Complete		May 1994	$1.2 M
14B	Pool A Spoil Mound Removal – A portion of a spoil mound in Pool A was degraded and two 48-inch culverts were installed under an access road.	Complete		October 2000	$0.62 M
3	S-65 Enlargement – The S-65 structure was enlarged from a three-bay to a five-bay spillway to maintain the existing level of flood protection for the headwater lakes.	Complete		May 2001	$4.8 M
2A	C-35 Dredging – Maintenance dredging was conducted in the C-35 canal to maintain the existing level of flood protection for the headwater lakes. A portion of C-36 was enlarged to maintain the existing level of flood protection.	Complete		July 2001	$2.6 M
4	Degradation of Local Levees in Pools A, B, and C – Local levees and associated borrow canals were restored to natural elevation.	Complete		2001	$1.5 M
5	S-65A Tieback Levee – The western tieback levee was degraded and box culverts installed in the eastern tieback levee. This allows additional discharge capacity adjacent to S-65A through the floodplain to avoid upstream impacts.	Complete		April 2001	$2.1 M
7	**Reach 1 Backfilling – Seven miles of the C-38 canal were backfilled, new river channels were constructed, and the S-65B structure was removed.**	**Complete**		**April 2001**	**$24.2 M**
2B	C-36 Enlargement – The C-36 and C-37 canals were enlarged to maintain the existing level of flood protection for the headwater lakes. Due to turbidity issues, the C-37 portion of this contract was terminated before completion.	C-36 Complete C-37 Terminated		April 2003	$14.5 M
8	U.S. Highway 98 Causeway – The causeway was elevated and resurfaced, a 100-foot flat-span bridge was built, and ten concrete culverts, each 2 meters by 3 meters by 30 meters, were installed under the highway for flood control and to improve hydrologic conditions in the Kissimmee River floodplain.	Complete		January 2004	$6.3 M
6A1A	8-83A/84A Spillways – When Kissimmee River floodplain water levels restrict Lake Istokpoga Basin discharges via the Istokpoga Canal, the C-41A spillway additions will offset the loss of discharge capacity by rerouting flows to the C-41A canal.	Complete		July 2007	$11.8 M
6B	Basinger Grove – Protection of the Basinger property from flooding due to elevated post-project Kissimmee River and Istokpoga Canal stages including construction of levees and pumping stations and a 22.5-acre detention area.	Complete		May 2008	$20 M
7B	Radio Tower – A radio tower at the S-65B structure was removed and a new one built approximately 11 miles to the west.	Complete		August 2007	$1.6 M
11	S-65D Grade Control Structure – Additional structures (S-65DX1 and S-65DX2) were built to increase the capacity of the S-65D structure.	Complete		October 2007	$7.5 M

Table 9-2. Continued.

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
13A	**Reach 4 Backfilling – 2.5 miles of the C-38 canal in Pool B were backfilled, a new river channel was excavated, and three existing navigable sheet pile weirs within the C-38 canal were removed.**	**Complete**		**October 2007**	**$29.8 M**
6A1B	S-68A Spillway – A new bypass channel was excavated, a gated spillway was constructed adjacent to the existing spillway, a portion of the existing levee was removed at the S-68 structure, and a temporary access road was constructed.	Complete		June 2009	$13.5 M
6A2	Istokpoga Canal Improvements – The G-85 weir was removed and replaced with the new S-67 control structure. Other features included construction of a tie-back levee, an access road, and a public boat ramp, and canal improvements.	Complete		March 2010	$14.3 M
13B	**Reach 4 Backfilling – 3.5 miles of the C-38 canal were backfilled along Reach 4 extending from the upstream limit of Contract 13A backfill northward to the upstream limit of the backfill.**	**Complete**		**December 2010**	**$18 M**
15	River Acres Flood Reduction – A seepage levee, flood protection tieback levee, and navigation canal were constructed for the River Acres community.	Complete	December 2009	July 2012	$2.97 M
2B1	C-37 Enlargement – The remainder of the C-37 canal, which was not completed under contract 2B, is being enlarged.	Complete	June 2010	September 2012	$15.6 M
9	CSX Railroad Bridge – An elevated single track railroad bridge is being constructed to allow navigation through the restored river channel.	Complete	November 2010	June 2013	$6.8 M
18	Pool D Oxbow Excavation and Embankment – A new oxbow connecting existing oxbows and an embankment along C-38 were constructed.	Complete	December 2010	November 2011	$2.8 M
10A	Oxbow Dredging – To accelerate completion of the KRRP, oxbow dredging to restore the historic river channel was removed from contract 10 and was completed in this separate contract.	Complete	September 2011	June 2012	$4.8 M
18B	Pool D Boat Ramp – A new boat ramp and small parking area will be constructed.	Complete	September 2011	October 2012	$0.9 M
12A	S-69 Weir – The S-69 weir will serve as the terminus of the C-38 canal backfill.	Not yet awarded	November 2015	January 2017	Not yet available
18A	S-65E Spillway Addition – A gated spillway will be constructed in the S-65E west tie-back levee.	Under construction	August 2012	October 2014	Not yet available
15A	River Acres Supplemental Work – Repair of S-65DX3 structure and miscellaneous construction features	Awarded	July 2014	April 2015	Not yet available
10B	**MacArthur Ditch will be backfilled.**	**Not yet awarded**	**October 2014**	**December 2015**	**Not yet available**
12	**Reach 3 Backfilling – New channels will be dredged and 2.5 miles of the C-38 canal will be backfilled.**	**Not yet awarded**	**July 2015**	**August 2016**	**Not yet available**
10	**Reach 2 Backfilling – New channels will be dredged, 6.5 miles of the C-38 canal will be backfilled, and the S-65C structure will be removed.**	**Not yet awarded**	**June 2015**	**December 2016**	**Not yet available**

KISSIMMEE BASIN HYDROLOGIC CONDITIONS AND WATER MANAGEMENT IN WATER YEAR 2013

This section discusses hydrologic conditions in the Upper and Lower Kissimmee basins and their relationship to water management activities during WY2014. In the upper basin, the District manages water levels in the KCOL; the KCOL is divided into seven groups of one or more lakes that are regulated by the same water control structure (**Figure 9-1**). In the lower basin, the District manages flow and water levels in the Kissimmee River (**Figure 9-4**). The description of hydrologic conditions focuses first on the timing and quantity of rainfall. It then switches to the resulting temporal patterns of stage (i.e., water surface elevation) and discharge and how these are influenced by water management activities.

This year's hydrologic conditions and water management section contains a new subsection—*Hypoxia in the Kissimmee River: Consequences, Causes and Water Management*—to discuss the relationship of hypoxia to water management. Hypoxia occurs when the concentration of oxygen dissolved in water (DO) decreases to less than 2 milligrams per liter (mg/L). In the Kissimmee River, DO concentrations less than 2 mg/L are stressful to centrarchids (largemouth bass [*Micropterus salmoides*] and other sunfish); concentrations below 1 mg/L may be lethal (Furse et al., 1996). Hypoxic conditions can also affect other organisms, such as many aquatic invertebrates, that depend on DO.

An important water management tool that has a strong influence on temporal hydrologic patterns is a stage regulation schedule, authorized by the USACE, for each water control structure. Each KCOL lake group has its own regulation schedule (e.g., **Figures 9-6** and **9-7**). The regulation schedule specifies a seasonally varying elevation that when exceeded by lake stage triggers water releases to bring lake stage back to the regulation line, and when lake stage is at or below the line, water may be discharged for environmental purposes. All the KCOL regulation schedules have a similar shape—each declines during the spring to its lowest elevation (low pool) on May 31, rises to a plateau (summer pool) on June 1 and in the fall begins rising again to its highest elevation (high pool) on November 1.

Hydrologic conditions in WY2014 were quantified with data collected by the SFWMD monitoring program at water control structures (**Figures 9-1** and **9-2**) and stage monitoring locations in the river channel and floodplain (**Figure 9-4**). This section follows the convention of District and USACE water managers and reports hydrologic conditions in English units—inches for rainfall, feet National Geodetic Vertical Datum of 1929 (NGVD) for stage, and cubic feet per second (cfs) for discharge.

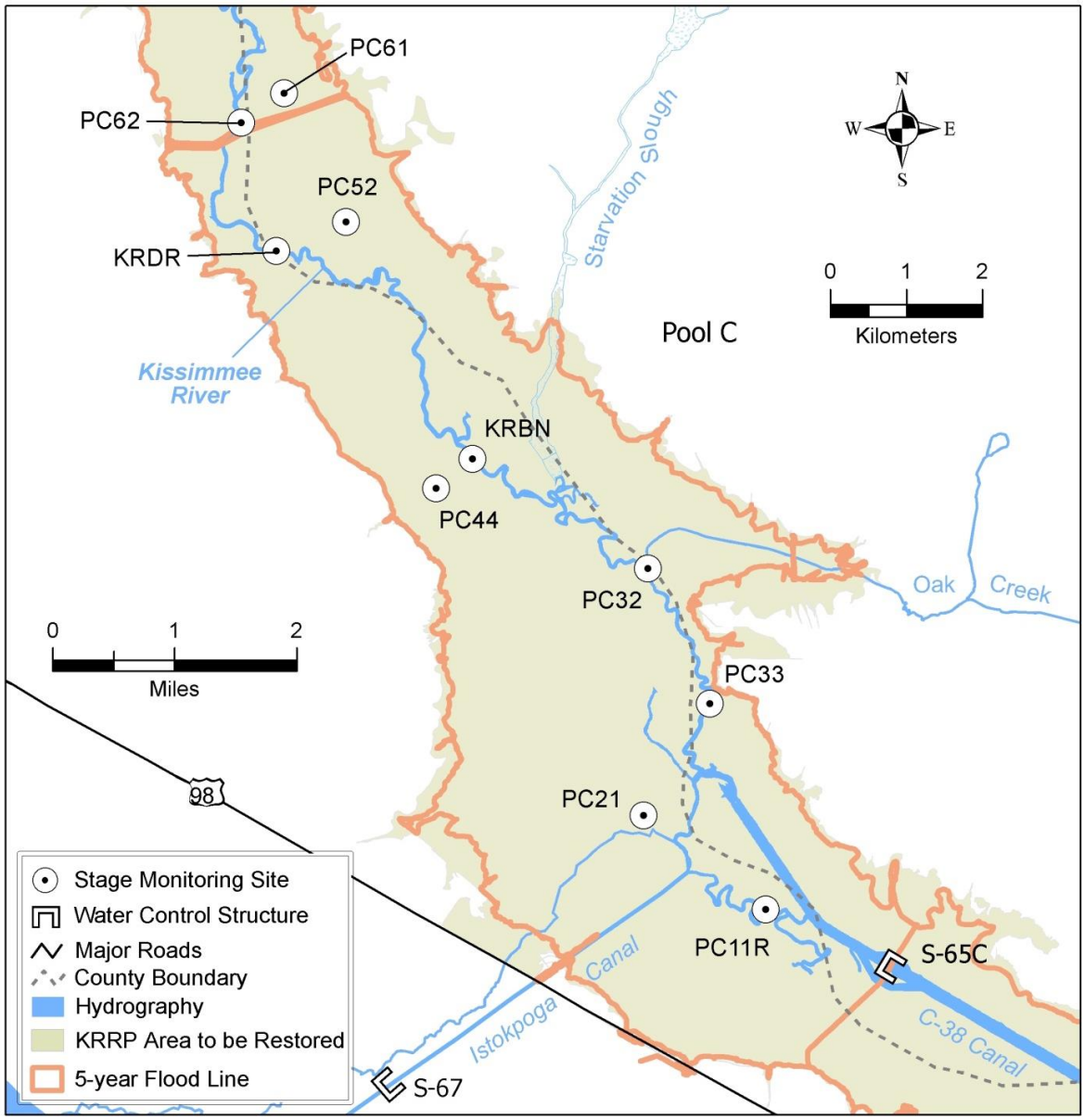

Figure 9-4. Locations of hydrologic monitoring sites in Pool C used to guide operations and to evaluate restoration expectations.

RAINFALL

During WY2014 annual rainfall was above average in both the Upper and Lower Kissimmee basins. The upper basin totaled 52.5 inches and was 4.8 inches above the long-term average (1971–2000); the lower basin totaled 53.3 inches and was 8.6 inches above average. In both basins, above average rainfall was due primarily to wet season (June–October) rainfall especially in June and July (**Figure 9-5**). Wet season rainfall totaled 33.7 inches (16.1 percent above average) in the upper basin and 37.4 inches (33.4 percent above average) in the lower basin.

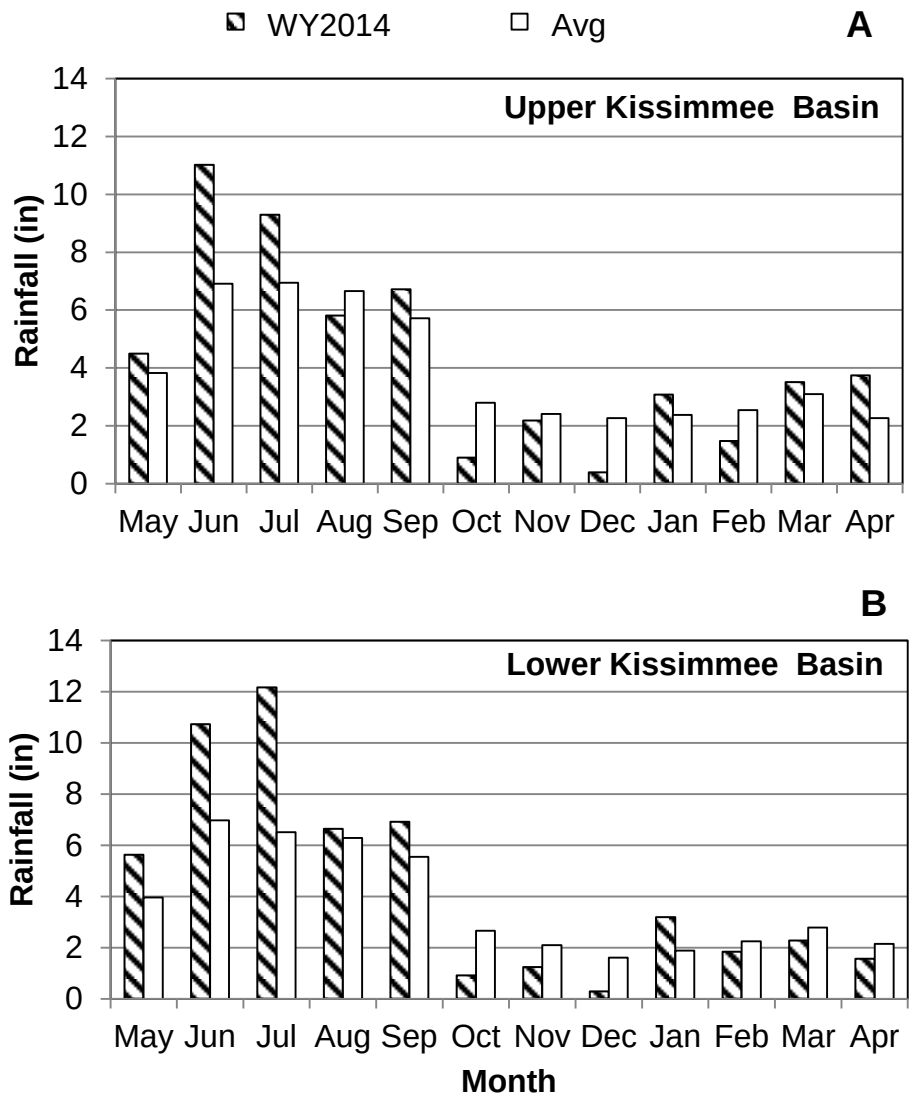

Figure 9-5. Monthly rainfall [in inches (in)] for Water Year 2014 (WY2014) (May 1, 2013–April 30, 2014) and average rainfall (1971–2000) in (A) the Upper Kissimmee Basin and (B) the Lower Kissimmee Basin.

TEMPORAL HYDROLOGIC PATTERNS

WY2014 began in May with the groups of smaller KCOL lakes (Lakes Myrtle, Preston, and Joel; Lakes Hart and Mary Jane; the Alligator Chain of Lakes; and Lake Gentry) being lowered to the low pool of their respective schedules on May 31. The three groups with the largest lakes (East Lake Tohopekaliga; Lake Tohopekaliga; and Lakes Kissimmee, Cypress, and Hatchineha) were lowered to 0.5 feet above their low pool by mid-May and held at that stage through the end of the month (see **Figure 9-6**, panel A, for East Lake Tohopekaliga; **Figure 9-6**, panel B, for Lake Tohopekaliga; and **Figure 9-7**, panel B, for Lakes Kissimmee, Cypress, and Hatchineha). In these lakes, stage was held above the low pool per a request from the United States Fish and Wildlife Service (USFWS) to maximize foraging conditions for the federally endangered snail kite (*Rostrhamus sociabilis plumbeus*), which nest on these lakes during the spring. During May, mean daily discharge at S-65 ranged between 340 and just over 1,000 cfs (**Figure 9-7**, panel C). The increase in discharge from 340 to 1,000 cfs was accompanied by a slight increase in stage in the river channel as shown for site KRBN, but it was not sufficient to raise water levels in the floodplain, as shown for PC61 (**Figure 9-8**, panel A).

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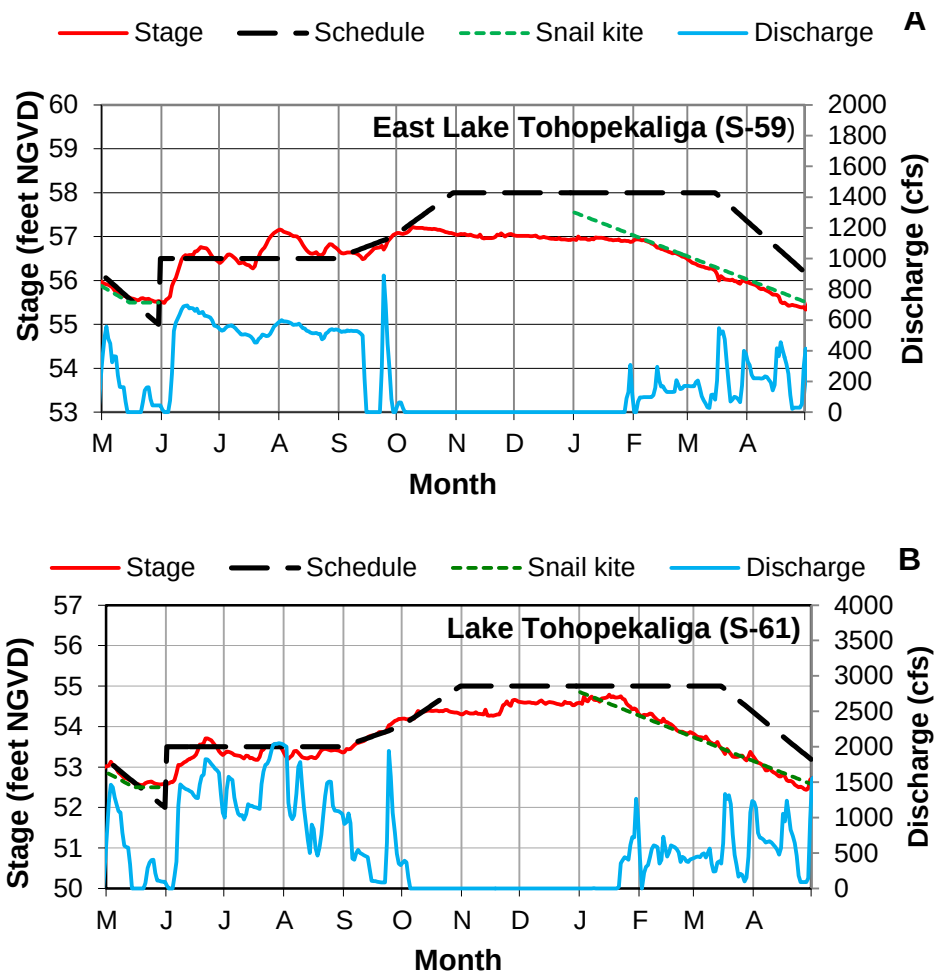

Figure 9-6. Regulation schedule (dashed line), water level (solid line) in feet relative to the National Geodetic Vertical Datum of 1929 (NGVD) and discharge in cubic feet per second (cfs) for (A) East Lake Tohopekaliga and (B) Lake Tohopekaliga during WY2014. Green dotted lines are desired water level recession for snail kites.

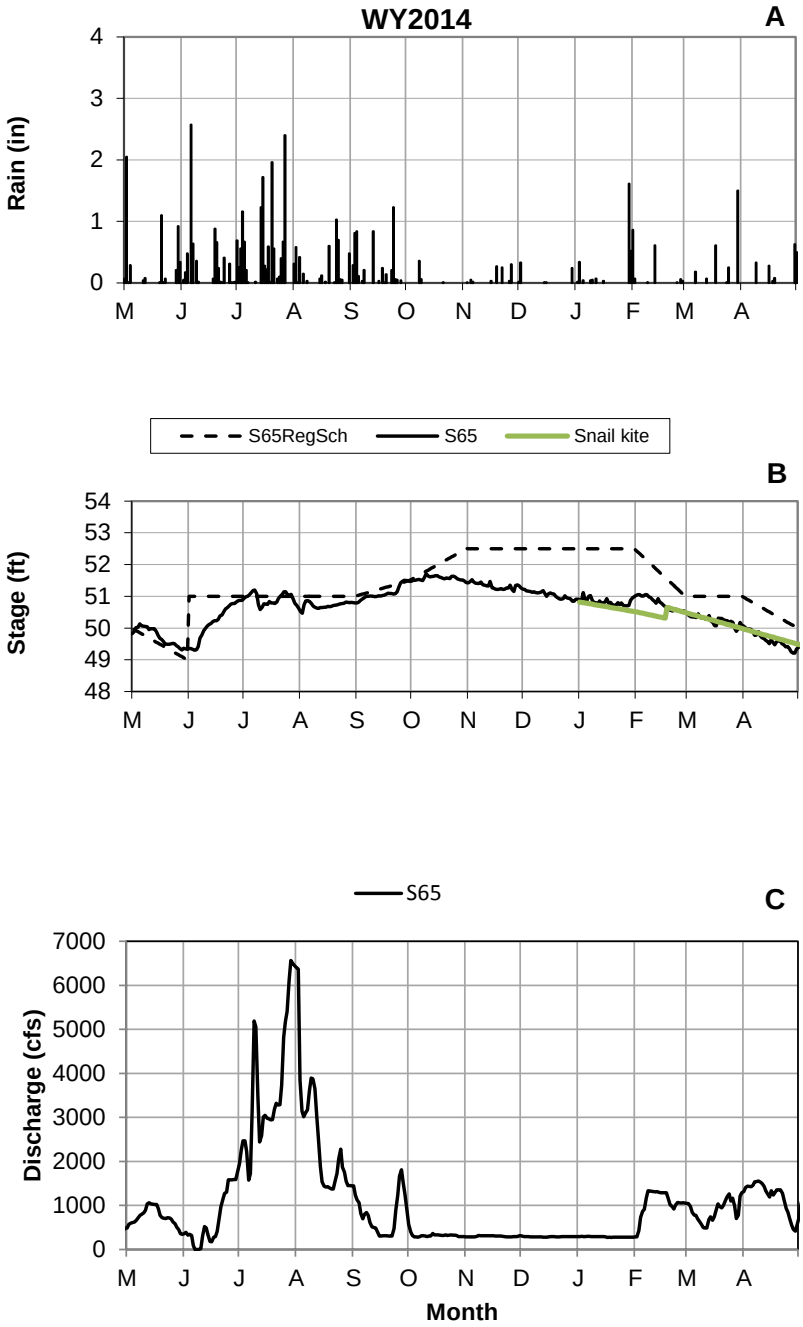

Figure 9-7. (A) Rainfall, (B) regulation schedule and water level in feet (ft), and (C) discharge in cfs at the outlet of Lake Kissimmee (S-65 structure) for WY2014. Environmental releases are made when the S-65 stage is between the regulation schedule line in panel B and 48.5 feet.

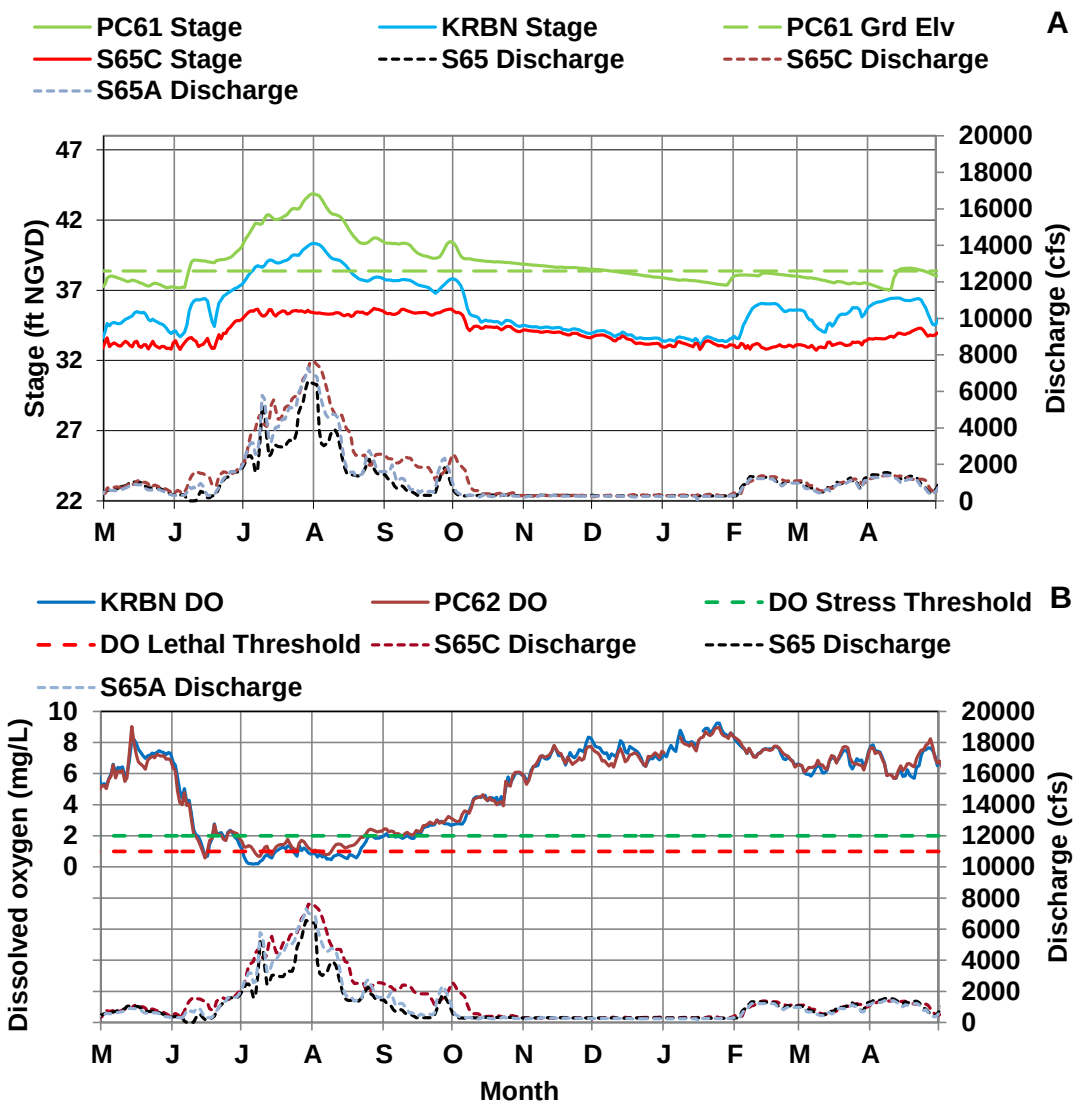

Figure 9-8. (A) Mean daily stage on the floodplain at PC61, in the river channel at KRBN, and in the C-38 canal on the upstream side of S-65C in relation to mean daily discharge at S-65, S-65A and S-65C during WY2014, and (B) mean daily dissolved oxygen (calculated from 15-minute measurements) in the river channel at KRBN and PC62, and discharge at S-65, S-65A, and S-65C. See **Figure 9-4** for locations of hydrological monitoring sites.

During the wet season, water levels in all of the lakes rose quickly in response to above average rainfall in June so that each lake group reached the summer pool of its regulation schedule by mid-June (see **Figure 9-6**, panel A, for East Lake Tohopekaliga and **Figure 9-6**, panel B, for Lake Tohopekaliga) or early July (**Figure 9-7**, panel B, for Lakes Kissimmee, Cypress, and Hatchineha). The summer pool was reached earlier in WY2014 than the previous year. A direct consequence of lake stages being at or near regulation schedule was that the continued rainfall (**Figure 9-5**, panel B) necessitated water having to be discharged almost continuously from all of the lakes through late September or early October to keep lake stages from exceeding regulation schedules. As rainfall tapered off and the rise in lake stage slowed, discharge from all of the lakes was reduced and ended by mid-October (see **Figure 9-6**, panel A, for East Lake Tohopekaliga and **Figure 9-6**, panel B, for Lake Tohopekaliga) except for Lakes Kissimmee, Cypress, and Hatchineha (**Figure 9-7**, panel B). For these lakes, discharge was reduced only to 300 cfs to provide flow to the Kissimmee River. The reduction to about 300 cfs has occurred in October in seven of the last eight years; 300 cfs at this time of the year is less than the 10th percentile of pre-channelization discharge for the same time of year.

In the lower basin, wet season discharge in the Phase I area was the result of inflow from the upper basin at S-65 and lower basin runoff from above average rainfall from June to September (**Figure 9-5**, panel B). Lower basin runoff is indicated when the discharge at S-65A (the structure between S-65 and the Phase I area) or S-65C (the structure immediately downstream of the Phase I area) is larger than the discharge at S-65 (**Figure 9-8**, panel A). Stage in the Phase I area varied with discharge (**Figure 9-8**, panel A). Early in the wet season, lower basin runoff resulted in rapid increases in discharge as shown for S-65A and S-65C (**Figure 9-8**, panel A). To slow the rate of increase in discharge in the Phase I area of the restoration project, the discharge at S-65 was stopped for three days in early June (June 7–9, 2013). This is an example of the use of water management to moderate changes in discharge to give the system time to adjust (see the discussion at the end of this section). After three days, the S-65 discharge was ramped up to control the rate of lake stage ascension due to rainfall. As discharge continued to increase, stage increased in both the river channel at KRBN and in the floodplain at PC61. Discharge peaked in late July at 6,500 cfs at S-65, 7,300 cfs at S-65A, and 7,600 cfs at S-65C; the stage at PC61 reached a maximum of 43.9 ft at the same time, which corresponds to a water depth of about 5.5 ft at this location. After the late July peak, discharge and stage declined until late September, when discharge at S-65 was increased as the lake stage exceeded the regulation schedule. In addition to the increased discharge at S-65, lower basin runoff was contributing to increases at S-65A and S-65C. The increase in discharge was accompanied by stage reversals in the river channel at KRBN and in the floodplain at PC61. As the lake stage decreased to the regulation schedule line and runoff from the Pool A basin (the basin between S-65 and S-65A) slowed, discharge at S-65 and S-65A was reduced to 300 cfs in early October. In the lower basin, the decrease in S-65 discharge to 300 cfs in late September (**Figure 9-8**, panel A) resulted in a fairly rapid decrease in stage in the river channel and on the floodplain (shown in **Figure 9-8**, panel A, for KRBN in the river channel and PC61 on the floodplain). This also resulted in the stage in the river channel being only slightly higher at KRBN than at S-65C.

Increases in discharge in early June were associated with a decrease in the concentration of DO and the development of hypoxia. Mean daily DO was greater than 7 mg/L at both sites (KRBN and PC62) on May 28, decreased to less than 2 mg/L by June 12, and decreased to 0.6–0.7 mg/L by June 15 (**Figure 9-8**, panel B). While DO briefly recovered to levels above 2 mg/L as discharge was reduced briefly, it declined again as S-65 discharge was increased steadily to recover and maintain a 0.5-ft buffer below the regulation schedule line (**Figure 9-8**, panel B). With continued discharge above 3,000 cfs, mean daily DO concentration dropped below 1 mg/L in mid-July and continued to decline to < 0.5 mg/L in late July. As discharge was reduced to about 1,000 cfs, DO concentration at both stations increased, averaging 1.2 mg/L on August 10.

DO did not rise above 2 mg/L again until late August at PC62 and early September at KRBN (**Figure 9-8**, panel B). The hypoxic event persisted for a total of 73 days.

Shortly after the initial DO decline to less than 1 mg/L, a fish kill was reported in the Phase I area. On June 17, the Phase I river channel was surveyed for dead fish; 24 dead fish were found, but such events are difficult to quantify due to the decomposition and drift of carcasses and consumption by scavengers. All dead fish were found in a single side-channel immediately upstream of KRBN, which suggests that it may have been a localized event. The dead fish located were medium to large-sized individuals and included 9 largemouth bass, 3 bluegill (*Lepomis macrochirus*), 3 black crappie (*Pomoxis nigromaculator*), and 9 catfish—a mixture of channel catfish (*Ictalurus punctatus*) and bullhead (*Ameiurus* spp.). A fish kill was also reported the previous year (Jones et al., 2014). See additional information on current water management for DO in the next subsection.

The November–May dry season began with the KCOL lakes below the high pool of the regulation schedule (**Figures 9-6** and **9-7**). While most of the wet season had above average rainfall, October was below average (**Figure 9-5**, panel A) and was not sufficient to raise lake stage to the high pool in any of the KCOL lakes by the beginning of the dry season. While rainfall later in the dry season, especially in January, March, and April, did cause stage to rise in some of the lakes; only Lake Gentry had stage rise to the high pool, which did not occur until January. Rising lake levels late in the dry season after the regulation schedule begins to decline to the low pool complicates efforts to manage water level recessions (see below).

In January, discharge was resumed from East Lake Tohopekaliga (**Figure 9-6**, panel A) and Lake Tohopekaliga (**Figure 9-6**, panel B) to begin an earlier, slower stage recession for the federally endangered snail kite per a request from the USFWS. This request also included Lakes Kissimmee, Cypress, and Hatchineha (**Figure 9-7**, panel B), although releases were already being made to the Kissimmee River. Lake stage generally declined along the requested recession lines in East Lake Tohopekaliga and Lake Tohopekaliga. This was accomplished by adjusting discharge from these lakes; sometimes increasing discharge to quite high values to constrain or recover from small stage reversals following rainfall events. The water discharged from Lake Tohopekaliga goes to Lakes Kissimmee, Cypress, and Hatchineha; discharge from the latter group of lakes is also constrained by how rapidly discharge can be increased to the Kissimmee River. With the increased inflows from Lake Tohopekaliga and local runoff, stage reversals were more difficult to control in Lakes Kissimmee, Cypress, and Hatchineha. In late January–early February, there was a stage reversal of 0.3 ft in Lakes Kissimmee, Cypress, and Hatchineha and the recession line was redrawn from the new stage after consultation with the USFWS and Florida Fish and Wildlife Conservation Commission. Subsequently, the stage in Lakes Kissimmee, Cypress and Hatchineha declined with the new recession line.

In the lower basin, dry season discharge was determined by the discharge at S-65; the discharge at S-65A and S-65C were almost identical to that at S-65 indicating little contribution from lower basin runoff (**Figure 9-5**). Discharge was about 300 cfs from mid-October until early February. During this time, stage in the floodplain decreased below ground elevation at PC61, and stage in the river channel at KRBN continued to decline until it matched the stage at the downstream water control structure (S-65C). From early February through April (the end of WY2014), discharge varied between 400 and 1,500 cfs. The increases in discharge were accompanied by increases in stage in the river channel of about 2.5 ft in February and again in March.

HYPOXIA IN THE KISSIMMEE RIVER: CONSEQUENCES, CAUSES AND WATER MANAGEMENT

Declines in DO resulting in hypoxic conditions (for the Kissimmee River defined as DO < 2 mg/L) have occurred in the Kissimmee River every year since completion of Phase I construction (2001–present), including in June of WY2014 as reported above in the previous summary of hydrologic patterns. For centrarchids (largemouth bass and other sunfish) in the Kissimmee River, DO concentrations of 1–2 mg/L are stressful and concentrations less than 1 mg/L can cause death [see Furse et al. (1996) and additional details in Bousquin et al. (2008) and the associated Response to Comments documentation in Appendix 1A-5 of the 2008 SFER–Volume I (SFWMD, 2008).] Fish kills were documented in some of these events; however, because fish kills are difficult to detect and quantify reliably, substantial hypoxia-related fatalities may have occurred that were not detected. Hypoxic conditions may stress or kill other aquatic organisms. Hypoxic events are most pronounced and severe in warm weather, when rainfall followed by increases in upstream discharge to the KRRP occurs after periods of low discharge. See discussions of several hypoxic events in the Kissimmee River in Williams et al. (2006), Bousquin et al. (2008), Bousquin et al. (2009), and Jones et al. (2010).

Because of the potential for hypoxic conditions to negatively affect the recovery of native fish and populations of other aquatic organisms in the restoration area, they are viewed as a high-priority water management challenge for the KRREP. Adaptive hydrologic management to address DO concerns is proceeding based on hypothesized relationships between flow and DO. District scientists are continuing to study the conditions associated with hypoxic events and their responses to adaptive hydrologic management actions. The study approach being used is by necessity primarily correlative and observational because the causes of hypoxia in relation to rain events in the Kissimmee River cannot be studied in a controlled experimental system.

Hypoxic events in the Kissimmee River are typically associated with substantial rain events early in the wet season (June–August) as temperatures rise above 30 degrees Celsius. For reasons described below, the effects of rainfall are exacerbated by increases in discharge from upstream water control structures. The mechanisms for these hypoxic events likely include some combination of the following: (1) inhibition of photosynthesis caused by flushing of photosynthetic aquatic organisms and greater attenuation of light with increased water depth and turbidity, (2) influx of organic material from the floodplain and tributaries causing a rapid increase in biochemical oxygen demand, (3) replacement or dilution of oxygenated river channel water with anoxic water from runoff and discharge from upstream (i.e., water discharged from the C-38 canal in Pool A via S-65A), and (4) seepage of anoxic groundwater from the surficial aquifer (Jones et al., 2013). Replacement hypotheses (e.g., #3 above) that depend on the DO concentration in inflow do not provide a satisfactory explanation of observed hypoxic events in the Kissimmee River. No evidence has been found that moving better-oxygenated water from upstream into the river can provide an effective management solution for DO sags, based on preliminary results from pilot DO monitoring of DO concentrations in the C-38 canal. This monitoring, initiated in 2013, was designed to evaluate this possibility. In practice, during and after the start of DO sags, a decrease in discharge typically results in an increase in DO. In the evaluations of the period of record since 2001, no examples were found of an increase in discharge followed by a sustained increase in DO concentration.

These findings have focused current DO management efforts on hypotheses that posit that processes involved in the production and consumption of oxygen in the river channel itself are disrupted by the combined effects of rainfall and discharge on water depth, turbidity, removal of photosynthetic organisms in the river channel, and influx or mobilization of organic matter. While all of these factors are affected by direct rainfall over the river, their effects on DO are further exacerbated by increases in discharge from upstream to the river. Because rainfall events

typically extend spatially over the entire Kissimmee Basin including the KCOL to the north, storms may initiate rapid increases in discharge from upstream water control structures S-65/S-65A, which control flows to the Kissimmee River. Such releases are greatly affected by the proximity of lake stages to the flood regulation schedule in the Upper Kissimmee Basin lakes. However, in cases where lake stages are at or above the flood regulation line, increases in discharge to the river may not be optional because of the regulatory, flood control nature of the regulation schedule. Therefore, there are times when additional discharge form upstream cannot be prevented. In many situations however, proactive operational planning can help. Water management measures that are now being used to anticipate and/or help reduce the need for sudden increases in discharge during and following rain-caused increases in lake stages, include (1) specification of buffer zones below the regulation lines to allow a preemptive period of moderate increases in discharge before the regulation line is reached; (2) judicious use of regulatory flexibility to remain briefly above the regulation lines during and after extreme rain events and, (3) careful management of the rate at which discharge is increased to the restoration area regardless of lake stage. Such operations are designed to limit the rate at which discharge is increased during and after rain events to help control DO declines by allowing time for the river system to adjust to increases in water depth, turbidity, and physical displacement of photosynthetic organisms that are associated with rain events. A promising operational approach being used in summer 2014 is manipulation of discharge at S-65C (immediately south of the Phase I area) to regulate the slope of the water surface and flow velocity, which allows limited control of water depth in the Phase I river channel. Such approaches allow time for the river system to recover from increases in water depth and turbidity, and for disturbed communities of photosynthetic organisms to reestablish under the new conditions, thus helping to attenuate the duration, severity, and/or rapidity of the onset of hypoxia. In the past two years, the use and refinement of management of discharge as a tool to ameliorate DO sags has accomplished the following:

- Slowing or postponement of DO declines, allowing fish species that are sensitive to low-oxygen conditions time to acclimate physiologically to hypoxic conditions (Moss and Scott, 1961; Gaulke, 2014), and/or to respond by dispersing to higher-DO refugia that may be available.
- Reduction of the severity of and duration of DO crashes.

KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM

A major component of the KRRP is assessment of restoration success through the KRREP, a comprehensive ecological monitoring program (Anderson et al., 2005; Bousquin et al., 2005; Williams et al., 2007) designed to evaluate the ongoing status and ultimate success of the project. Restoration evaluation for KRRP was identified as a SFWMD responsibility in its cost-share agreement with the USACE (Department of the Army and SFWMD, 1994). Success is being tracked, in part, using 25 hydrologic, biotic, and abiotic performance measures (Anderson et al., 2005) to evaluate how well the project meets its ecological integrity goal. Ecological integrity is defined as a reestablished 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” (Karr and Dudley, 1981). Targets for these performance measures, called restoration expectations, are based on estimated conditions in the prechannelized system (reference conditions) and have undergone extensive external peer-review. Trends and results from these evaluations are reported in several ways, including conferences, peer-reviewed and SFWMD technical publications, and annual SFER chapters. Many of the restoration expectations,

particularly those related to floodplain responses, depend on removal of the S-65C structure during upcoming phases of construction, and implementation of the HRS. Therefore, a final evaluation of project success must wait until all restoration components are in place. However, ecological responses being documented prior to project completion are used to evaluate the ongoing status of ecosystem recovery and to guide adaptive management of the system. Monitoring for ecological evaluations will continue for at least five years after construction is complete or until ecological responses have stabilized (USACE, 1991).

Limited post-construction monitoring continued in WY2014 in the Phase I restoration area. Newly available results are presented here. Many of the Phase I studies, which involve collection and analysis of data on hydrology, geomorphology, water quality, river channel and floodplain vegetation, herpetofauna, fish, and birds, have already documented changes consistent with those predicted by the expectations developed for the KRREP (Anderson et al., 2005). A comprehensive update of initial responses to Phase I reconstruction was published in Chapter 11 of the 2005 SFER – Volume I (Williams et al., 2005b), with updates using newly available monitoring data published in subsequent SFERs. The combined results for a group of interrelated river channel studies were presented in Chapter 11 of the 2006 SFER – Volume I (Williams et al., 2006). **Table 9-3** provides a directory of KRREP monitoring study updates presented in the SFER since 2005 [Note: See the subsection at the end of this section for recently published papers on KRREP topics].

To contain costs, most KRREP studies do not collect data continuously. Most studies are active for two to five years during the baseline (pre-restoration), interim, and/or post-restoration response periods. The interim period for KRREP evaluations of the Phase I area is defined as the years between completion of Phase I construction (2001) and completion of all remaining construction phases and implementation of the HRS. During the interim period, the river's physical and hydrologic characteristics are only partially reestablished. Therefore, the full array of hydrologic management options and the resulting effects of ecological processes expected to lead to full restoration are not yet fully in place.

Only studies that collected new data in WY2014 are updated in this section. These new results from studies on hydrology, DO, nutrients, floodplain vegetation, and wading birds and waterfowl document the current interim status of these ecosystem components. Where applicable, the results are evaluated in relation to associated restoration expectations.

Photos illustrating ecological conditions in the Phase I restoration area throughout WY2014 are available on the District's website in the *Library & Multimedia* section at www.sfwmd.gov/library, see *Kissimmee River Restoration Environmental Conditions, Water Year 2014 (May 1, 2013 – April 30, 2014)* (compiled by B. Anderson, SFWMD). Of particular interest is the early and rapid recession event in October, and the increases in stage (reversals) toward the end of the dry season (February, April, and May). Foraging wading birds appeared to respond negatively to these reversals in late winter/spring, declining in numbers during surveys conducted after each event (see the *Wading Birds and Waterfowl* section below).

Table 9-3. Directory of Kissimmee River Restoration Evaluation Program (KRREP) Phase I restoration response monitoring study updates in the *2005–2015 South Florida Environmental Reports* (SFERs).

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2014 SFERs — Volume I										
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kissimmee River Restoration Evaluation Program		11-8	11-37	11-22	11-28	11-36	11-26	11-25	9-16	9-19	9-20	9-22
Hydrology												
Stage-discharge relationships	None	11-20										
Continuous river channel flow	1	**11-18**				**11-39**	**11-29**	**11-29**	**9-20**	**9-23**	**9-22**	**9-26**
Variability of flow	2					**11-40**	**11-31**	**11-32**	**9-20**	**9-23**	**9-23**	**9-28**
Stage hydrograph	3	**11-22**				**11-41**	**11-32**	**11-33**	**9-21**	**9-24**	**9-24**	**9-30**
Stage recession rate	4	**11-23**	11-23	11-16	11-19	**11-42**	**11-34**	**11-35**	**9-24**	**9-27**	**9-28**	**9-33**
Flow velocity	5	**11-25**					**11-35**	**11-37**	**9-24**			
Broadleaf marsh indicator	None					11-43						9-33
Geomorphology												
River bed deposits	6	**11-26**						**11-70**				
Sandbar formation	7	**11-26**						**11-70**				
Channel monitoring	None					11-54		11-68				
Sediment transport	None							11-71				
Floodplain processes	None							11-72				
Dissolved Oxygen	8	**11-28**	**11-44**	**11-25**	**11-28**	**11-45**	**11-36**	**11-38**		**9-27**	**9-30**	**9-36**
River Channel Metabolism	None				11-35							
Phosphorus	None	11-33	11-52	11-30	11-32	11-51	11-43	11-43	9-25	9-31	9-34	9-40
Turbidity	9	**11-30**	**11-48**	**11-27**								
Periphyton	None	11-46										
River Channel Vegetation												
Width of littoral vegetation beds	10	**11-36**				**11-59**						
River channel plant community structure	11	**11-37**				**11-59**						
Floodplain Vegetation												
Areal coverage of floodplain wetlands	12	**11-39**			**11-35**			**11-47**			**9-42**	**9-50**
Areal coverage of broadleaf marsh	13	11-40			**11-35**			**11-47**			**9-43**	**9-51**
Areal coverage of wet prairie	14	11-40			**11-35**			**11-47**			**9-43**	**9-51**
Invertebrates												
Macroinvertebrate drift composition	15	**11-45**	11-57									
Snag invertebrate community structure	16	**11-46**	11-55			11-62						
Aquatic invertebrate community structure in broadleaf marsh	17		11-57									
Benthic invertebrate community structure	18	**11-45**	11-58			11-62						
Native and nonnative bivalves	None							11-52				

Table 9-3. Continued.

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2014 SFERs – Volume I										
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Herpetofauna												
Floodplain reptiles and amphibians	19	11-48	Response data will be collected after implementation of the Headwaters Regulation Schedule (HRS).								9-47	
Floodplain amphibian reproduction and development	20	11-48	Response data will be collected after implementation of the HRS								9-47	
Fish Communities												
Small fishes in floodplain marshes	21	11-50	Response data will be collected after implementation of the HRS.									
River channel fish community structure	22	11-52	**11-59**			**11-66**			**9-29**			
Mercury in fish	None					11-20						
Floodplain fish community composition	23	11-50	Response data will be collected after implementation of the HRS.									
Birds												
Wading bird abundance	24	**11-58**	**11-71**	**11-32**	**11-44**	**11-72**	**11-50**		**9-36**	**9-41**	**9-53**	**9-57**
Waterfowl	25		**11-67**	**11-35**		**11-73**	**11-52**		**9-37**	**9-42**	**9-55**	**9-59**
Shore birds	None	11-57										
Wading bird nesting	None		11-68		11-40	11-72	11-47		9-33	9-38	9-47	9-53
Threatened and Endangered Species	None	11-60										

Bolded page numbers indicate a major update in reference to the status of a restoration expectation (performance measure)

HYDROLOGY

Reestablishment of hydrologic conditions comparable to those of the pre-channelization system is the primary driver for restoring ecological integrity to the Kissimmee River and its floodplain. The reestablishment of pre-channelization hydrologic conditions depends on the reconstruction of physical form of the river channel and floodplain as well as changes to water management at S-65 to provide flows (discharge) from the upper basin with the appropriate magnitude, timing, duration, rates of change, and frequency. The former was completed for the Phase I area in 2001; the latter will be reestablished when the project is completed by the implementation of the new HRS regulation schedule for S-65. Restoration project components, including the HRS, are described in more detail in the above description in the *Restoration Construction Components* section. Until implementation of the HRS, an interim regulation schedule for S-65 is providing discharge to the river from the headwater lakes (Kissimmee, Hatchineha, and Cypress). However, the interim schedule does not fully deliver the seasonal hydrologic pattern needed for river and floodplain restoration. This section evaluates progress towards reestablishment of pre-channelization hydrologic conditions during the interim period. The evaluation focuses on expectations (performance measures) for restored hydrology of the river channel and floodplain that reflect criteria that have guided the restoration project since its inception (Anderson et al., 2005).

The evaluation quantifies the status of the hydrologic expectations under interim flow conditions. The addition of WY2014 data extends the evaluation of the Phase I interim period to thirteen years (WY2002–WY2014). This year's update focuses on four hydrologic expectations—two for discharge and two for stage (water surface elevation). A fifth expectation

for water velocity was most recently evaluated in Chapter 9 of the 2012 SFER – Volume I (Jones et al., 2012). Chapter 11 of the 2011 SFER – Volume I (Jones et al., 2011) includes more detail on methods. For purposes of scientific evaluation of restoration, hydrologic responses are presented in the International System of units (SI units) instead of English units, which are the convention for water management and are used elsewhere in this chapter.

Discharge

Discharge is the volume of water flowing through a river ecosystem per unit time; it is an important determinant of the availability and suitability of habitat for aquatic and semi-aquatic organisms. In the Phase I area of the KRRP, discharge is a function of direct rainfall over the river and runoff from the Upper Kissimmee Basin regulated at S-65, runoff from the Pool A basin regulated at S-65A, and runoff from Pool BC basin that is regulated downstream of the Phase I area by S-65C. Discharge is evaluated with two restoration expectations Expectation 1 for continuous flow throughout the year and Expectation 2 for variability of flow. The evaluation of these expectations focuses on discharge measured at S-65, the outlet from Lake Kissimmee, because there is a pre-channelization time series of discharge data measured immediately downstream of this structure.

Expectation 1

The number of days that discharge is equal to 0 cubic meters per second (m^3/s) in a water year will be zero for restored river channels of the Kissimmee River (Anderson et al., 2005).

In WY2014, mean daily discharge at S-65 ranged from 0 m^3/s to 186 m^3/s and averaged 30 m^3/s (**Figure 9-9**, panel A). As described in the *Temporal Hydrologic Patterns* section above, discharge at S-65 was stopped for three days in June (June 7–9) to slow the rate of increase in discharge in the Phase I area. In previous years, discharge at S-65 has been stopped temporarily (for a five-day period in July 2011 and for one day in December 2012) to conserve water while runoff from the S-65A sub-basin maintained discharge to the Kissimmee River. Consequently, although discharge at S-65 was not continuous during WY2014 (as in WY2012 or WY2013), discharge to the Phase I area was maintained continuously through S65A. In three prior years, the expectation was not met, including an 84-day interval at the beginning of WY2002 and a 251-day interval (November 9, 2006–July 17, 2007) that included parts of WY2006 and WY2007 (both of these time intervals were associated with extreme basin-wide droughts). Therefore, the expectation has been met in 10 of 13 years, including WY2014 (**Figure 9-9**, panel B). Because the target for Expectation 1 is to have continuous discharge every year, this expectation is not being met during the interim period.

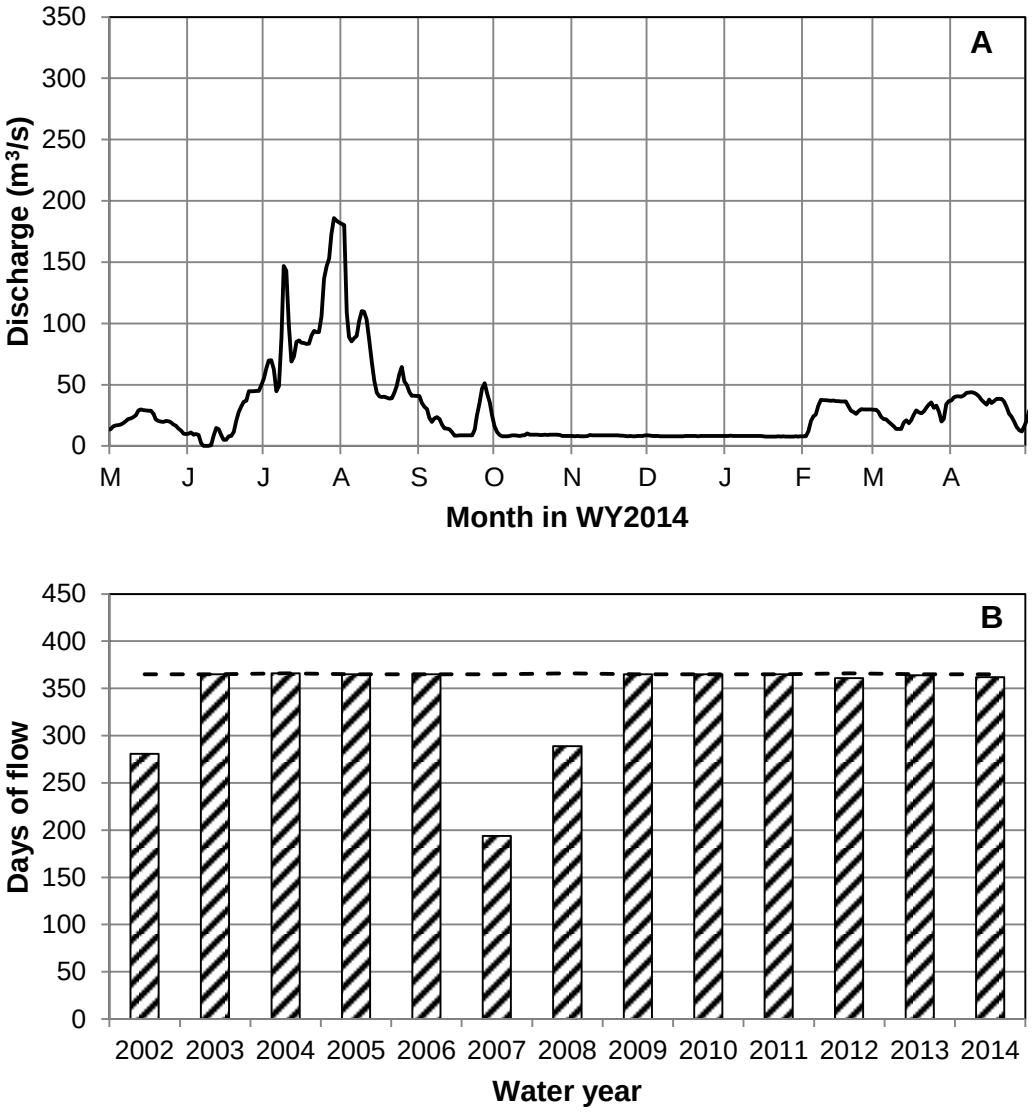

Figure 9-9. (A) Mean daily discharge [cubic meters per second (m^3/s)] at the S-65 structure, the outlet from the Upper Kissimmee Basin during WY2014, and (B) number of days with flow at S-65 for WY2002–WY2014.

Importance of Continuous Flow

Continuous flow was an important characteristic of pre-channelization hydrology in the Kissimmee River. It is needed to maintain water levels in the Phase I area; otherwise, stage is determined by the headwater stage at the downstream structure (currently, S-65C for the Phase I area) (Anderson, 2014a). Continuous flow also promotes physical mixing of the water and reaeration via atmospheric exchange, which can be important to maintain the concentration of DO (Colangelo, 2014) and prevents the accumulation of fine organic sediments on the channel bed such as occurred in the channelized system (Anderson, 2014b).

Expectation 2

Intra-annual monthly mean flows will reflect historical seasonal patterns and have inter-annual variability (coefficient of variation) < 1.0 (Anderson et al., 2005).

Evaluation of the intra-annual component of this expectation has been modified to follow Anderson (2014a); it focuses on the timing of the maximum and minimum of mean monthly discharge and the frequency (percentage of water years) with which the maximum and minimum fall in their respective windows during the interim period. In keeping with the KREEP standard of use of reference data to define restoration goals, it uses pre-channelization reference period discharge data from near the current location of S-65 to define target windows for the maximum and minimum of mean monthly discharge and to calculate target frequencies for each window (**Figure 9-10**). Based on the reference period data, the target frequency for maximum discharge in the October window is 43 percent of water years; the target for the minimum discharge in the April–June window is 64 percent of water years; the target for having both the maximum and the minimum discharges in their respective windows is 32 percent of water years. During WY2014, the maximum of mean monthly discharge was 102 m^3/s and occurred in July (**Figure 9-10**). The minimum was 8 m^3/s and occurred in January; the mean monthly discharge in each of the three preceding months (October–December) was no more than 1 m^3/s higher than that for January. Therefore, neither the maximum nor the minimum occurred in its target window. October, the target window for the maximum, had almost the lowest discharge of months in WY2014. Evaluated over the entire interim period, the maximum occurred in the October target window only once (WY2012), or 8 percent of water years—much less frequently than the reference period target of 43 percent. During the interim period, the maximum of monthly discharge occurred in the target window for the minimum in 31 percent of years; in contrast, this happened in only 13 percent of years during the reference period. The minimum occurred in the April–June target window in 54 percent of water years in the interim period—also less frequently than the reference period target of 64 percent. During the interim period, the maximum and minimum never occurred in the target window in the same water year, which is much less often the reference period target value of 32 percent of water years. Thus, the intra-annual variability component of Expectation 2 is not being met over the interim period.

Inter-annual variability was assessed with the coefficient of variation. The addition of WY2014 to the interim period resulted in a coefficient of variation for monthly mean discharge that ranged from 0.78 to 1.53. Only five months (May, August, September, February, and March) during the interim period had a coefficient of variation less than 1.0, so the expectation was not met. Thus, neither the intra-annual nor the inter-annual component of Expectation 2 is being met during the interim period.

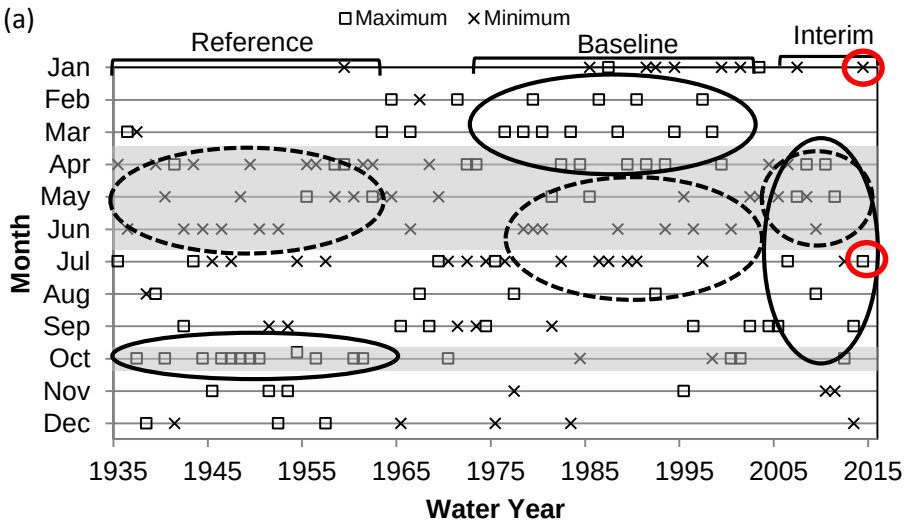

Figure 9-10. Month of the maximum and minimum of mean monthly discharge at S-65 for each water year of the pre-channelization or reference period (WY1935–WY1962, used to derive restoration targets), channelized or baseline period (WY1972–WY1999), and interim period (WY2002–WY2014). Shading indicates the target windows of April–June for the minimum and October for the maximum based on high concentration of values during the reference period. Circles indicate the concentration of points for the maximum (solid line) and minimum (dashed line) values for mean monthly discharge during the reference, baseline, and interim periods. Red circles enclose the maximum and minimum values for WY2014. (From Anderson, 2014a.)

Importance of Intra- and Inter-annual Flow Patterns

Occurrence of the maximum and minimum of monthly discharge in their respective target windows at an appropriate frequency, especially if there is a gradual recession between them (see Expectation 4 below), aligns the annual discharge pattern with the life cycles of many organisms that use the river and floodplain, as it did during the reference period. The timing of the maximum and the minimum create a pattern of decreasing discharge and a corresponding decrease in stage during the dry season. In years when the maximum discharge is sufficient to inundate at least a portion of the floodplain, the general decline in discharge allows fish and aquatic invertebrates to move into the floodplain to forage and reproduce. The gradual decline in water levels also helps to concentrate prey for foraging wading birds (Weller, 1995). Even in years when the floodplain is not inundated, the seasonal pattern of declining discharge is important for organisms in the river channel. For example, the strength of largemouth bass year-classes in four Florida rivers is negatively related to the median discharge during the spring (Bonvechio and Allen, 2005). Decreasing discharge during dry seasons helps protect nests from being destroyed and the washing out of offspring.

Stage

Stage (water surface elevation) at specific locations is a function of discharge of water flowing through the Phase I area and characteristics of the river channel and floodplain where it is measured. At specific measurement locations, stage can be compared to the ground elevation to determine water depth and the duration of inundation (hydroperiod). Temporal and spatial patterns of stage are an important aspect of habitat for many aquatic organisms.

Pre-channelization stage data for two locations in the pre-channelization Kissimmee River have been used to develop two restoration expectations: Expectation 3 for amplitude of stage fluctuation and hydroperiod, and Expectation 4 for stage recession events. This year's stage evaluation includes a criterion for the hydroperiod and depth requirements of broadleaf marsh (BLM), the dominant wetland plant community in the pre-channelization floodplain. The BLM Criterion is based on what is known about the hydrologic requirements of this plant community (Spencer and Bousquin, 2014).

At five floodplain sites (see locations in **Figure 9-4)**, hydrographs for WY2014 showed stage rising at the beginning of the wet season, reaching a peak in late July, and then generally declining (**Figure 9-11**). The stage decline in WY2014 was interrupted by periodic stage reversals, especially in September and late January, in response to increases in discharge from upstream and basin runoff. The change in stage was greater at the northern floodplain sites than in the southern floodplain; stage increases in the southern floodplain were constrained by limitations of the headwater stage of S-65C, the downstream water control structure.

Expectation 3

River channel stage will exceed the average ground elevation for 180 days per water year and stages will fluctuate by at least 1.14 meters (m) (Anderson et al., 2005).

Expectation 3 has two components relating to hydroperiod, specifying an amplitude of stage fluctuation of ≥ 1.14 m in a water year and a hydroperiod of ≥ 180 days. The three northern floodplain sites (PC61, PC52, and PC44) exceeded the amplitude of stage fluctuation criterion of 1.14 m as they have in all previous years (**Table 9-4**). Hydroperiods in the northern floodplain were variable with only one site (PC61) exceeding the 180-day criterion. Only one of the northern floodplain sites (PC61) met both the amplitude and hydroperiod criteria of Expectation 3 in WY2014. In the southern floodplain, stage is influenced by a backwater effect from S-65C, the downstream water control structure, which will be removed during the final phases of KRRP construction. The amplitude of stage fluctuation was much less in the southern floodplain than in the northern floodplain; only one of the southern floodplain sites (PC32) exceeded the 1.14 m criterion. The lack of stage fluctuation in the southern floodplain resulted in both sites exceeding the hydroperiod criterion of 180 days. Both the amplitude and hydroperiod components of Expectation 3 were met an average of 7.2 years per site or 55 percent of the 13-year interim period. All five sites met both criteria in only 2 of 13 years (15 percent) during the interim period. During the reference period, both components were met in 82 percent of years—a higher frequency of occurrence than is occurring during the interim period.

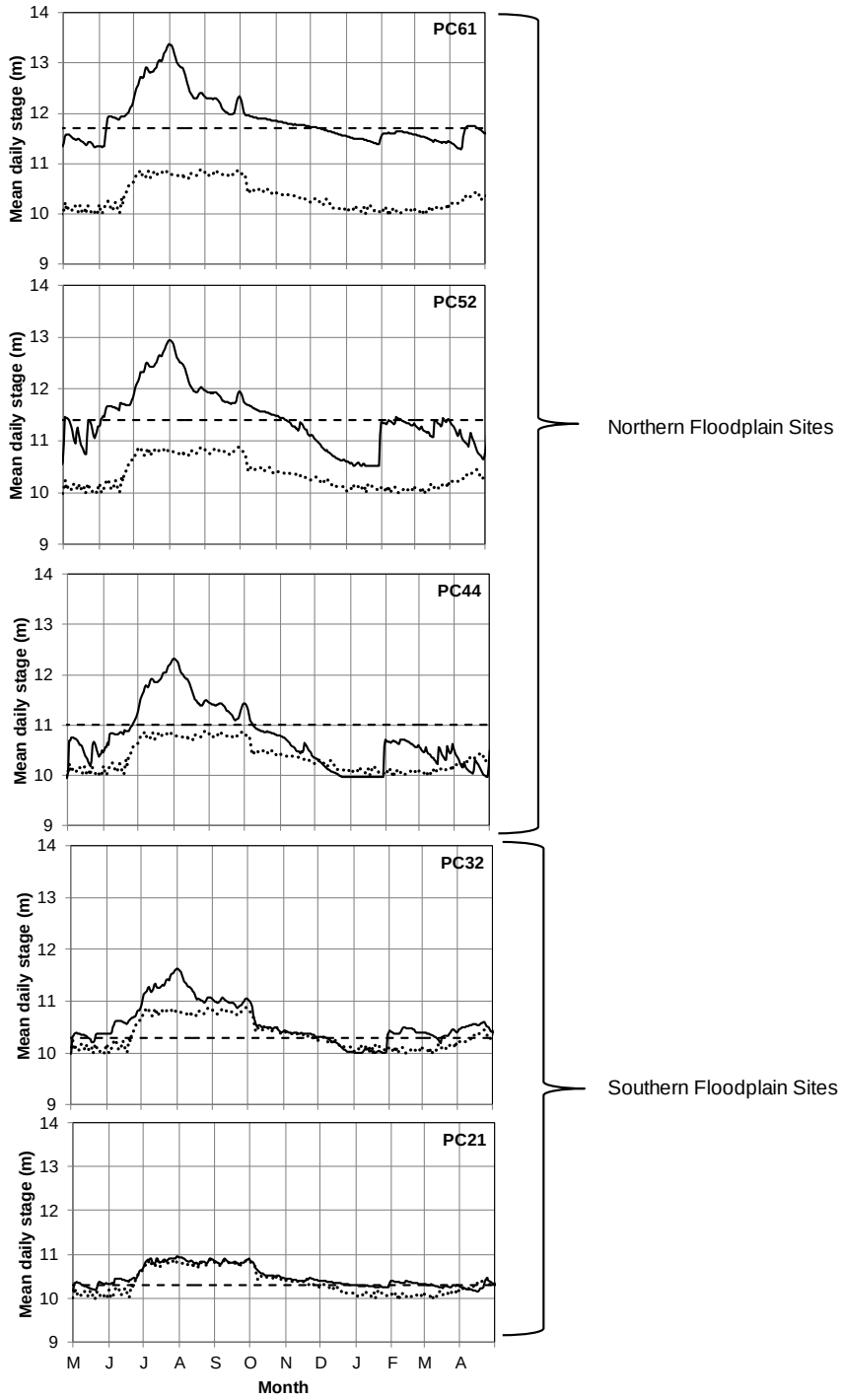

Figure 9-11. Water level (stage) in meters (m) during WY2014 at five floodplain locations. The dashed line is the ground elevation at the location. The dotted line is the headwater stage at S-65C. Sites are arranged from north (PC61) to south (PC21). Northern floodplain sites occur at higher elevations than the range of managed water levels at S-65C, the downstream water control structure; southern floodplain sites occur at elevations near the lower end of managed water levels at S-65C.

Table 9-4. Values for amplitude of stage fluctuation and hydroperiod in WY2014, whether the criteria of amplitude of at least 1.14 m and hydroperiod of at least 180 days were both met at a site in WY2014, the frequency that both criteria were met at each site during the 13-year interim period, and the Broadleaf Marsh Criterion. PC61, PC52, and PC44 are located in the northern floodplain; PC32 and PC21 are located in the southern floodplain.

Site	Expectation 3 - Amplitude of Stage Fluctuation and Hydroperiod				Criterion - BLM Hydroperiod (days)		
	Amplitude (m) in 2014	Hydroperiod (days) in 2014	Both Metrics Met in 2014	Number of Years Met in the Interim Period	2014	Interim Average	Number of Years Met
PC61*	2.09	197	Yes	10	97	115	2
PC52	2.42	174	No	8	105	108	1
PC44	2.36	104	No	5	82	88	1
PC32	1.63	299	Yes	10	116	269	11
PC21	0.79	273	No	3	104	265	11
			Interim Period Average =	7.2			5.3
			Interim Period Percentage =	55			40
			Target (Pre-channelization Percentage) =	82			53

*PC61 has only 12 years of data; averages across sites are weighted by the number of years

Broadleaf Marsh Criterion

> Water depth greater than or equal to 0.3 m for at least 210 days per water year (Anderson, 2014a).

The northern floodplain sites did not meet the BLM Criterion of water depth of 0.3 m for 210 days in WY2014 and have only occasionally met it during the interim period (**Table 9-4**). In the northern floodplain, hydroperiods with a depth of 0.3 m were only 39–54 percent of the 210-day duration in the criterion, which is insufficient to reestablish broadleaf marshes. The southern floodplain sites met the BLM Criterion in WY2014 as they have in most years of the interim period. When values were averaged across the five sites over the interim period, the BLM Criterion was met in only 40 percent of the years and did not meet the target of 53 percent from the pre-channelization data. Therefore the BLM Criterion is not being met during the interim period. This corresponds with findings based on vegetation data reported in Spencer and Bousquin (2014).

Importance of the Stage Criteria (Expectation 3 and BLM Criterion)

The first component of Expectation 3, amplitude of stage fluctuation, evaluates whether water levels are (undesirably) stabilized as they were in the channelized system; the hydroperiod component is intended to evaluate whether the long period of floodplain inundation that was characteristic of the pre-channelization period is occurring. The BLM Criterion is a refinement of the hydroperiod component of Expectation 3, specifying the hydroperiod and depth requirements of the dominant and most characteristic wetland plant community of the pre-channelization floodplain. Fluctuating water levels meeting the BLM Criterion also will provide sufficient water depth for extended periods that allow aquatic organisms such as aquatic invertebrates and fish to access and use the floodplain. Inundated areas of floodplain are also used by foraging waterfowl and wading birds.

Expectation 4

> An annual prolonged recession event will be reestablished with a duration of > 173 days and with peak stages in the wet season receding to low stage in the dry season at a rate that will not exceed 0.3 m per 30 days (Anderson et al., 2005).

In WY2014, a single prolonged recession event with the characteristics described in Expectation 4 did not occur. Multiple recession events occurred at two monitoring sites (PC52, PC44) in the northern floodplain (**Table 9-5**). The second and third events were the result of increases in discharge causing stage reversals (increases) that were larger than the 0.45-m threshold used to identify a new recession event. In late September, stage reversals also occurred at PC62, PC52, and PC44 that almost exceeded the 0.45-m threshold (**Figure 9-11**). Almost all of the events measured in WY2014 had shorter durations than the 173-day threshold in the expectation and exceeded the target maximum recession rate of 0.3 m per 30 days. Thus, in WY2014, Expectation 4 was not met.

Considered over the entire interim period, Expectation 4 is not being met. During the interim period, all five sites averaged more than one recession event per year (**Table 9-6**). Recession events had shorter mean durations and faster recession rates than the criteria in Expectation 4 at all of the sites except for PC21. On average, only 42 percent of water years had an event that met the duration and recession rate criteria of Expectation 4, compared to 73 percent during the reference period.

Table 9-5. Calculation of recession rates in meters (m) for WY2014 events at five sites. Recession rate is calculated from the timing (T_{max}) and elevation (h_{max}) of the maximum stage for the event to the timing (T_{min}) and elevation (h_{min}) of the minimum stage. The recession rate (R) is calculated by dividing the change in water level elevation (Δh) by the change in time (ΔT) and multiplying by 30 days.

Site	T_{max}	h_{max} (m)	T_{min}	h_{min} (m)	Δh (m)	ΔT (days)	R (m per 30 days)
PC61	31-Jul-13	13.37	10-Apr-14	11.27	2.09	253	0.25
PC52	1-Aug-13	12.94	8-Jan-14	10.52	2.42	160	0.45
PC52	13-Feb-14	11.47	29-Apr-14	10.64	0.82	75	0.33
PC44	5-May-13	10.75	20-May-13	10.18	0.57	15	1.14
PC44	1-Aug-13	12.32	27-Dec-13	9.96	2.35	148	0.48
PC44	13-Feb-14	10.72	29-Apr-14	9.97	0.75	75	0.30
PC32	1-Aug-13	11.62	1-Jan-14	10.01	1.61	153	0.32
PC21	29-Jul-13	10.95	15-Apr-14	10.16	0.79	260	0.09

Table 9-6. Total number of recession events during the interim period measured at five sites and mean (standard error) values for the number of events per water year, the change in stage during an event (Δh), the duration of the event (ΔT), and the recession rate (R).

Site	Total Number of Events	Number per Water Year	Δh (m)	ΔT (days)	R (m per 30 days)
PC61	28	2.3 (0.33)	1.13 (0.03)	111 (3)	0.52 (0.02)
PC52	38	2.8 (0.26)	1.16 (0.02)	86 (2)	0.53 (0.01)
PC44	38	2.8 (0.25)	1.11 (0.02)	90 (2)	0.58 (0.01)
PC32	24	1.8 (0.28)	0.99 (0.02)	125 (4)	0.42 (0.01)
PC21	16	1.2 (0.23)	0.77 (0.02)	201 (10)	0.19 (0.01)

Importance of a Single, Slow Recession Event

A slow recession rate prolongs floodplain inundation, with multiple positive, ecosystem-level benefits including helping to meet the hydroperiod requirements of wetland vegetation, especially long-hydroperiod BLM community that dominated the pre-channelization floodplain, and providing expanded habitat for fish, aquatic invertebrates, and other organisms. A slow recession after periods of inundation also creates drying pools that concentrate prey used by foraging wading birds; large reversals late in the dry season can cause wading birds foraging in the floodplain to disperse.

Summary of Hydrologic Evaluation

- Expectation 1: the continuous discharge requirement was met in WY2014 but overall is not being met in the interim period.
- Expectation 2: the intra-annual and inter-annual discharge components were not met in WY2014. Neither the maximum nor the minimum of mean monthly discharge occurred in the target window; the target window for the maximum had almost the lowest value of mean monthly discharge. Over the entire interim period, neither the maximum nor the minimum of mean monthly discharge is being met at the reference period target frequencies.
- Expectation 3: the amplitude of stage fluctuation and hydroperiod criteria were both met at only two sites in WY2014. Over the interim period, these components are being met less often than in the reference period.
- The BLM Criterion was met in WY2014 only at sites in the southern floodplain, which are influenced by the backwater effect of S-65C; northern floodplain sites did not meet the BLM Criterion in WY2014 and have rarely met it in the interim period.
- Expectation 4 for recession events was not met in WY2014; two monitoring sites had multiple recession events, and only two sites had events that met the duration and recession rate criteria. On average, the duration and recession rate criteria for this expectation are being met less often in the interim period than during the reference period, so this expectation is not being met in the interim period.

A recent paper that reviewed hydrologic conditions during the interim period (WY2002–WY2011) concluded that although none of the hydrologic expectations was being met during the interim period, most metrics showed improvements during the interim period when compared with the channelized baseline period (Anderson, 2014a).

Adaptive flow management provides a mechanism for water control operations in the Kissimmee Basin to be changed in response to ongoing collection and evaluation of hydrologic and other ecological data to help us better meet at least some of the hydrologic expectations during the interim period prior to completion of KRRP and implementation of the HRS. It may be possible to address aspects of floodplain stage criteria (Expectation 3 and BLM Criterion) that affect the extent, duration, and timing of inundation of the northern floodplain in the Phase I area; the timing of maximum and minimum mean monthly discharge (Expectation 2); and avoid multiple stage recession events within a water year (Expectation 4). A planned modification of interim S-65 operations would be implemented as rainfall abates near the end of the wet season, i.e., before the regulation schedule reaches its high pool (maximum elevation). Such operations would involve adjusting discharge in the target window to either achieve peak flow in or in months adjacent to the October window, or to better-mimic pre-regulation patterns within the target window for years when discharge peaks earlier in the wet season. Implementation of such operations involves continuing S-65 discharge and (conditions permitting), increasing rather than reducing discharge to a minimum in the late wet season. [In recent years, discharge has been minimized at this time to allow stage in the headwater lakes to rise as high as possible, even in years when it was unlikely that lake stages could reach high pool; despite that since 2001 discharge has been generally held low (<~14.2 m^3/s) except during flood control releases, high pool has been reached almost exclusively in years when wet season rainfall was well above average]. Both lake stage highs and periods of extremely high discharge within this window are dependent on—and therefore should occur at about the same frequency as—extreme rain events within the window (approximately 30 percent of years). Continuing or increasing discharge in this critical window moves hydrologic conditions toward pre-channelization patterns. The

benefits of such operational changes for river/floodplain hydrology include (1) improvement in the seasonal timing of the maximum and minimum of mean monthly discharge; (2) reduction of the chances of large increases in discharge late in the dry season, which can cause reversals that negatively impact fish and wading birds; (3) potentially initiate slow dry season recessions that help to retain water on the northern floodplain longer into the dry season, potentially encouraging snail kite nesting in the northern floodplain where the species has shown pre-mating behavior with the arrival of apple snails in the Phase IV restoration area; and (4) enter dry season with lower stage in the lakes to help avoid problems of high dry season recession rates and unnatural patterns of increased discharge in late dry season as noted above and in **Figure 9-10**.

DISSOLVED OXYGEN

Expectation 8

> Mean daytime concentration of DO in the Kissimmee River channel at 0.5–1.0 m depth will increase from < 1–2 mg/L to 3–6 mg/L during the wet season (June–November) and from 2-4 mg/L to 5–7 mg/L during the dry season (December–May). Mean daily concentrations will be greater than 2 mg/L more than 90 percent of the time. DO concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50 percent of the time (Colangelo and Jones, 2005).

Restoration is expected to improve DO concentrations in the river channel by reintroducing flow to the river channel, which should increase rates of reaeration and reduce the amount of organic matter that accumulated on the channel bed after the river was channelized and flow was cut-off by construction of the canal. However, reference DO data from the prechannelized, flowing river are not available to support quantitative performance measures. Therefore, reference conditions used to provide restoration targets were derived from data from other free-flowing, blackwater streams in South Florida (Colangelo, 2014).

Reference data were comprised of at least 11 manual grab samples (daytime only) collected from each of the seven streams over a minimum of one year. Some streams were sampled for more than 10 years (**Figure 9-12**). The period of record for these reference data is 1973–1999. These data were used to develop the expectation metrics for mean daytime DO concentrations during the wet and dry seasons. The mean daytime DO concentration in the reference streams was 4.2 mg/L during the wet season and 6.1 mg/L during the dry season (**Figure 9-13**). In five of the seven streams, DO was greater than 5 mg/L in more than 50 percent of the samples. In all of the streams, more than 90 percent of the samples had concentrations greater than 2 mg/L.

To establish baseline conditions in the stagnant river runs before restoration, DO was monitored daily at 15-minute intervals, day and night, from 1997 through 1999 at a depth of approximately 1 m at two stations in remnant river channels in Pool C. Sampled river channels were approximately 20–30 m wide and 2–3 m deep. These data were used to evaluate the expectations for the percentage of time that mean daily DO concentrations in the river channel were beyond their respective thresholds (see *Expectation 8* above). DO also was sampled monthly using manual grab samples, during the day, within seven remnant river runs in Pools A and C. Both of these monitoring efforts have continued beyond the 1997–1999 baseline period into the interim period (2001–current) and provide comparisons of conditions before, during, and after restoration construction.

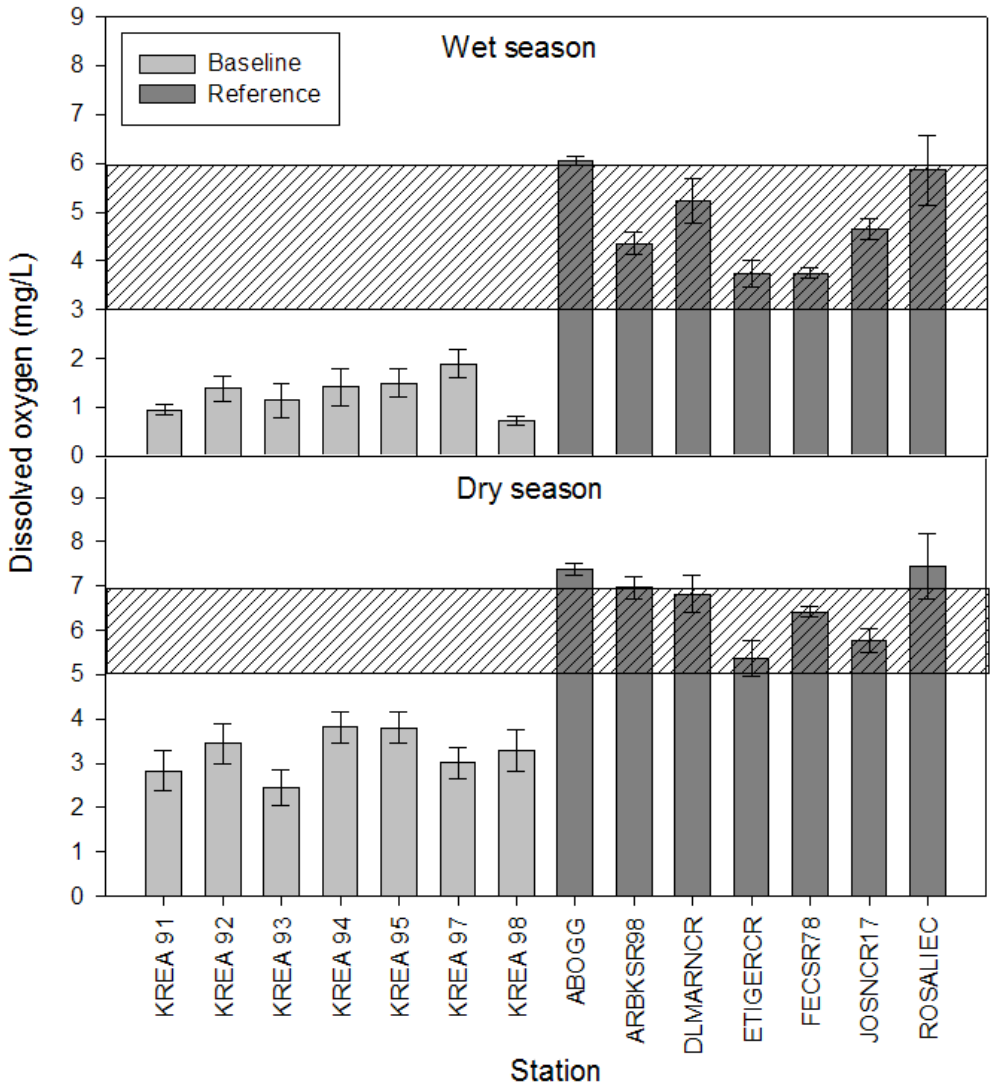

Figure 9-12. Mean [± standard error (S.E.) of the mean] dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) in free-flowing, blackwater South Florida streams (dark-shaded) and remnant runs (light-shaded) of the channelized Kissimmee River during the wet (June–November) and dry (December–May) seasons. Hatched areas represent expected range of DO concentrations in the Kissimmee River after restoration. Station names shown are South Florida Water Management District (SFWMD) monitoring sites.

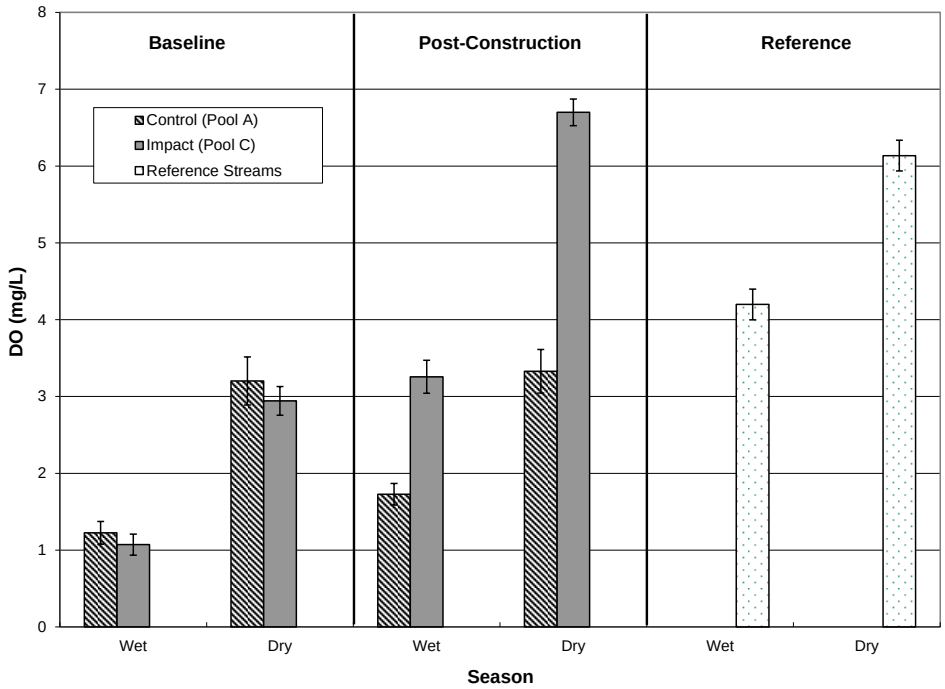

Figure 9-13. Mean (± S.E.) DO concentrations (mg/L) in reference streams (period of record = 1973–1999) and control and impact areas during the wet and dry seasons, during the baseline (1997–1999) and post-restoration (2001–present) periods.

During the baseline period, DO concentrations in the remnant river runs were frequently below 1 mg/L throughout the water column at all times of day. A gradient in DO concentration, decreasing with depth, was common during the warmer months of the year. DO concentrations near the surface could reach 4–5 mg/L, but concentrations near the bottom were lower than the detection limit (< 0.2 mg/L). During 1997–1999, mean DO concentrations in remnant river runs in Pool A and C were 1.2 mg/L and 1.1 mg/L, respectively, during the wet season, and 3.2 mg/L and 3.0 mg/L, respectively, during the dry season (**Figure 9-13**). DO concentrations exceeded 2 mg/L for only 22 percent of the baseline period, and 5 mg/L for only 6 percent of this period. The reference and baseline data were used to develop four components of Expectation 8 (Colangelo and Jones, 2005) to evaluate changes in DO as restoration proceeds (**Table 9-7**).

Table 9-7. Dissolved oxygen (DO) restoration expectation metrics and Water Year 2014 (WY2014) (May 1, 2013–April 30, 2014) values.

Expectation Metric	WY2014 Value	Metric Achieved in WY2014?
Mean daytime DO concentration in the river channel at 0.5–1.0 meter (m) depth will increase from < 2 milligram per liter (mg/L) to 3–6 mg/L during the wet season (June–October).	2.8 ± 0.5 mg/L	No
Mean daytime DO concentration in the river channel at 0.5–1.0 m depth will increase from 2–4 mg/L to 5–7 mg/L during the dry season (December–May).	7.1 ± 0.2 mg/L	Yes
Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90 percent of the time (annually).	79%	No
DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50 percent of the time annually.	--	Data not collected in WY2014

Following completion of the first phase of construction, DO concentrations within the restoration area (Pool C) averaged 3.3 mg/L during the wet season and 6.7 mg/L during the dry season (average of all post-construction data) (**Figure 9-13**). In comparison, post-construction DO concentrations in the control area (Pool A) averaged 1.7 and 3.3 mg/L during the wet and dry seasons, respectively (**Figure 9-13**). Mean DO concentrations in the restoration area increased from less than 3.0 mg/L before construction to 7.1 mg/L in WY2014 (**Figure 9-14**). Also in WY2014, mean daily water column DO concentrations were greater than 2.0 mg/L for 79 percent of the time. In summary, one of the three metrics measured in WY2014 to evaluate DO response to restoration was met under the interim regulation schedule (**Table 9-7**). Despite the general improvement in DO concentrations within the river channel, short-term declines coinciding with high flow events continue to be an issue during the wet season. See the *Hypoxia in the Kissimmee River: Consequences, Causes and Water Management* section for more information on DO sags. The causes of these DO sags are being determined and techniques are being developed to ameliorate them through adaptive management of water control operations. The final determination of restoration success with respect to DO in the river channel will be made after implementation of the HRS.

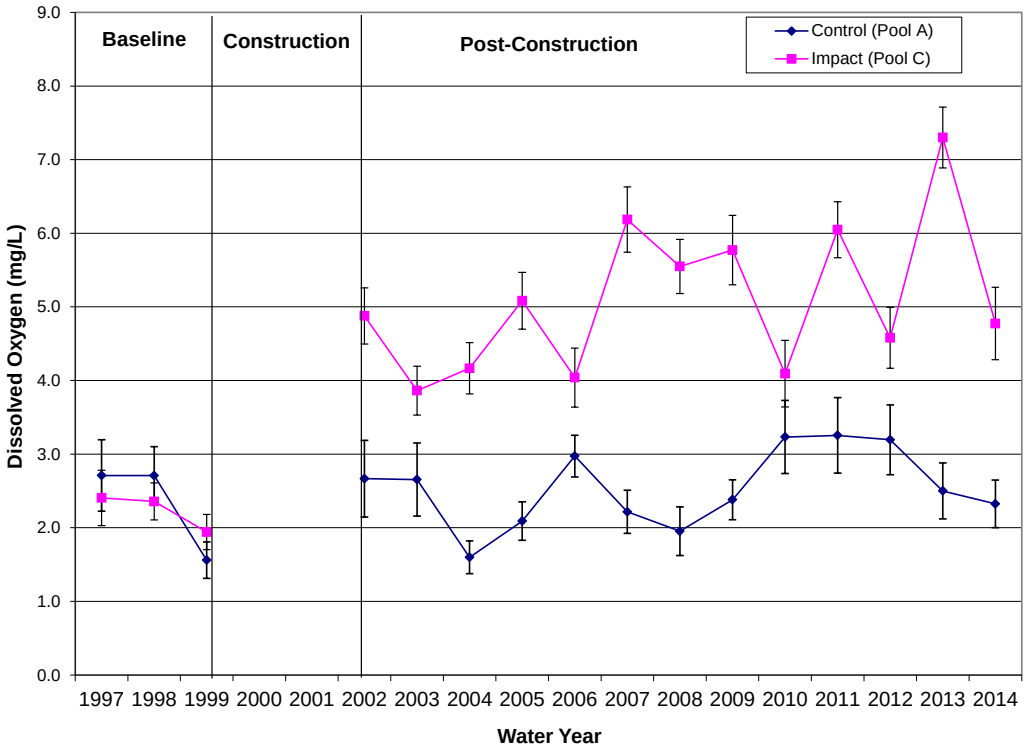

Figure 9-14. Mean DO concentrations (mg/L) in the Kissimmee River for each water year during the baseline and post-construction periods.

PHOSPHORUS AND NITROGEN

Expectation

No expectation has been established for phosphorus and nitrogen.

As Lake Okeechobee's largest tributary, the Kissimmee River conveys a major portion of phosphorus to the lake (see Chapter 8 of this volume). Construction of the C-38 canal and lateral drainage ditches has presumably contributed to phosphorus loading from the Kissimmee Basin by facilitating downstream transport of phosphorus runoff and limiting opportunities for detention and assimilation in floodplain wetlands. Because nutrients were not monitored before channelization, the amount of increase, if any, resulting from the C&SF Project cannot be estimated from historical data. However, knowledge of the river's former characteristics and its floodplain and watershed (Bousquin et al., 2005; HDR Engineering, Inc., 2012) make it reasonable to assume that concentrations were lower prior to channelization and watershed development.

Although the lack of pre-channelization data has precluded development of a quantitative expectation for nutrient loading reduction, the restored river is anticipated to attenuate loading from lateral tributaries and the headwater lakes once a more natural hydroperiod and a stable wetland ecosystem become established. In the meantime, phosphorus concentrations may increase periodically as the nutrient runs off former pastures and the floodplain transitions from terrestrial to wetland vegetation.

This section presents nutrient loads and concentrations monitored at the five C-38 water control structures and two stations in Lake Kissimmee. Data collected since completion of Phase I restoration construction (WY2002–WY2014) are compared to baseline data (WY1975–WY1995) obtained prior to construction.[1]

To estimate phosphorus and nitrogen loading along the C-38 canal, total phosphorus (TP) and total nitrogen (TN) concentrations were monitored routinely at each of the canal's water control structures along with daily estimates of discharge. Concentrations were measured in grab samples that were usually collected every two weeks. Total phosphorus concentrations were also monitored with auto-samplers that collected sub-samples multiple times per day and combined them into composite samples that were picked up weekly.[2] Estimates of daily nutrient loads were computed from measured or interpolated concentrations and daily discharges with preference given to auto-sampler data. These daily loads were then summed annually.[3] Differences between sub-sets of annual nutrient loads or concentrations were examined with the non-parametric Mann-Whitney U-Test (due to non-normal data distributions) and Student's t-test.

Nutrient loads are highly dependent on discharge and vary greatly from year to year. At S-65, for example, annual discharges during the post-Phase I period ranged over 10-fold from approximately 121,000 ac-ft to over 1,500,000 ac-ft, while annual TP loads ranged from 16 to 239 metric tons (mt) (**Figure 9-15**).

Relative to other years since Phase I construction, WY2014 was an average year for discharge and nutrient loads. For example, WY2014 discharge at S-65 (about 766,000 ac-ft) was the median of annual discharges at this location during WY2002–WY2014. The TP and TN loads at S-65 (72 mt and 1,176 mt, respectively) were between the medians and means for this period. Nutrient loads at other structures were also near their respective means and medians for this 13-year period (**Figure 9-15**).

Compared to the baseline period, the C-38 structures did not convey significantly more discharge during the post-Phase I period, but most of the structures did release significantly more TP (**Table 9-8** and **Figure 9-16**). The largest percent increase was at S-65, whose median annual TP load rose 97 percent. This increase is only partially attributable to discharge, which increased by 25 percent. TP loads also increased significantly at S-65A, S-65C, and S-65D. Although TP load was also higher at S-65E, the change was not statistically significant. TN loads did not change significantly at any of the structures (**Table 9-8**).

[1]In previous SFERs, the baseline period for a similar analysis was the calendar years 1974–1995. Here, the baseline period has been changed to the WY1975–WY1995 to be consistent with the use of water years for the post-Phase I period. WY1996–WY2001 were not included in this analysis because certain events and activities, including Phase I construction, gate construction at S-65, and the Lake Kissimmee managed drawdown in WY1996, could have affected the water quality results.

[2]TP samples from the auto-samplers were usually composited on a weekly basis except for daily composite samples that were collected in calendar years 1997–1999. The frequency of auto-sampling was usually time-proportional (samples of equal volume collected evenly throughout a 24-hour day regardless of flow). In recent years, samples at S-65E have been collected with a flow-proportionally programmed auto-sampler.

[3]Loads at S-65A include estimates of loads at S-65AX and other estimated loading over the S-65A tieback levee during a severe storm in October 2011 (loads calculated from S-65A concentrations and estimated discharge data from Dr. Ken Konyha, SFWMD). Discharge and loads at S-65D include the auxiliary structures S-65DX1 and S-65DX2 for WY2010–WY2014.

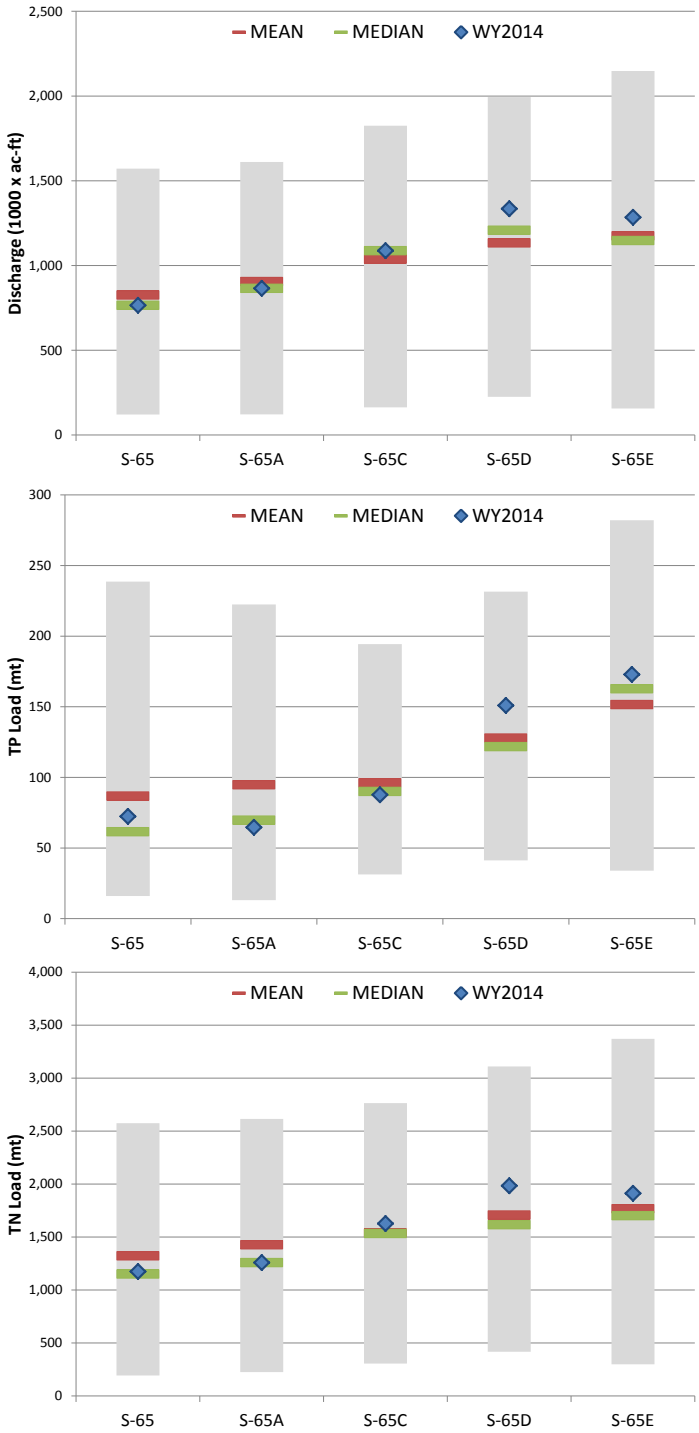

Figure 9-15. Annual discharge, TP load, and TN load at C-38 structures in WY2014 in relation to means and medians for the post-Phase I construction period (WY2002–WY2014). The shaded columns indicate the range of annual values during this 13-year period.

Table 9-8. Comparison of median and mean annual discharges in acre-feet (ac-ft), nutrient [total phosphorus (TP) and total nitrogen (TN)] loads in metric tons (mt), and flow-weighted mean (FWM) nutrient concentrations in milligrams per liter (mg/L) at C-38 structures for the baseline period (WY1975–WY1995) and post-Phase I construction period (WY2002–WY2014). Values in red and larger font indicate a statistically significant change between the two periods.*

	Structure				
	S-65	**S-65A**	**S-65C**	**S-65D**	**S-65E**
Discharge (ac-ft)					
Median – Baseline	612,629	736,560	849,498	812,334	969,973
Median – Post-Phase I	765,563	865,623	1,087,973	1,208,712	1,147,369
Percent Change	25%	18%	28%	49%	18%
Mean – Baseline	646,302	702,457	790,478	851,430	936,941
Mean – Post-Phase I	826,400	905,674	1,037,977	1,133,815	1,174,978
Percent Change	28%	29%	31%	33%	25%
TP Load (mt)					
Median – Baseline	31.33	36.16	49.27	69.90	97.96
Median – Post-Phase I	61.58	69.71	90.07	121.81	162.77
Percent Change	**97%**	**93%**	**83%**	**74%**	66%
Mean – Baseline	33.32	40.81	51.16	77.09	116.30
Mean – Post-Phase I	86.77	94.82	96.17	127.87	151.55
Percent Change	**160%**	**132%**	**88%**	**66%**	30%
TP FWM Concentration (mg/L)					
Median – Baseline	0.042	0.046	0.053	0.077	0.102
Median – Post-Phase I	0.077	0.075	0.070	0.088	0.109
Percent Change	**83%**	**63%**	**32%**	**14%**	7%
Mean – Baseline	0.043	0.050	0.054	0.078	0.111
Mean – Post-Phase I	0.084	0.083	0.082	0.096	0.112
Percent Change	**95%**	**64%**	**51%**	**22%**	1%
TN Load (mt)					
Median – Baseline	1,164.1	1,265.4	1,302.1	1,167.1	1,566.1
Median – Post-Phase I	1,151.4	1,258.8	1,534.5	1,616.6	1,702.8
Percent Change	-1%	-1%	18%	39%	9%
Mean – Baseline	1,084.2	1,164.1	1,320.4	1,421.2	1,577.7
Mean – Post-Phase I	1,322.9	1,427.7	1,538.4	1,708.5	1,767.9
Percent Change	22%	23%	17%	20%	12%
TN FWM Concentration (mg/L)					
Median – Baseline	1.39	1.33	1.37	1.34	1.38
Median – Post-Phase I	1.30	1.32	1.23	1.28	1.27
Percent Change	-6%	-1%	-10%	-5%	-8%
Mean – Baseline	1.42	1.40	1.39	1.36	1.43
Mean – Post-Phase I	1.31	1.30	1.26	1.26	1.27
Percent Change	-7%	-7%	-10%	-7%	**-11%**

* Because data sets were not always normally distributed, the non-parametric Mann-Whitney U-Test was used to determine the statistical significance of differences between median values for the two periods. The significance of differences between means was examined with Student's t-test. Differences are statistically significant at $p < 0.05$.

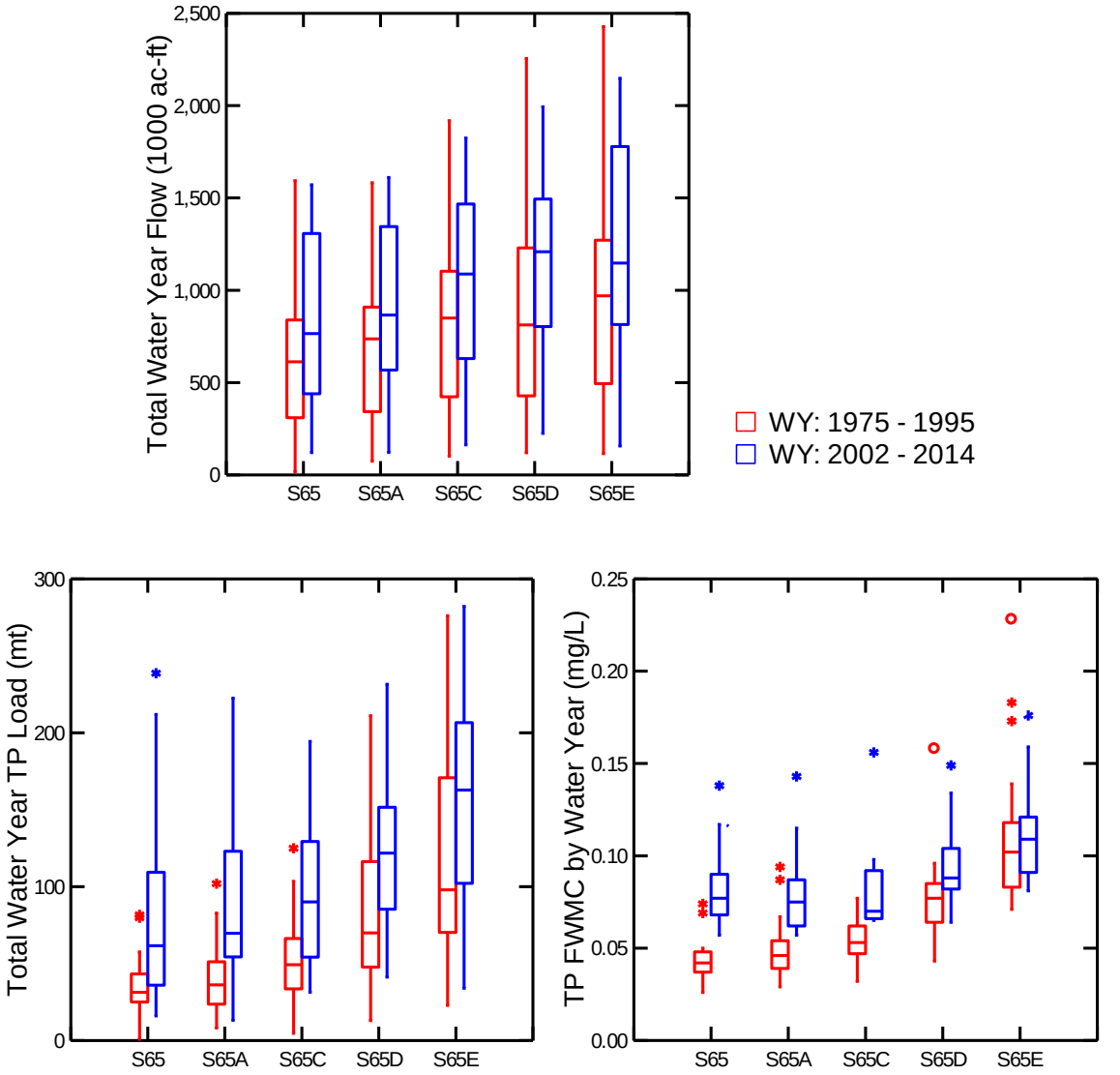

Figure 9-16. Comparison of annual discharges, total phosphorus (TP) loads, and flow-weighted mean (FWM) TP concentrations at C-38 structures for the baseline period (WY1975–WY1995) and post-Phase I construction period (WY2002–WY2014). Each box plot shows the median, and 25th and 75th percentiles of the data distribution. Lines extending from the box indicate the spread of values within approximately two standard deviations of the mean. Asterisks and circles represent values >2 and >4 standard deviations from the mean, respectively.

The flow-weighted mean (FWM) nutrient concentration represents the average quantity of TP or TN transported by the river for a given volume of water. By normalizing nutrient loads for discharge, the FWM concentration is a useful metric for assessing change due to other factors such as land use practices in the watershed.

Annual FWM concentrations were calculated for each structure by dividing the annual nutrient load by the annual discharge. Median and mean concentrations for the baseline and post-Phase I periods were determined from these annual values (**Table 9-8** and **Figure 9-16**). Over these two periods, the median annual FWM TP concentration at S-65 increased significantly from 0.042 mg/L to 0.077 mg/L. Concentrations also increased significantly at S-65A, S-65C, and S-65D, but not at S-65E. No significant change occurred in FWM TN concentrations except for a small decline in the mean concentration at S65E (**Table 9-8**).

Closer examination of the FWM TP concentrations reveals that values upstream (S-65) and downstream (S-65C) of the restoration area are related, with values from the post-Phase I period being generally higher than values from the baseline period (**Figure 9-17**). Linear regression performed on log-transformed values from both periods combined demonstrated a significant positive relationship ($R^2 = 0.58$; $p < 0.05$).

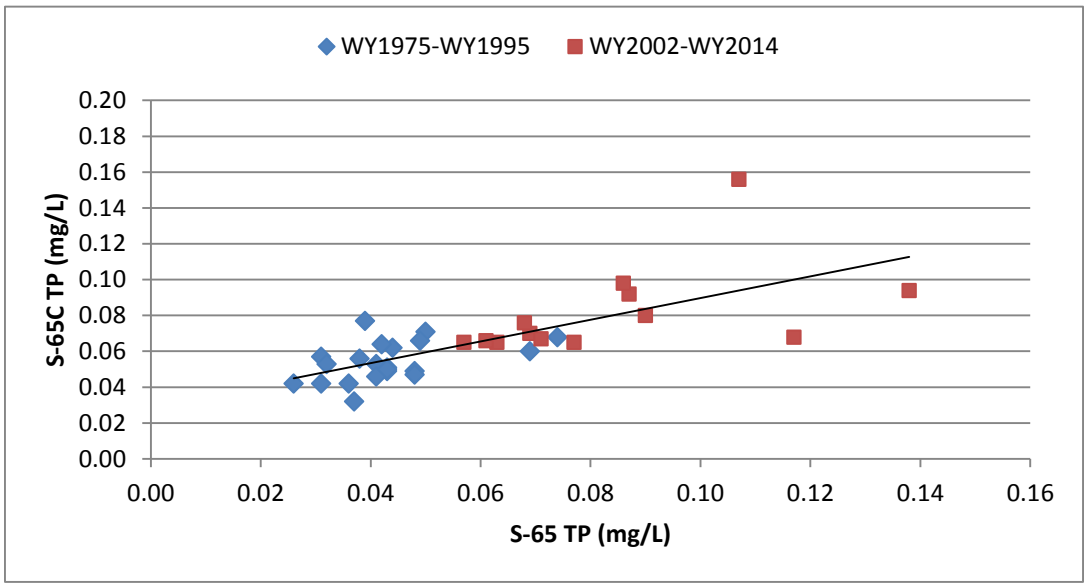

Figure 9-17. Comparison of annual FWM TP concentrations at S-65C versus S-65 during the baseline period (WY1975–WY1995) and post-Phase I construction period (WY2002–WY2014). The regression line is for both periods combined.

Statistical analysis (t-test) also shows that the mean FWM TP concentration at S-65C (0.054 mg/L) was significantly higher ($p < 0.01$) than the mean at S-65 (0.043 mg/L) during the baseline period. In the post-Phase I period, mean concentrations at these structures had both risen significantly (**Table 9-8**), but they were no longer significantly different from each other. In fact, in each year of the post-Phase I period, the difference between values at these two structures was less than 16 percent except in WY2005–WY2006 when S-65 was higher (due to hurricane disturbance) and WY2007 when S-65C was higher (a drought during which S-65 discharged only part of the year). Therefore, barring events such as hurricanes and drought, TP concentrations at S-65 and S-65C have been more similar than they were before the restoration project began,

perhaps due to nearly continuous flow prescribed under the current interim headwater regulation schedule. It is reasonable to conclude that TP at S-65C is now more dependent on TP at the headwater structure and has increased due to the higher concentrations and loads at S-65.

To evaluate whether the increase at S-65 was due to higher TP concentrations in Lake Kissimmee, data were examined from two lake stations that the SFWMD has monitored since 1982: E02 in the northwest portion of the lake and E04 in the east-central portion. These data were compared to S-65 data for the periods WY1983–WY1995 and WY2002–WY2014. **Figure 9-18** plots the annual mean TP concentrations (not flow-weighted) at each station.

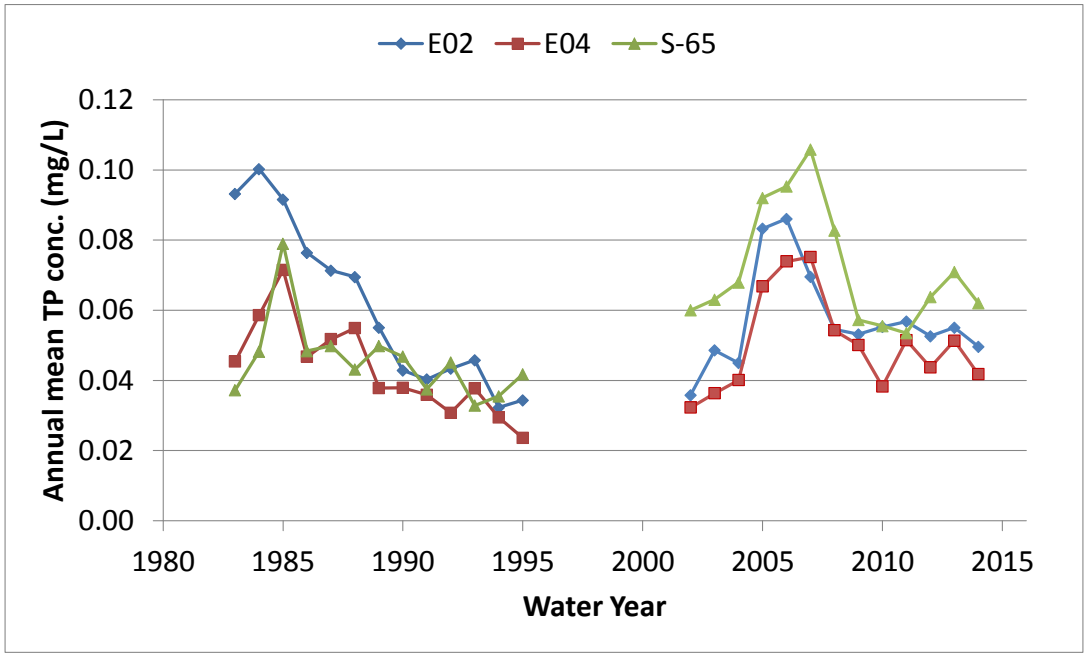

Figure 9-18. Annual mean (non-flow weighted) TP concentrations at S-65 and lake stations E02 and E04 during WY1983–WY1995 and WY2002–WY2014.

During the earlier period (WY1983–WY1995), TP in Lake Kissimmee may have been affected by effluent from wastewater treatment plants that discharged to Lake Tohopekaliga. Initially, higher TP at E02 was probably due to the stations' proximity to inflow from the impacted lakes upstream. As the effluent was diverted from Lake Tohopekaliga and water quality in that lake improved (James et al., 1994), TP levels at the Lake Kissimmee stations converged, with E02 exhibiting the largest decline. During this period, mean annual concentrations at E04 (0.043 mg/L) and S-65 (0.046 mg/L) were not significantly different (t-test).

In the post-Phase I period, TP concentrations at all three stations increased after hurricanes passed over the region. Despite the hurricane impacts, median annual concentrations at E02 and E04 during WY2002–WY2014 (0.055 mg/L and 0.050 mg/L, respectively) were not significantly different from the prior period (WY1983–WY1995). However, like the FWM TP concentrations discussed earlier, the median non-weighted TP concentration at S-65 rose significantly from 0.045 mg/L to 0.064 mg/L (**Figure 9-19**). As a result, the mean annual concentration at S-65 was significantly higher than the mean annual concentrations at E02 and E04 (t-test; $p < 0.05$) in the post-Phase I period.

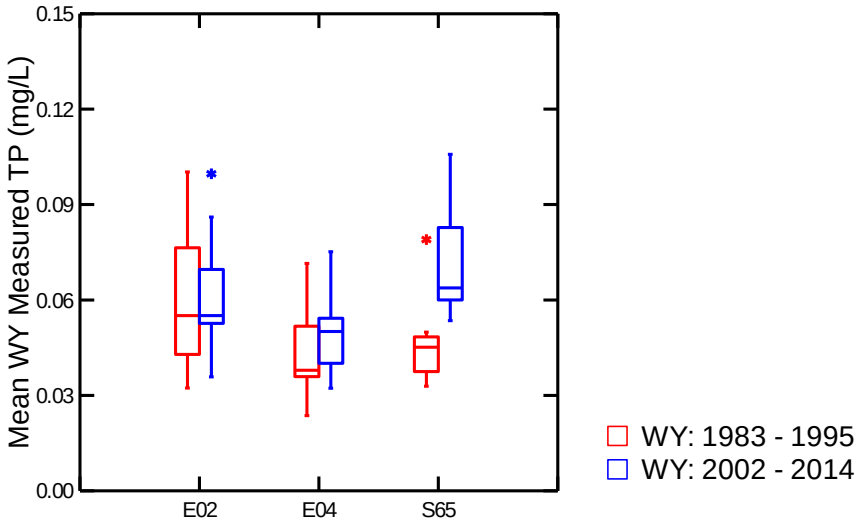

Figure 9-19. Annual mean (non-flow-weighted) TP concentrations at S-65 and lake stations E02 and E04 during WY1983–WY1995 and WY2002–WY2014. Each box plot shows the median, and 25th and 75th percentiles of the data distribution. Lines extending from the box indicate the spread of values within approximately two standard deviations of the mean. Asterisks represent values > 2 standard deviations from the mean. The median concentrations for these two periods did not change significantly at stations E02 and E04, but a significant increase did occur at S-65 (Mann-Whitney U-Test; $p < 0.001$).

In conclusion, although changes in TP concentrations in Lake Kissimmee do affect concentrations at S-65 (as demonstrated by the hurricane impact), the increase in TP at S-65 is not attributable to a general increase in lake concentrations. Instead, as discussed in previous SFERs, the higher concentrations at S-65 appear to be due to local influences on the southern extremity of the lake, the most evident being runoff from the local watershed. Several water quality samples obtained by the SFWMD and Florida Fish and Wildlife Conservation Commission indicate that local runoff can strongly influence TP in the south end of Lake Kissimmee (B.L. Jones, SFWMD, unpublished). Due to the confined nature of the area immediately above S-65, this runoff probably does not mix into the main body of the lake, but instead remains in the vicinity of the structure where its high TP content is detected in samples collected during no or low flow.

With regard to the restoration project's effectiveness in retaining phosphorus within the restoration area, the interim regulation schedule has allowed intermittent flooding of the restoration area, but periodic dry conditions, and generally short hydroperiods in the northern floodplain (Anderson, 2014a) have limited hydrologic interaction between the river channel and the floodplain. Consequently, the river-floodplain system probably has not sequestered nutrients at its highest potential efficiency. The higher concentrations and loads at S-65 probably explain why TP downstream of the restoration area has increased rather than declined.

FLOODPLAIN VEGETATION

KRRP scientists developed expectations predicting coverage of wetland vegetation communities on the restored Kissimmee River floodplain (Carnal, 2005a, b, c) based on historical areal coverage using data from the 1952–1954 pre-channelization vegetation map (**Figure 9-20**, map a). The expectations for overall wetland area and two dominant vegetation types, Broadleaf Marsh (BLM) and Wet Prairie, are enumerated in the sections below. These expectations refer to the entire restored floodplain area and predict full response only after the HRS is implemented.

A vegetation map based on 2011 aerial imagery of the Kissimmee River floodplain was completed in 2014 covering the Phase I construction area (**Figure 9-20**, map e). An accuracy assessment showed this map has an estimated overall accuracy of 90 percent. To evaluate interim responses of floodplain vegetation, this map was compared with previous maps (**Figure 9-20,** maps a–d) of floodplain vegetation from four time periods: 1952 (pre-channelization), 1974 (three years following completion of channelization), 2003 (two years following completion of Phase I), and 2008 (seven years following completion of Phase I).

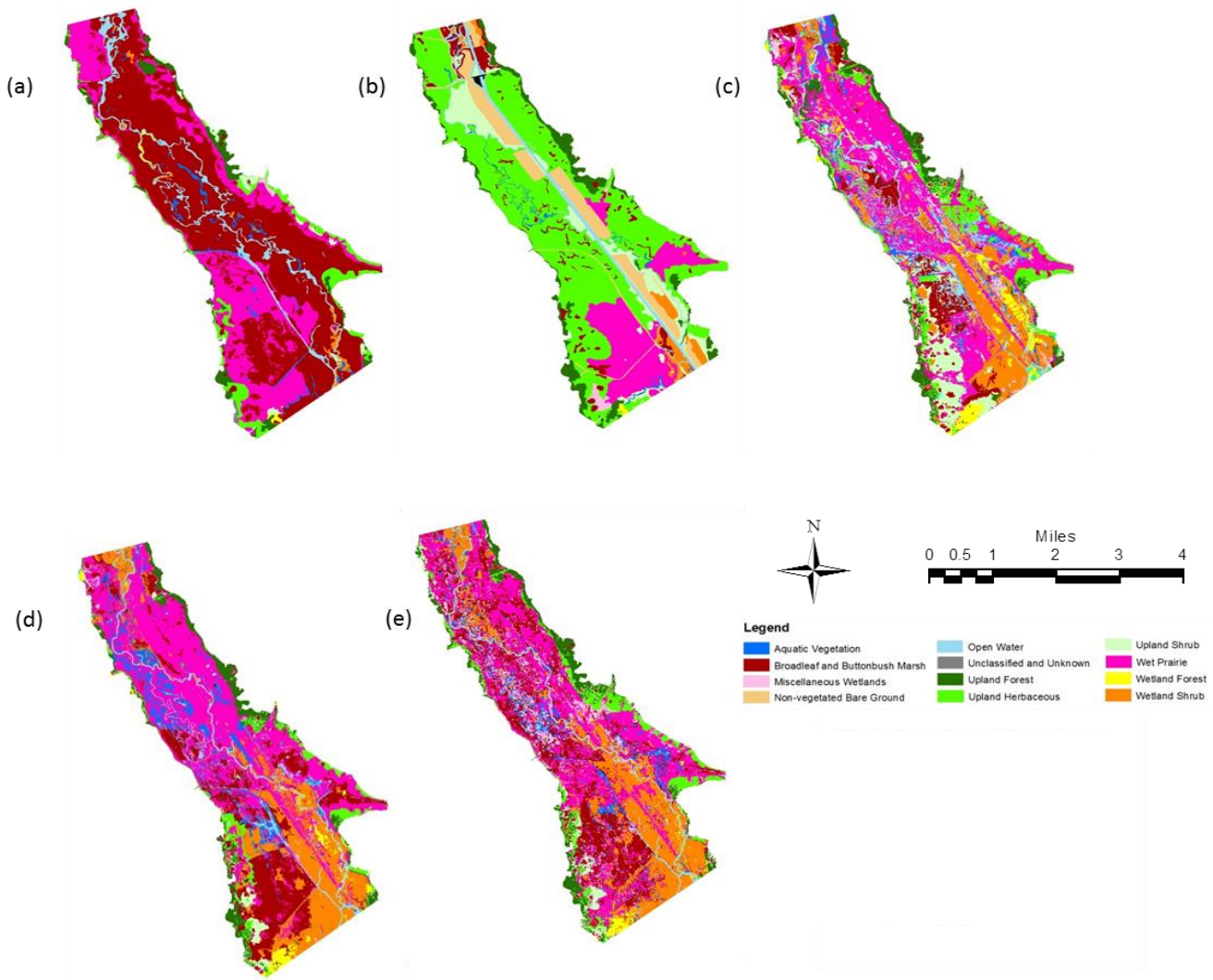

Figure 9-20. Vegetation maps of the Phase I construction area from five time periods in the history of the Kissimmee River: (a) 1952–1954, (b) 1974, (c) 2003), (d) 2008, and (e) 2011.

Expectation 12

Wetland plant communities will cover > 80 percent of the area of the floodplain restored in Phases I–IV (Carnal, 2005a).

After increasing to the expected areal coverage in 2008, total wetland plant community coverage of the Phase I floodplain has remained steady at about 3,200 hectares (83 percent) between 2008 and 2011 (**Table 9-9**).

Table 9-9. Sum of area in hectares (and percent area) of vegetation types within the Phase I restoration area over five time periods.

	1952	1974	2003	2008	2011
Broadleaf (including Buttonbush) Marsh	1,913 49.7%	175 4.6%	304 7.9%	658 17.1%	793 20.6%
Wet Prairie	1,186 () 30.8%	525 13.6%	1,270 33.0%	1,513 39.3%	1,167 30.3%
Wetland Shrub	36 0.9%	104 2.7%	637 16.6%	706 18.3%	734 19.1%
Other Wetland	82 2.1%	68 1.8%	341 8.9%	331 8.6%	508 13.2%
Includes:					
Aquatics	61 1.6%	36 0.9%	136 3.5%	241 6.3%	173 4.5%
Miscellaneous Wetlands	9 0.2%	26 0.7%	76 2.0%	25 0.6%	298 7.8%
Wet Forest	12 0.3%	6 0.1%	129 3.3%	65 1.7%	37 0.9%
Total Wetlands	**3,216** **83.6%**	**872** **22.7%**	**2,553** **66.4%**	**3,208** **83.4%**	**3201** **83.2%**
Other Classes	631 16.4%	2,975 77.3%	1,294 33.7%	639 16.6%	646 16.9%
Includes:					
Non-Vegetated	0 0.0%	385 9.9%	1 0.0%	0 0.0%	3 0.1%
Open Water	210 5.5%	176 4.6%	373 9.8%	183 4.8%	104 2.7%
Upland	421 10.9%	2414 62.8%	920 23.9%	456 11.8%	539 14.0%
Total Area	**3,847**	**3,847**	**3,847**	**3,847**	**3,847**

Expectation 13

BLM will cover at least 50 percent of the restored floodplain in Pools B, C, and D (Carnal, 2005b).

BLM vegetation [including Buttonbush (*Cephalanthus occidentalis*) communities] increased in the latest period to about 790 hectares (21 percent) of the total floodplain area, up from about 660 hectares (17 percent) in 2008 (**Table 9-9**). Areal coverage of BLM thus remains well below the restoration expectation of 50 percent of the Phase I floodplain. The small (4 percent) change in this vegetation community between 2008 and 2011 suggests that interim hydrologic conditions are not significantly changed since 2008. As noted previously (see Jones et al., 2011), the north-central portion of the Phase I area is dominated by Maidencane Wet Prairie, a close associate of BLM vegetation, suggesting that even small improvements in hydroperiod could increase coverage of BLM vegetation (Spencer and Bousquin, 2014).

Expectation 14

Wet Prairie communities will cover at least 17 percent of the floodplain restored by Phases I–IV of the restoration project (Carnal, 2005c).

Although Wet Prairie vegetation was still dominant in 2011, as it was in 2008, in 2011 it occurred over about 1,170 hectares (30 percent) of the area, down from about 1,500 hectares (39 percent) in 2008 (**Table 9-9**). This contraction of Wet Prairie area seems to be the result of the small expansion of BLM mentioned above and a larger expansion the Miscellaneous Wetlands group, made up of a mixed set of several wetland plant species, including swamp rosemallow (*Hibiscus grandiflorus*) and cattail (*Typha* spp.) that have not often been widespread on the floodplain (**Table 9-9**).

Miscellaneous Wetlands expanded from 25 hectares (0.6 percent) to 298 hectares (7.8 percent) between 2008 and 2011 (**Table 9-9**). Most of this expansion is the result of unexpected prolific growth of swamp rosemallow and some addition to cattail populations in the west-central portion of the Phase I area. It is unclear what caused this expansion, but since both swamp rosemallow and cattail require hydroperiods equal to or greater than most Wet Prairie communities, this change does not seem to indicate a negative change in floodplain hydroperiod.

Wetland Shrub vegetation increased marginally from 706 hectares to just over 730 hectares (about 19 percent) of the floodplain area (**Table 9-9**). As it did in the 2008 map, Wetland Shrub vegetation, predominantly consisting of invasive primrose willow (*Ludwigia peruviana*) communities, continues to dominate a swath of the south-central portion of the floodplain near the southern portion of the Phase I area closest to the S-65C water control structure. Relatively stable water levels associated with the structure have allowed this invasive exotic to out-compete native species in this area. When this structure is removed and the HRS is implemented, it is hypothesized that conditions may not be as favorable for primrose willow, and native vegetation may dominate this area again (Spencer and Bousquin, 2014).

Although the floodplain was inundated intermittently during the 10 years that elapsed between completion of Phase I and the 2011 imagery, historic hydroperiods have not been fully reestablished in the Phase I area (Anderson, 2014a), particularly in the northern Phase I area. Historic hydrology is expected to be more closely approximated when the HRS is implemented and should drive further changes in the relative abundance of vegetation types.

HERPETAFAUNA SURVEYS

Anuran (frog and toad) breeding chorus surveys were conducted to collect baseline data prior to construction of Phase II/III of the KRRP as well as in the Phase I restoration area, where flow and partial floodplain inundation were reestablished in 2001. During the two-year study, 16 monthly nighttime anuran vocalization surveys were conducted at fixed locations in both the Phase I restoration area (n = 9) and the channelized (unrestored) sections of the river/floodplain system (n = 18). A significantly greater number of choruses were detected in the restoration area than in the channelized system (**Figure 9-21**; Poisson regression $P < 0.0001$). These results demonstrate there is a larger breeding population of anurans in the restoration area than in the unrestored portion of the Kissimmee River, suggesting that backfilling of the C-38 canal and partial seasonal re-inundation of floodplain wetlands has been beneficial to anuran populations in general.

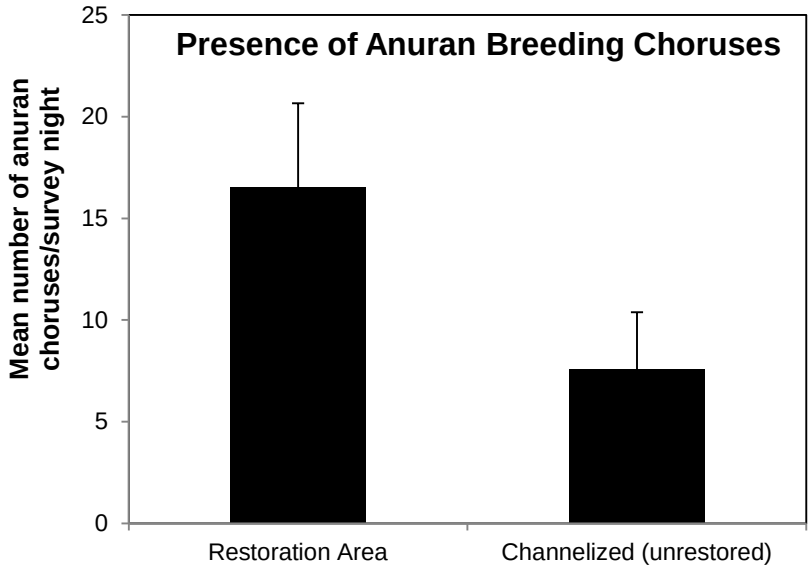

Figure 9-21. Comparison of the number of breeding choruses detected in the restoration area versus channelized sections of the river/floodplain system. Bars show means ± 1 SE.

WADING BIRDS AND WATERFOWL

Birds are integral to the Kissimmee River-floodplain ecosystem and highly valued by the public. While quantitative pre-channelization data are sparse, available data and anecdotal accounts indicate that the system supported an abundant and diverse bird assemblage (National Audubon Society, 1936–1959; FGFWFC, 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Since many bird groups (e.g., wading birds, waterfowl) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller, 1995). Detailed information regarding the breadth of the avian evaluation program and the initial response of avian communities to Phase I restoration can be found in Chapter 11 of the 2005 SFER – Volume I (Williams et al., 2005b) and in a recent research article published in the journal Restoration Ecology (Cheek et al., 2014). The objective of this section is to highlight portions of the avian program for which data were collected during the winter and spring of 2013–2014, and compare recent data to restoration expectations.

Wading Bird Nesting Colonies

Expectation

No expectation has been established for wading bird nesting colonies.

As part of the KRREP, the SFWMD performed five aerial surveys (February 18 and 25, March 21, April 22, and May 13, 2014), and one ground survey (April 8, 2014), to visit known wading bird nesting colonies and search for others in the Kissimmee Basin and Lake Istokpoga. The survey area was expanded this season to include the entire Kissimmee Basin where wading bird colonies were likely to occur, with the exception of the non-C&SF Project water bodies near Orlando and Disney World. Nesting colonies were also monitored, when encountered, during separate aerial surveys of foraging wading birds on November 13 and December 17, 2013, and January 14, February 11, March 11, April 17, and May 20, 2014. Known colonies in Lakes Mary Jane, Kissimmee (Rabbit Island), and Istokpoga (Bumblebee Island) were surveyed at least once, and two surveys were conducted throughout the Kissimmee Basin to search for previously undocumented colonies. The numbers of nests reported here represent the maximum number of nests for each species observed. It is likely the nests for a relatively small number of dark-colored wading birds, such as little blue heron (*Egretta caerulea*), glossy ibis (*Plegadis falcinellus*), tricolored heron (*Egretta tricolor*), yellow-crowned night heron (*Nyctanassa violacea*) and black-crowned night heron (*Nycticorax nycticorax*), were undercounted during the aerial surveys because of their lower visibility from above (Frederick et al., 1996). Thus, the colony totals presented in **Table 9-10** are considered conservative. Nest fate and nesting success were not monitored, but one ground survey was conducted at the Lake Mary Jane colony on April 8, 2014 to obtain a more accurate nest count and determine the presence of less visible dark-colored species.

Twenty-one colonies were located during the 2014 surveys. None of the colonies occurred within 3 kilometers (km) of the restored portions of the Kissimmee River, but several did occur in unrestored portions of the river both north and south of the restoration area (**Table 9-10**; **Figures 9-22** and **9-23**). As a result of the expanded survey area this season, 10 previously undocumented wading bird colonies were located**.**

The number of wading bird nests documented this season (3,671) was slightly higher than the long-term average of approximately 3,123 [± 160 standard error (SE)]; however, part of the increase is due to the 10 previously undocumented colonies, which included a total of approximately 234 nests. The remaining additional nests this season were largely the result of increased white ibis (*Eudocimus albus*) nesting on Lake Mary Jane. All other species, except the terrestrial cattle egret (*Bubulcus ibis*), were similar to the long-term average overall. There was a decrease in the number of cattle egrets nesting on the Kissimmee River and Lakes Mary Jane, Istokpoga, and Kissimmee compared to last season; although in past years the peak number of cattle egret nests has occurred in late May and June, after the final survey in May. The S-65C Boat Ramp Colony, typically the largest colony within the 100-year flood line of the Kissimmee River and dominated by cattle egrets, did not form this season. One likely reason is a decline in suitable nesting substrate. The colony had previously formed in shrubs that had established on floating mats of vegetation; these invasive and/or exotic shrub stands were treated with herbicide in 2011 and have now completely decomposed.

All colonies this season were dominated by aquatic species as of late May, with the exception of Bumblebee Island on Lake Istokpoga, which was dominated by cattle egrets. As was the case last year, the largest colony to form in the Kissimmee Basin was on Lake Mary Jane (1,792 nests), which was dominated by white ibis, great egret (*Ardea alba*), and wood stork (*Mycteria americana*) (**Table 9-10**).

Most nesting of both aquatic wading bird species and cattle egrets continues to occur outside of the KRRP area on islands in the Upper Kissimmee Basin and Lake Istokpoga. To date, only one colony of aquatic bird species (S-65C Boat Ramp Colony) has formed within 3 km of the partially restored portion of the Kissimmee River, and during most years it contains less than 50 nests of aquatic species. The continued small numbers of aquatic species nesting along the restored portion of the river suggests that prey availability on the floodplain is not yet sufficient to support the completion of breeding for these wetland-dependent birds. While foraging conditions on the floodplain can become optimal for wading birds during certain times of the year (see the *Wading Bird Abundance* section), the timing and magnitude of floodplain inundation and recession is not currently optimal for rookery formation due to constraints and other demands on water control operations. Implementation of the HRS in 2019 will allow water managers to more closely mimic the historical stage and discharge characteristics of the river, presumably leading to suitable hydrologic conditions for wading bird nesting colonies.

Table 9-10. Peak (maximum) numbers of wading bird nests within the Upper and Lower Kissimmee basins during the breeding season (February–May) 2014.

Colony Name	CAEG	GREG	WHIB	GBHE	SMDH	SMWH	GLIB	WOST	BCNH	Total Nests
Arbuckle Creek	-	18	-	5	-	-	-	-	-	23
Bumblebee Island (Lake Istokpoga)	658	210	75	55	-	-	-	-	-	998
Cat Island (Lake Conlin)	-	-	-		-	-	-	40	-	40
Indian Lake Estates	-	-	-	2	-	-	-	-	-	2
Kissimmee River*	5	48	0	35	1	0	0	0	0	89
Lake Arbuckle	-	-	-	8	-	-	-	-	-	8
Lake Marian east	-	-	-	3	-	-	-	-	-	3
Lake Marian north	-	-	-	28	-	-	-	-	-	28
Lake Marian south	-		-	2	-	-	-	-	-	2
Lake Mary Jane	-	245	1254		53	35	2	188	15	1,792
Lake Rosalie	-	44	-		-	-	-	9	-	53
Lake Russel	-	2	-		-	-	-	45	-	47
Lakeshore (Fedhaven)	-	-	-	9	-	-	-	-	-	9
Rabbit Island (Lake Kissimmee)	85	186	157	75	-	15	-	-	-	518
Twin Islands (Lake Marion)	-	52	-	7	-	-	-	-	-	59
Total Nests	748	805	1486	229	54	50	2	282	15	3,671

CAEG = cattle egret (*Bubulcus ibis*)

GREG = great egret (*Ardea alba*)

WHIB = white ibis (*Eudocimus albus*)

SNEG = snowy egret (*Egretta thula*)

GBHE = great blue heron (*Ardea herodias*)

BCNH = black-crowned night heron (*Nycticorax nycticorax*)

SMWH = small white heron [snowy egret and juvenile little blue heron (*Egretta caerulea*) combined]

SMDH = small dark heron [little blue heron and tricolored heron (*Egretta tricolor*) combined]

GLIB = glossy ibis (*Plegadis falcinellus*)

WOST = wood stork (*Mycteria americana*)

*****(3-kilometer vicinity of Kissimmee River, includes Chandler Slough East, Melaleuca Island, Orange Grove Northwest, Pool E Spoil Island, River Ranch C-38 Island, S-65C Structure, and Seven Mile Slough,)

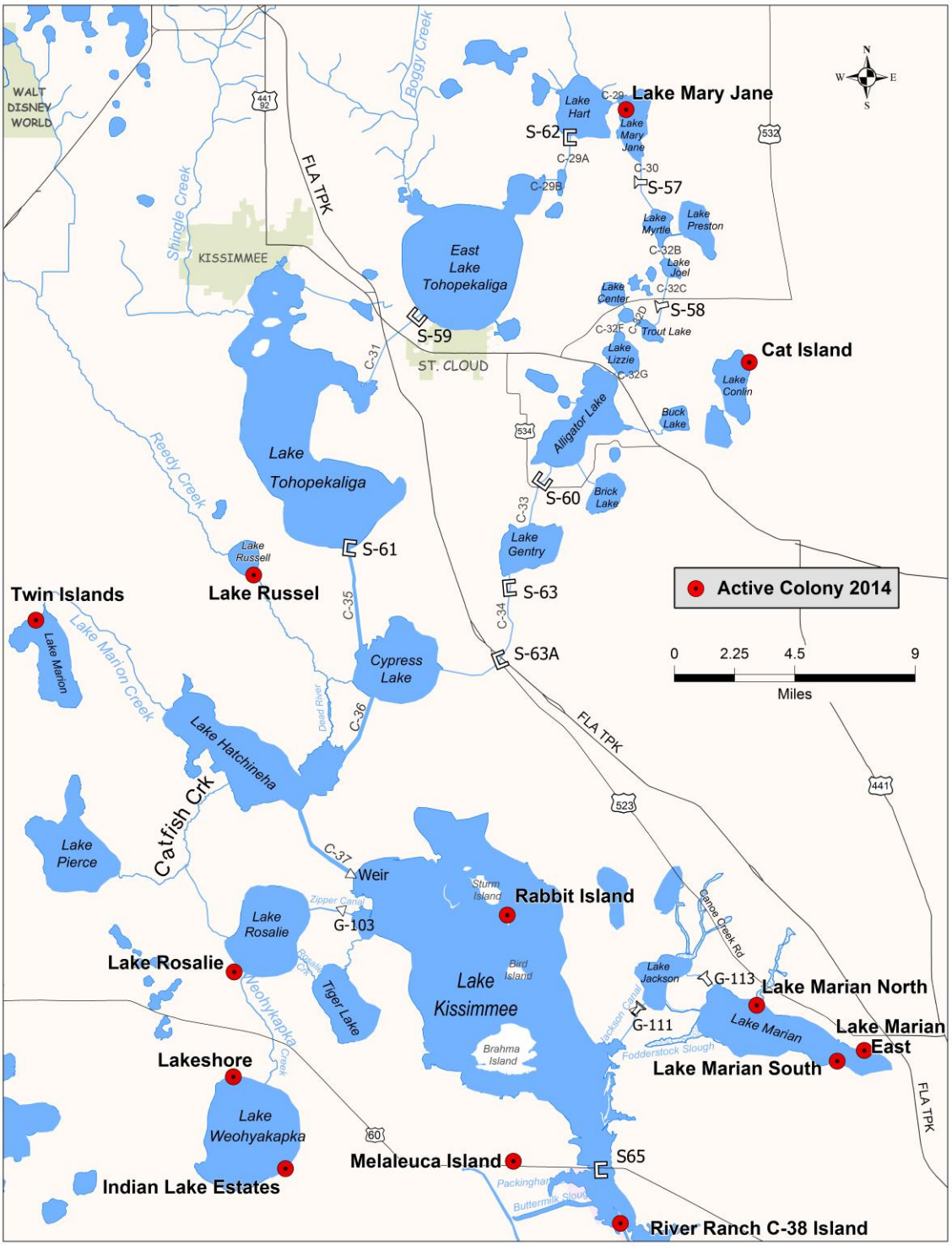

Figure 9-22. Observed nesting colony sites within the Upper Kissimmee Basin during 2014.

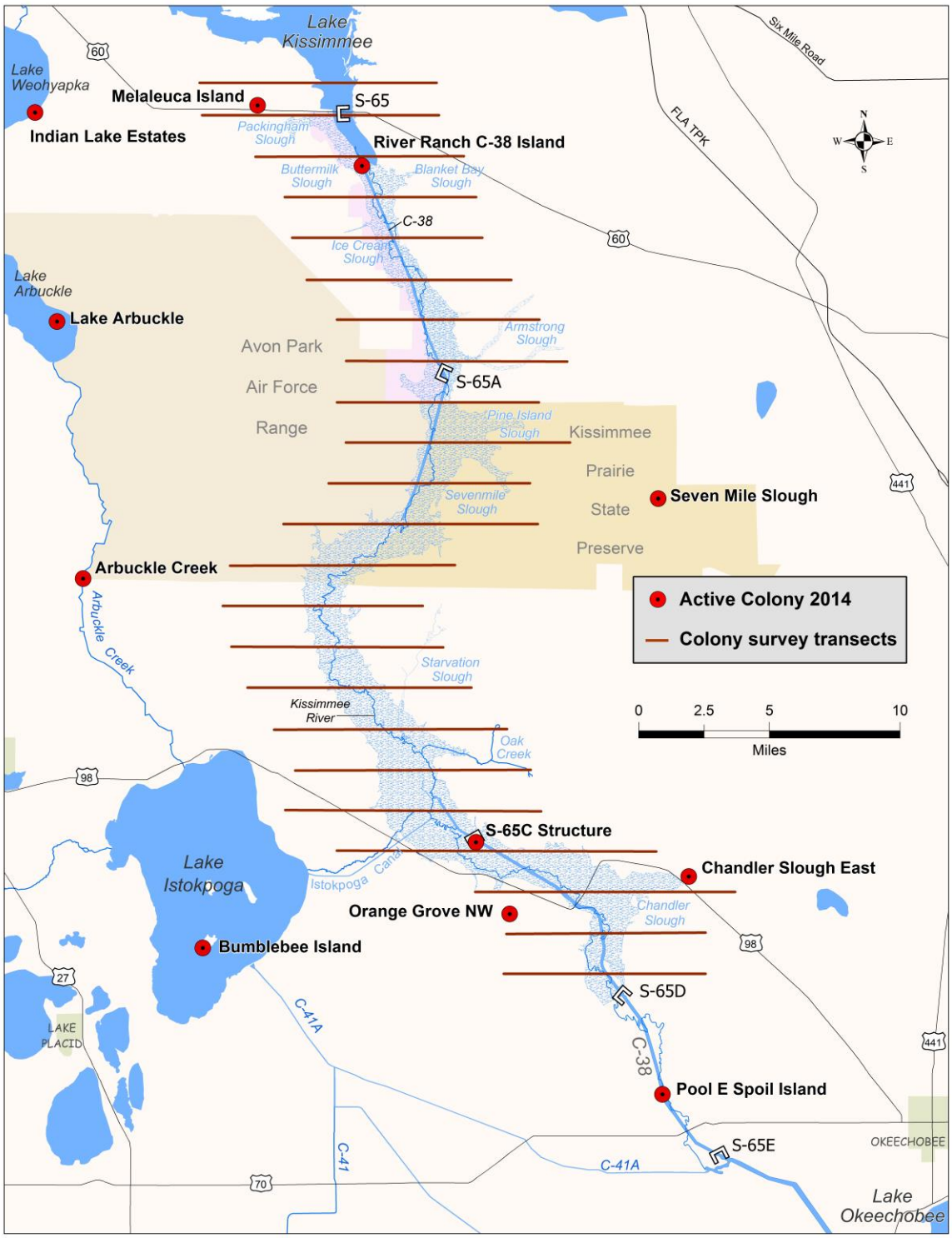

Figure 9-23. Aerial survey transect routes and nesting colony sites within the Lower Kissimmee Basin during 2014.

Wading Bird Abundance

Expectation 24

Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be ≥ 30.6 birds per square kilometer (birds/km^2) (Williams and Melvin, 2005a).

Monthly aerial surveys were used to estimate foraging wading bird abundance. Prior to the restoration project, dry season abundance of long-legged wading birds in the Phase I restoration area averaged ±S.E. 3.6 ± 0.9 birds/km^2 in 1997 and 14.3 ± 3.4 birds/km^2 in 1998. Since completion of Phases I, IVA, and IVB of restoration construction in 2001, 2007, and 2009, respectively, abundance has exceeded the restoration expectation of 30.6 birds/km^2 (evaluated as a three-year running average, Williams and Melvin, 2005a), except during 2007–2009 and 2009–2011 (**Figures 9-24** and **9-25**).

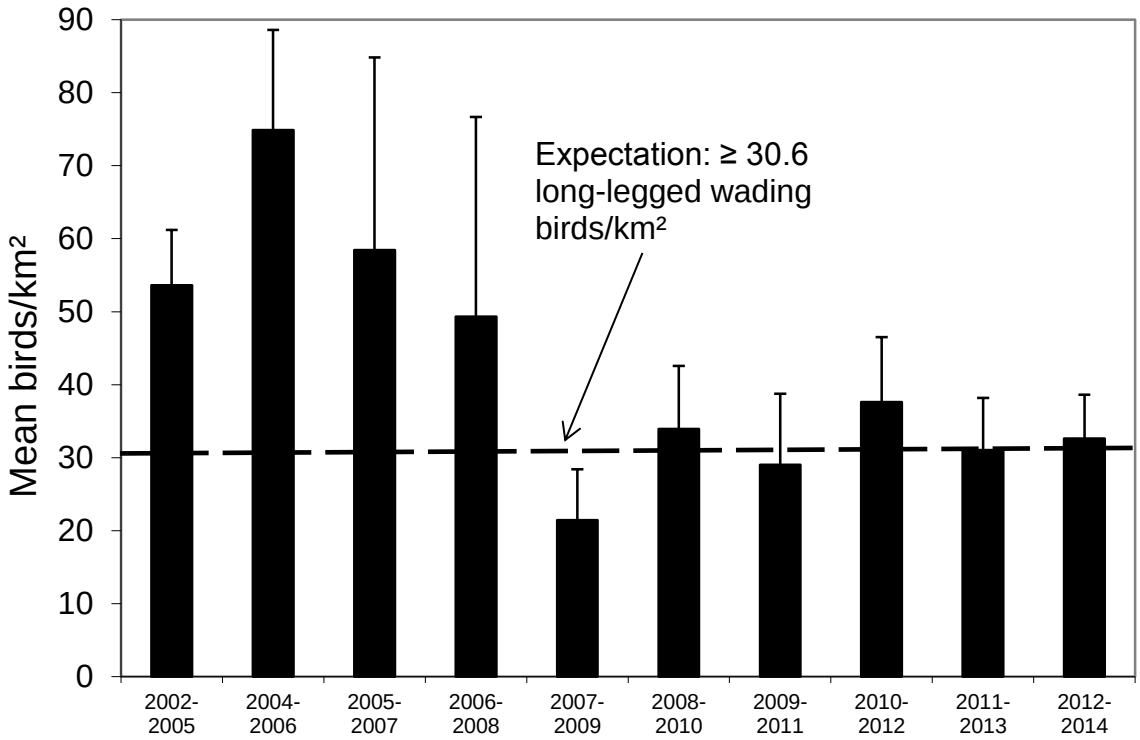

Figure 9-24. Post-restoration abundance as three-year running averages ± S.E. of long-legged wading birds per square kilometer (birds/km^2) excluding cattle egrets during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

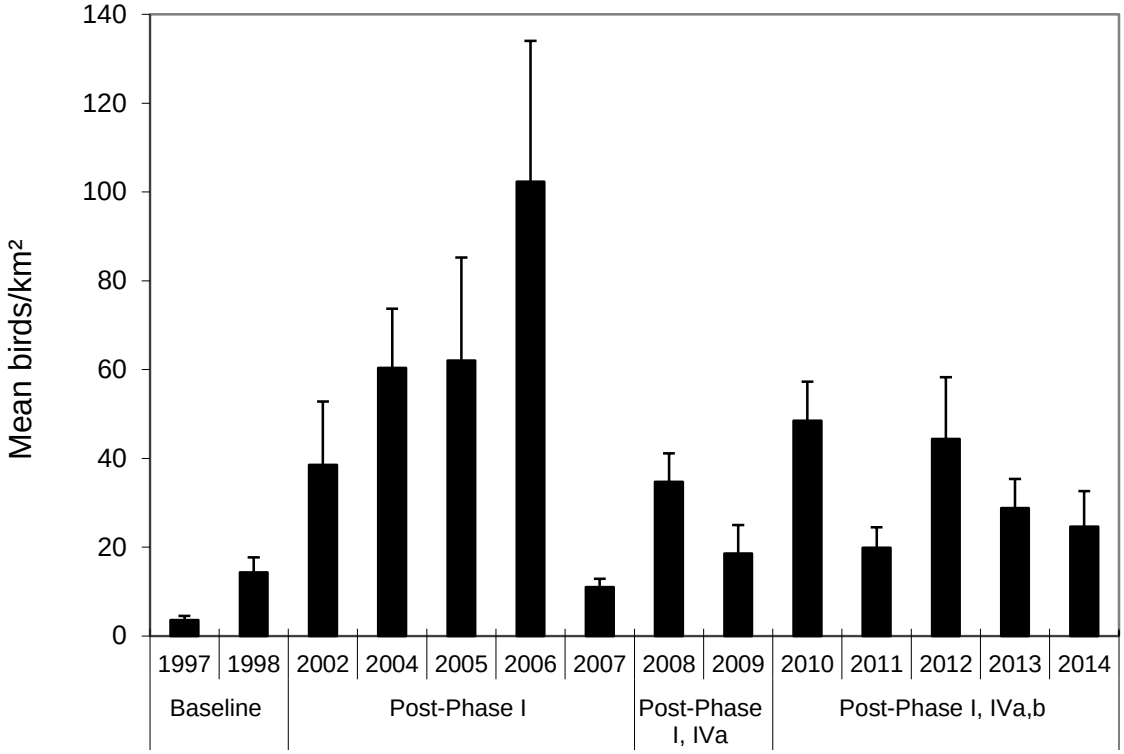

Figure 9-25. Baseline and post-Phases I, IVA, and IVB mean abundance ± S.E. of long-legged wading birds (excluding cattle egrets)/km^2 during the dry season (December–May) within the 100-year floodline of the Kissimmee River.

Mean monthly wading bird abundance within the restored portions of the river during the 2013–2014 season (24.6 ± 8.0 birds/km^2) was less than last year's estimate of 28.8 ± 6.6 birds/km^2, bringing the three-year running average to 32.6 ± 6.0. Wading bird numbers were above average in November as water levels receded relatively quickly on the floodplain and began to concentrate prey items. December numbers were below the long-term average for that month before rebounding to above average during the January survey. In February, numbers dropped substantially after a reversal (increase in water level) of approximately 0.34 ft occurred on the floodplain and presumably dispersed potential prey over a larger area. Water levels then receded again on the floodplain through mid-March, when survey numbers showed an uptick in bird use. A second, smaller reversal (~0.16 ft) occurred in mid-April prior to the survey flight, which showed a slight decrease in bird use. Floodplain water levels receded a third time prior to another reversal in early May (~0.31 ft), when bird numbers were extremely low (~5.8 birds/km^2).

White ibis dominated numerically, followed in order of abundance by great egret, glossy ibis, small white heron [snowy egrets (*Egretta thula*) and juvenile little blue heron], wood stork, great blue heron, cattle egret, small dark heron (tricolored heron and adult little blue heron), roseate spoonbill (*Platalea ajaja*), and black-crowned night-heron.

Waterfowl Abundance

Expectation 25

Winter densities of waterfowl within the restored area of the floodplain will be ≥ .9 ducks per square kilometer (ducks/km^2). Species richness will be ≥ 13 (Williams et al., 2005a).

Four duck species, blue-winged teal (*Anas discors*), green-winged teal (*A. crecca*), mottled duck (*A. fulvigula*), and hooded merganser (*Lophodytes cullulatus*), were detected during baseline aerial surveys. During the same period, casual observations of wood ducks (*Aix sponsa*) were made during ground surveys for other projects (Williams and Melvin, 2005b). Mean annual abundance ± S.E. was 0.4 ± 0.1 ducks/km² in the Phase I area before restoration construction, well below the restoration expectation of 3.9 ducks/km². The three-year running average of waterfowl abundance has consistently exceeded this expectation since Phase I restoration construction was completed in 2001 (**Figure 9-26**). Waterfowl abundance during the 2013–2014 survey (6.0 ± 1.7 ducks/km²) was less than the previous year's mean of 9.4 ± 1.1 duck/km^2, bringing the three-year running average down slightly to 9.7 ± 2.2 birds/km², but still well above the restoration target (**Figure 9-27**). Blue-winged teal dominated numerically, followed closely by mottled duck and a small number of hooded mergansers (N=6) and black-bellied whistling ducks (*Dendrocygna autumnalis*) (N=4). There was an increase in the number of opportunistic observations of black-bellied whistling ducks this dry season, suggesting that their numbers may be increasing along the Kissimmee River.

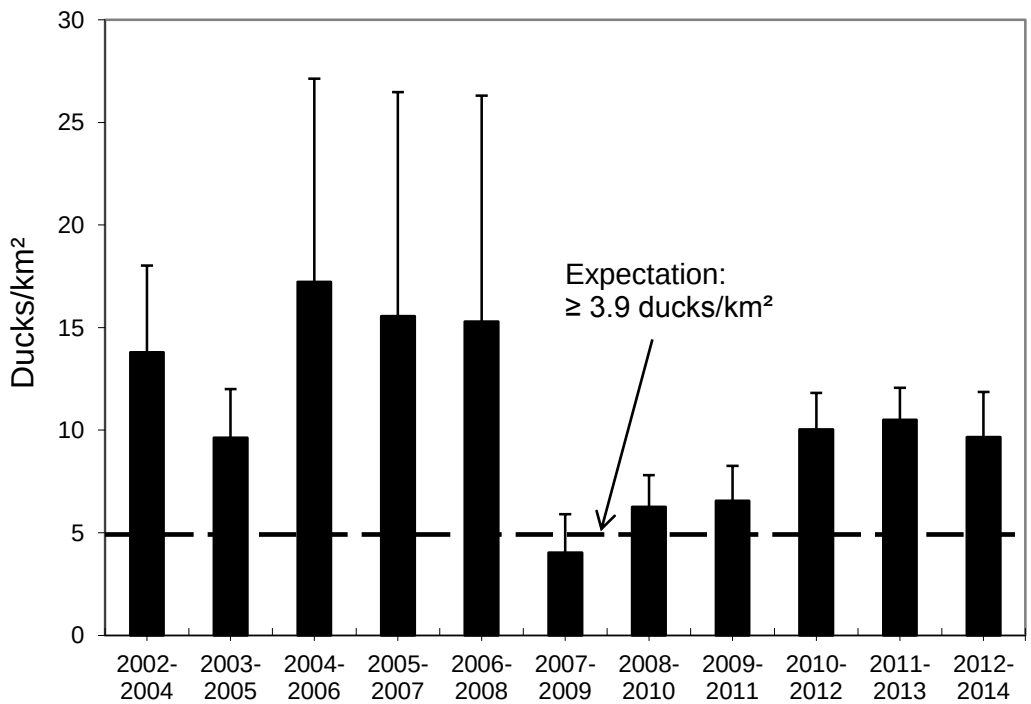

Figure 9-26. Post-restoration abundance as three-year running averages ± S.E. of waterfowl [ducks per square kilometer (ducks/km^2)] during the winter November–March) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

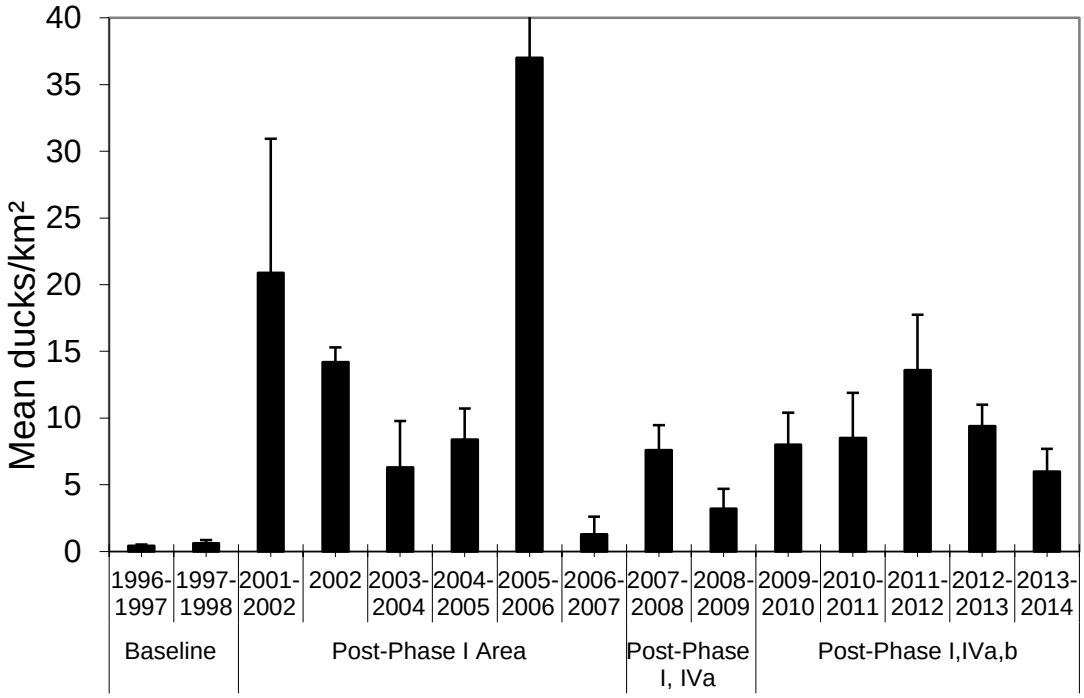

Figure 9-27. Baseline and post-Phases I, IVA, and IVB mean abundance ± S.E. of waterfowl during winter (November–March) within the 100-year floodline of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately nine months following completion of Phase I.

The American wigeon (*Anas americana*), northern pintail (*A. acuta*), northern shoveler (*A. clypeata*), ring-necked duck (*Aythya collaris*), and black-bellied whistling duck were not detected during baseline surveys, but have been present following restoration. However, these species are not regularly observed, and the restoration target for waterfowl species richness (≥ 13 species) has yet to be reached on an annual basis. Blue-winged teal and mottled duck remain the two most commonly observed species, accounting for over 95 percent of observations since 2001.

Restoration of the physical characteristics of the Kissimmee River and floodplain, along with the hydrologic characteristics of headwater inputs, is expected to produce hydropatterns and hydroperiods that will lead to the development of extensive areas of Wet Prairie and BLM, two preferred waterfowl habitats (Chamberlain, 1960; Bellrose, 1980). Changes in the species richness and abundance of waterfowl within the restoration area are likely to be directly linked to the development of floodplain plant communities and the faunal elements they support, particularly populations of aquatic invertebrates (Harris et al., 1995). Extrinsic factors, such as annual reproductive output on summer breeding grounds and local and regional weather patterns, also may play a role in the speed of recovery of the waterfowl community.

KISSIMMEE RIVER RESTORATION PROJECT: SPECIAL SECTION PUBLISHED IN MAY 2014 *RESTORATION ECOLOGY*

The May 2014 issue of the international journal *Restoration Ecology* included a special section featuring nine articles examining ecological responses to Phase I of the KRRP (Anderson, 2014a, 2014b; Bousquin and Colee, 2014; Cheek et al., 2014; Colangelo, 2014; Jordan and Arrington, 2014; Koebel and Bousquin, 2014; Koebel et al., 2014; and Spencer and Bousquin, 2014) (**Figure 9-28**). The articles document responses by a suite of indicators including hydrology, geomorphology, DO, river channel and floodplain vegetation, aquatic invertebrates, fish, and wading birds and waterfowl. Publications like this showcase the District's restoration accomplishments to a diverse audience worldwide. It is available online at http://onlinelibrary.wiley.com/doi/10.1111/rec.2014.22.issue-3/issuetoc.

Figure 9-28. *Restoration Ecology* issue containing a special section on the KRRP.

FIELD NOTES

Record Number of Snail Kites Observed in Restoration Area

A record number (N=78) of snail kites was observed on the Kissimmee River on September 17, 2013. Prior to this observation, no more than two snail kites had ever been documented to occur along the Kissimmee River at any one time (National Audubon Society, 1936–1959; M. Cheek, SFWMD, pers. comm.).

Kites were first observed opportunistically on September 4, 2013 while conducting field work along the Avon Park Bombing Range (APBR) fence line in the northernmost reaches of the restoration area (Phase IVb; **Figure 9-29**). Birds were seen perched along the fence and foraging on exotic apple snails (*Pomacea maculata*), an invasive species that had not been previously recorded within the KRRP area (**Figure 9-29**).

The largest number of snail kites observed along the river occurred on September 17, when at least 78 individuals were counted in the vicinity of the APBR fence line within the Phase IVb restoration area. Again, most birds were perched on the fence posts eating exotic apple snails or foraging over the marshes to the west of the fence line within the APBR. At least 67 birds were observed in the same area on September 26, 2013.

After the September observations, a kite survey was conducted February 2014 and an attempt was made to look for signs of kite breeding/nesting in a stand of Carolina willow (*Salix caroliniana*) within the APBR. No nesting was confirmed, but two birds did display possible courtship behavior (mutual soaring and tumbling) and a total of six birds remained in the area throughout the peak of the breeding season (February–April).

A recent survey conducted on July 30, 2014 by University of Florida researchers documented over 40 snail kites using the area. Birds were comprised of both adults and juveniles (fledged during the 2013 breeding season) and leg bands on some individuals indicated most birds originated from Lakes Kissimmee and Tohopekaliga. The presence of unbanded juveniles suggests some breeding activity may have occurred at the site during the 2014 breeding season.

District staff and the snail kite survey crew from the University of Florida will continue to monitor snail kite use of the partially restored Kissimmee River this breeding season.

Figure 9-29. Snail kites (*Rostrhamus sociabilis plumbeus*) and exotic apple snail (*Pomacea maculata*) egg clusters along the Avon Park Bombing Range fence in the KRRP area (Phase IVb). Note the high density of exotic apple snail egg clusters (pink) in the foreground attached to the base of the fence posts.

First Meander Breakthrough on Kissimmee River in Over 25 Years

In mid-March 2014, a meander cutoff formed in the Kissimmee River in Micco Run (**Figure 9-30**). This is the first cutoff to be documented along the Kissimmee River since February 23, 1988, when a cutoff formed within the Kissimmee River Restoration Demonstration Project area (Scarlatos et al., 1990). That cutoff occurred as the result of high hydraulic gradients created by discharge tests near Weir 3 of the demonstration project, or what is now the northernmost reach of the C-38 canal backfill within Phase IVb of the KRRP. The new cutoff in Micco Run may eventually become an oxbow lake if the meander loop is cut off from the main river channel by movement of sediments.

Figure 9-30. A newly formed meander cutoff (center-left of photo) created an island in Micco Run in the Kissimmee River restoration area (Phase I). The cutoff began to form in mid-March 2014.

KISSIMMEE BASIN MODELING AND OPERATIONS STUDY

The goal of the Kissimmee Basin Modeling and Operations Study (KBMOS) was to evaluate alternative operations for C&SF Project water control structures in the Kissimmee Basin to align upstream and downstream operations with KRRP headwater discharges at S-65 and enhance/sustain habitat conditions for fish and wildlife throughout the KCOL. The study was put on hold in October 2013 due to KRRP cost-crediting issues that have since been resolved. In November 2013, the SFWMD and USACE concurred on moving forward with implementation of the HRS after completion of KRRP as outlined in the Central and Southern Florida Project, Kissimmee River Headwaters Revitalization Project: Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement (USACE, 1996) and authorized in the 1996 record of decision. If restoration targets are not being met after implementation of the HRS, then the USACE and SFWMD will determine (1) if modifications to the schedule are required and (2) the approach that will be taken to develop potential modifications.

UPPER KISSIMMEE BASIN PROJECTS

KISSIMMEE CHAIN OF LAKES AND KISSIMMEE UPPER BASIN MONITORING AND ASSESSMENT PROJECT

The Kissimmee Upper Basin Monitoring and Assessment Project, initiated in October 2010, addresses deficiencies in ecological data identified over the past 10 years that are needed to support management decision making in the KCOL. The focus of the project over the past water year was water quality in the East Lake Tohopekaliga and Lake Tohopekaliga contributing watersheds. This assessment provides estimates of land-based phosphorus loads into these lakes from major and minor tributaries that will be useful for the in-lake nutrient budget study and the implementation of a nutrient reduction plan in these basins.

KCOL Water and Nutrient Budgets

Water and nutrient budgets of East Lake Tohopekaliga and Lake Tohopekaliga indicated that minor tributaries contributed 25 and 43 percent of the phosphorus load on an average annual basis from 1996 to 2012 (James, 2014a, 2014b). Because the loads from minor tributaries were estimated indirectly, the accuracy of nutrient budgets, in particular the sediment water interactions, was unknown. James (2014a, 2014b) recommended that a select number of minor tributaries believed to contribute significant flow and load to the lake be measured for flow so that rainfall runoff relationships could be developed. TP and TN monitoring data collected as part of the Lake Tohopekaliga Nutrient Reduction Plan (Camp, Dresser, and McKee, Inc., 2011; **Figure 9-31**) also can be used to indicate minor tributaries that may contribute significant loads. District Lake and Rivers Ecosystem staff met with Osceola County staff in September 2013 to evaluate potential key tributary sites. A follow-up trip by District Stream Gauging staff in December 2013 made specific recommendations regarding methods and locations to measure flow in these key tributaries (Iudicello, 2014; **Figure 9-31**).

A watershed-focused nutrient budget study completed in 2013 identified relative contributions of phosphorus from land uses and related sources as part of the Lake Okeechobee Watershed Protection Program (JGH Engineering, 2013). PN-Budget, a nutrient budget tool, also was developed to estimate the amount of phosphorus that enters, exits or remains within a study area, as well as phosphorus load and concentrations from all major contributing basins of the KCOL.

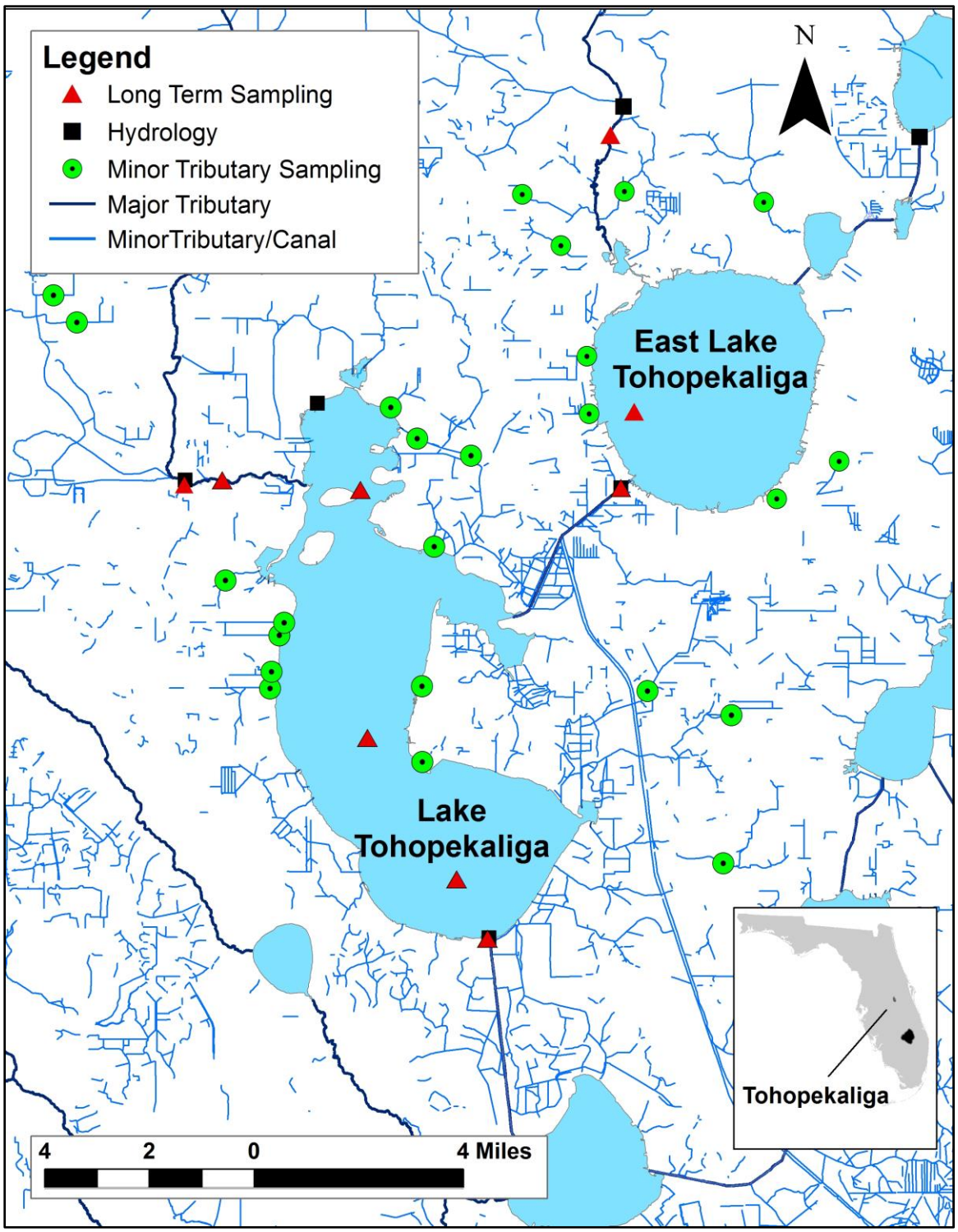

Figure 9-31. Hydrological sampling locations in Lake Tohopekaliga and East Lake Tohopekaliga (including major and minor tributaries).

As a check for the lake nutrient budgets, an alternative method was used to estimate major and minor tributary flows and loads to these lakes. District staff applied the PN-Budget Tool to the East Lake Tohopekaliga and Lake Tohopekaliga drainage basins to estimate the runoff and loads from major and minor tributaries for the period of 2006 to 2010. PN-Budget has the capability to analyze nutrient (phosphorus and nitrogen) budget characteristics within selected areas of a given watershed (Hiscock and Zhang, 2014). Results are presented as tables and maps that can be used to compare phosphorus and nitrogen control alternatives.

A material balance approach is used to estimate the total amount of nutrients that enter and exit a user-specified area on an annual average basis. There are two sources of nutrients to the drainage basins. The first is rainfall, which was estimated as a constant value based on average rainfall amount for the selected area and concentration. The second is the net nutrient contribution resulting from anthropogenic land use activities, also known as net import. The runoff phosphorus is estimated with the Watershed Assessment Model (WAM; SWET, 2011a, 2011b), a component of the PN-Budget tool (JGH Engineering, 2013). On-site storage is the amount of nutrients retained in the soils and is calculated as the nutrients in rainfall plus net nutrient import minus the nutrients in runoff (source load) (**Figure 9-32**) . The net phosphorus import coefficients (net import standardized by area) are determined based on average information obtained for each land use and developed by region because land use activities vary in different geographic locations due to soil and climate conditions. The net phosphorus import coefficients are applied spatially to the land use data set to derive the areal extent and distribution of the net phosphorus imports (**Figure 9-33**) and total net phosphorus imports within the East Lake Tohopekaliga and Lake Tohopekaliga contributing areas (**Table 9-11**).

Overall, there was an estimated annual net phosphorus import to the East Lake Tohopekaliga and Tohopekaliga watersheds of approximately 707 mt per year through anthropogenic activities (**Table 9-11**). Rainfall contributed 27 mt. The land use with the highest net import contribution was medium density residential followed by improved pasture. Urban land uses (including residential and other urban) represent approximately 41 percent of the total study area and contribute about 80 percent of net import to the region. Improved pasture contributes about 12 percent of the net phosphorus import and represents about 9 percent of the area. An estimated 54 mt was discharged via runoff and groundwater from the individual land uses into wetlands, streams, and lakes. It is estimated that as much as 680 mt could be retained annually in the soils, referred to as onsite storage.

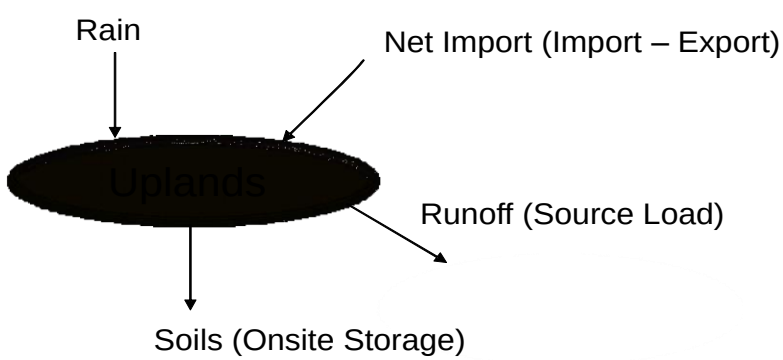

Figure 9-32. Phosphorous budget mass balance components for uplands in the Upper Kissimmee Sub-watershed (**Figure 9-33**). Net import was determined based on surveys and runoff value was calculated using the Watershed Assessment Model (WAM) model.

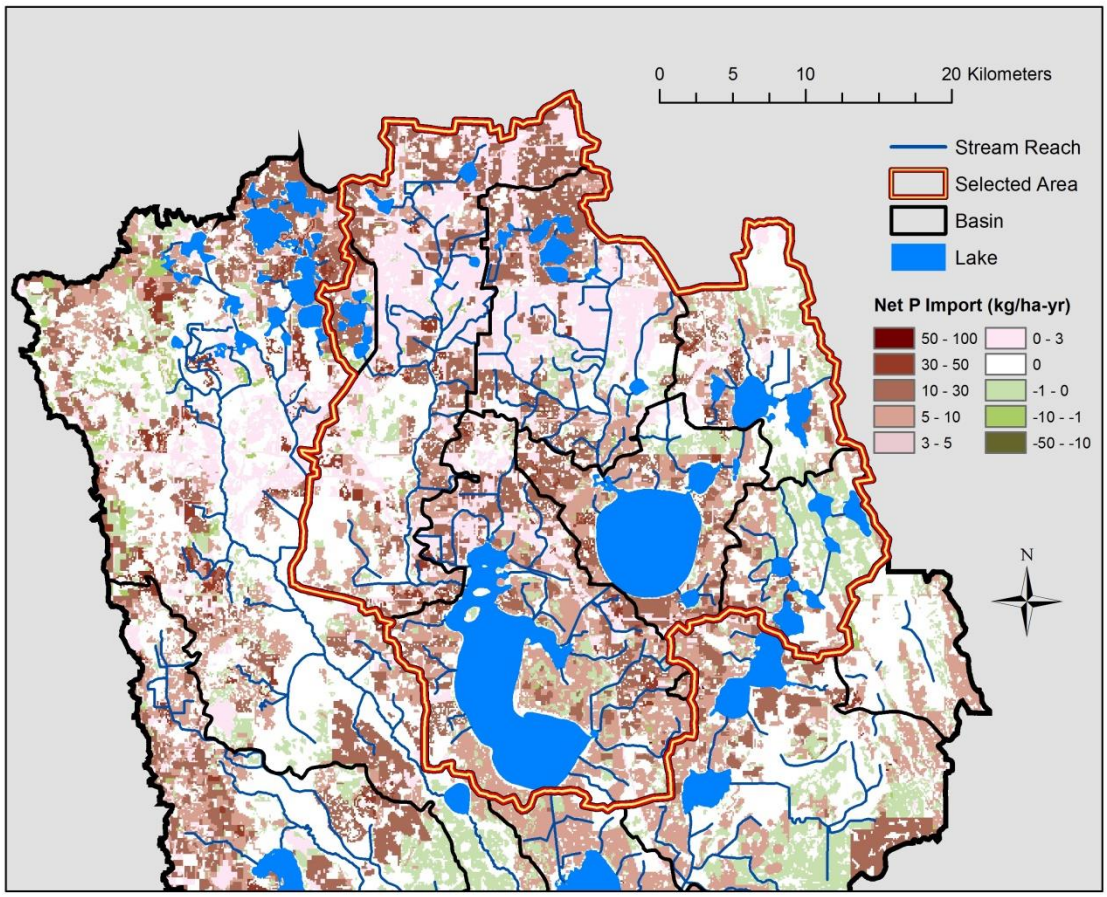

Figure 9-33. Areal extent and distribution of net phosphorus imports within Lake Tohopekaliga, East Lake Tohopekaliga, and the upstream drainage areas (areas in brown indicate that the land use is a net importer; green areas indicate a net exporter, e.g., more nutrient removed from the basin than added).

Table 9-11. Summary of phosphorus import, export, net import, and on-site storage for Lake Tohopekaliga, East Lake Tohopekaliga, and their upstream drainage areas. [Note: ha – hectares.]

Land Use	Area (ha)	P Import (mt)	P Export (mt)	Net Import (mt)	Rainfall (mt)	Source Load (mt)	Onsite Storage (mt)
Aquaculture	3	0.2	0.0	0.2	0.0	0.0	0.2
Barren Land	1,036	0.0	0.0	0.0	0.2	0.7	-0.5
Citrus	1,415	27.0	7.7	19.3	0.3	1.8	17.8
Commercial Forestry	266	3.7	4.2	-0.5	0.1	0.1	-0.5
Field Crop	334	13.5	10.9	2.6	0.1	0.4	2.3
Forested - Coniferous	4,402	0.0	0.0	0.0	0.9	0.0	0.9
Forested - Deciduous	2,751	0.0	0.0	0.0	0.6	0.0	0.6
Golf Course	1,314	42.4	0.0	42.4	0.3	0.3	42.4
Horse Farm	46	0.9	0.0	0.9	0.0	0.0	0.9
Improved Pasture	10,936	88.2	7.4	80.8	2.3	4.6	78.6
Ornamental	116	2.5	3.5	-0.9	0.0	0.3	-1.2
Other Urban	22,454	40.3	0.0	40.3	4.9	23.9	21.3
Poultry	3	0.0	0.0	0.0	0.0	0.0	0.0
Residential - High Density	4,288	40.6	0.7	39.9	0.9	2.6	38.3
Residential - Low Density	6,753	66.9	0.2	66.7	1.4	1.4	66.8
Residential - Medium Density	17,203	394.6	2.4	392.2	3.7	3.5	392.4
Residential - Mobile Home Unit	634	42.1	13.5	28.6	0.1	1.9	26.8
Sod Farm	24	0.9	1.3	-0.4	0.0	0.1	-0.5
Tree Nurseries	12	0.3	0.0	0.2	0.0	0.0	0.2
Truck Crop	18	1.5	0.9	0.6	0.0	0.0	0.6
Unimproved Pasture	9,388	0.0	6.2	-6.2	2.0	2.1	-6.4
Water	21,213	0.0	0.0	0.0	4.6	5.6	-1.0
Wetland	21,123	0.0	0.0	0.0	4.6	4.6	-0.1
Total	**125,732**	**765.5**	**58.9**	**706.6**	**27.1**	**54.0**	**679.8**

The PN-Budget Tool provided estimates of loads from various reaches of tributaries to Lake Tohopekaliga and East Lake Tohopekaliga for calendar years 2006 to 2010. These were summed to estimate both the major and minor tributary inputs to these lakes (**Table 9-12**). These PN-Budget Tool tabulations were compared to the estimates from the lake nutrient budget for the same period. This comparison of essentially a top down (e.g., PN-Budget Tool; Hiscock and Zhang, 2014) and bottom up (Lake Nutrient Budgets; James 2014a, 2014b) approach should determine if the original estimates of minor tributaries from the Lake Nutrient Budgets are reasonable and if the PN-Budget Tool can be used to improve the Lake Nutrient Budgets. With the exception of minor tributary inflows for East Lake Tohopekaliga, flow estimates of the PN-Budget Tool are within a standard deviation of the average values for the Lake Nutrient Budgets. Phosphorus load estimates of the PN-Budget Tool for Lake Tohopekaliga are also within a

standard deviation of the Lake Nutrient Budget values. For East Lake Tohopekaliga, the PN-Budget tool estimates for major tributary and TP loads were more than a standard deviation higher than the Lake Nutrient Budget, while the estimates for the minor tributaries were more than a standard deviation lower than the Lake Nutrient Budget. In summary, the Lake Nutrient Budget results for Lake Tohopekaliga seem reasonable. Additional efforts to further calibrate the PN-Budget tool using flow measurements of minor tributaries should improve the overall model estimates.

Table 9-12. Comparison of average (±1 standard deviation) of flows and load estimates from East Lake Tohopekaliga and Lake Tohopekaliga nutrient budgets (James, 2014a; 2014b) and the average estimated values (Hiscock and Zhang, 2014) from the PN-Budget tool for calendar years 2006–2010.

Estimate	East Lake Tohopekaliga		Lake Tohopekaliga	
	Lake Nutrient Budget	PN Budget Tool	Lake Nutrient Budget	PN Budget Tool
Major tributary inflows (thousands of cubic meters)	86,843 ± 49,393	118,214	251,021± 102,312	265,936
Estimated minor tributary inflows (thousands of cubic meters)	24,086 ± 7,093	11,016	194,026± 49,159	108,939
Total Inflows (thousands of cubic meters)	110,930 ± 57,932	129,230	445,046± 151,471	374,875
Major tributary phosphorus load (metric tons)	3.25 ± 1.5	7.7	12.9 ± 4.4	17.1
Estimated (minor tributary) phosphorus load (metric tons)	1.6 ± 0.5	0.9	15.7 ± 4.0	13.1
Total phosphorus Load (metric tons)	4.2 ± 2.0	8.6	28.6 ± 8.4	30.2

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