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, 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, 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 41,296 hectares (ha) of land in the river's floodplain and headwaters, backfilling 35.5 kilometers (km) 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, reestablished flow to approximately 39 km of river channel and allowed intermittent inundation of 3,121 ha of floodplain. Issues related to remaining land acquisition in the Lower Kissimmee Basin (LKB) and cost crediting were resolved in Water Year (WY) 2014 (May 1, 2013–April 30, 2016), and the authorized Headwaters Revitalization Schedule (HRS) will be implemented upon completion of the KRRP. Remaining restoration construction (backfilling of the C-38 canal) for Reach 3 (Phase III) and Reach 2 (Phase II) construction has been scheduled for 2015 and 2016, respectively. The new projected completion date for the KRRP is 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 component 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 SFWMD's responsibility in its cost-share agreement with USACE (Department of the Army and SFWMD 1994). Success is being tracked, in part,

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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 prechannelized river or similar systems. A final evaluation of KRRP success will follow completion of all project components.

This year's update on KRREP evaluations includes analyses of newly available data from studies of hydrology, dissolved oxygen (DO), wading birds, and waterfowl. This subset of restoration evaluation studies assesses the level of response of critical ecosystem components to physical restoration under interim (pre-project completion) hydrologic conditions based on new data that have not been reported in previous *South Florida Environmental Report* chapters. Results from these studies provide information for sound water management decision making as the KRRP progresses and guide water management after the project is complete. Key WY2016 (May 1, 2015–April 30, 2016) highlights of this chapter include the following:

- **Hydrologic conditions.** The Kissimmee Basin received above-average rainfall in WY2016; the Upper and Lower Basins were above average by 2.9 inches and 6.8 inches, respectively. Wet season stage ascension rate targets had 0 exceedances in East Lake Tohopekaliga, 2 in Tohopekaliga, and 21 in Kissimmee-Cypress-Hatchineha (Headwaters Lakes); the higher frequency of exceedances in the Headwaters Lakes reflects, in part, inflows from Tohopekaliga and limits on the rate of discharge changes at S-65 for KRRP. A new discharge plan for S-65 was developed to improve the duration and continuity of floodplain inundation; implementation of the plan improved on previous years' operations by producing a single continuous inundation event during the wet season and increased the duration of floodplain inundation. Dry season operations were strongly influenced by concerns for anticipated above average rainfall and its potential effects on discharge from Lake Okeechobee. Although fish and wildlife (F&W) recession lines were requested by the United States Fish and Wildlife Service (USFWS)/Florida Fish and Wildlife Conservation Commission (FWC) for Lakes East Tohopekaliga, Tohopekaliga, and the Headwaters Lakes, the F&W lines were replaced by operational guidance lines intended to reduce the amount of flow to Lake Okeechobee. Dry season operations for the Headwaters Lakes resulted in two additional inundation events in the Kissimmee River floodplain separated by drydowns of the floodplain; following operations similar to the new discharge plan may have improved hydrologic performance for KRRP by joining these two events as one much longer event.

- **KRREP hydrology.** Expectation 3 for hydroperiod requirements (1 foot [ft] of depth for 210 consecutive days) of broadleaf marsh (BLM), the dominant and most characteristic wetland plant community of the pre-channelization floodplain, and Expectation 4 for recession rates were evaluated for WY2016. While the new discharge plan improved hydrologic performance (longer, more continuous floodplain inundation and slower water depth recession in the floodplain), the targets were not met in WY2016 for Expectation 3 or Expectation 4. The targets for Expectation 3 (hydroperiod) and Expectation 4 (recession events) have not been met in any year of the Interim Period. While it may not be possible to fully meet the criteria of these two expectations during the Interim Period, continued implementation of the new discharge plan in future years is recommended to improve performance for these two expectations.

- **Dissolved oxygen.** Concentrations of daytime DO in the river channel of the Phase I restoration area continued to be higher in WY2016 than pre-restoration levels. Of the four metrics used to evaluate DO response, three were met in WY2016. For the first two metrics, mean daytime DO concentrations exceeded the dry season (November–May) target range but fell just short of the wet season (June–October) target range in WY2016. The third metric, frequency of DO concentration >1 milligram per liter (mg/L) within 1 meter (m) of

the channel bottom, exceeded its 50 percent target. The fourth metric, frequency of concentrations >2.0 mg/L, exceeded its 90 percent target.

- **Wading bird nesting.** Five colonies were active during the 2016 season within the KRRP area and Lakes Istokpoga and Kissimmee. The peak number of aquatic wading bird nests documented throughout the basin was 1,828. All colonies combined were dominated by white ibis (*Eudocimus albus*) nests (1,296), followed by smaller numbers of cattle egret (*Bubulcus ibis*) (646), great egret (*Ardea alba*) (487), and great blue heron (*Ardea herodias*) (45). The largest of these colonies was Bumblebee Island in Lake Istokpoga (1,847), followed by Rabbit Island (526), Chandler Slough East (85), River Ranch C-38 (12), and S-65C Structure (4).

- **Wading bird abundance.** Mean monthly wading bird abundance within the restored portions of the river during the 2015–2016 season was 40.1 ± 7.4 birds per square kilometer (km^2), bringing the three-year (2014–2016) running average to 40.9 ± 9.6; not significantly different from the restoration expectation of 30.6 birds/km^2. The long-term mean annual three-year running mean (2002–2016) is 41.7 ± 4.3 birds/km^2, significantly greater than the restoration expectation of 30.6 birds/km^2.

- **Waterfowl abundance.** Waterfowl abundance during the 2015–2016 survey was 12.1 ± 4.6 ducks/km^2, bringing the three-year (2014–2016) running average to 8.5 ± 1.9 birds/km^2; not significantly different from the restoration expectation of 3.9 ducks/km^2. The long-term mean annual three-year running average (2002–2016) of waterfowl abundance is 10.4 ± 1.1 birds/km^2, significantly greater than the restoration expectation of 3.9 birds/km^2. 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, a review of emerging issues, ongoing projects, monitoring and management activities, and ecological conditions is provided in this chapter. Multiple agencies manage and monitor resources in the KCOL, including FWC, Osceola County, SFWMD, and USFWS. Summarizing those efforts provides an overview of the breadth of activities occurring in the region:

- **Osceola County.** New, high-resolution elevation data were collected via a cost-share grant from the United States Geological Survey (USGS). The county acquired 1-ft contour light detection and radar (LiDAR) for the entire county footprint, which will allow emergency managers, county planners, natural resource managers, and engineers to better plan for development impacts, emergency flood response, and many other important functions. The county also completed its fourth year of study for the nutrient reduction plan, building two water quality treatment systems on the west side of Lake Tohopekaliga that provided 150 percent of the required treatment. The eight-year average of total phosphorus concentration for Lake Tohopekaliga continues to decline.

- **Vegetation monitoring.** FWC monitors littoral zone vegetation in the major water bodies of the KCOL via aerial imagery collections every few years, and in 2016 mapped Lake Kissimmee. SFWMD also completed the first year of data collection in long-term vegetation monitoring plots in Lakes East Tohopekaliga, Tohopekaliga, and Kissimmee in 2016. The plots are intended to establish baseline conditions for reference after implementation of the Kissimmee River Restoration, which will coincide with a new water regulation schedule for the Headwater Lakes, including Lake Kissimmee.

- **Fisheries.** FWC electrofishing data from the spring of 2015 for Lakes East Tohopekaliga, Tohopekaliga, Cypress, Kissimmee, and Marian indicated the lakes support largemouth bass (*Micropterus salmoides*) populations with high mean relative weights on

Tohopekaliga and Kissimmee (99), and that East Tohopekaliga had fewer large bass (> 498 millimeters [mm]) than the other three lakes, while Marian had the highest.

- **Everglade snail kites.** The KCOL supported 30 percent of the statewide Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nesting activity in the 2015 breeding season, which halted a downward trend from 57 percent in 2012 to 25 percent in 2014. The total number of active nests and the total number of successful nests in the KCOL were up from at least a seven-year low in 2014; however, for the second year in a row, the KCOL did not have more total nests, more successful nests, or more fledglings produced than any other region in the state. This trend is primarily due to increases in total nests and successful nests in other areas of the state, and decreases on East Tohopekaliga and Tohopekaliga, which generally are the two primary nesting lakes in the KCOL.
- **Alligators.** FWC monitors American alligator (*Alligator mississippiensis*) populations using spotlight surveys at night, which showed good populations on Lakes Tohopekaliga, Kissimmee, and Hatchineha, with Kissimmee having roughly twice the population of any other lake in the KCOL. Lake Tohopekaliga showed a continuing recovery from a low in 2005, and Lakes Kissimmee and Hatchineha both showed increases from a low in 2010. Populations on East Lake Tohopekaliga and Lake Cypress were the smallest of the major lakes in the KCOL, but remained steady.

INTRODUCTION

The Kissimmee Basin includes more than two dozen lakes in the 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 compose the Kissimmee-Okeechobee-Everglades system. In the 1960s, the C&SF Project modified Kissimmee Basin's water resources extensively by constructing canals and installing water control structures to achieve flood control. In the LKB, construction of a 56-mile long canal through the Kissimmee River resulted in profound negative ecological consequences caused by elimination of flow in the original river channel, which prevented seasonal floodplain inundation. In the Upper Kissimmee Basin (UKB), C&SF Project modifications and regulation schedules 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 KRRP. SFWMD has been working since the early 1990s to coordinate, operate, and evaluate the KRRP through the KRREP.

The KRREP 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 water 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 (SFERs) – Volume I* (Jones et al. 2010, 2011).

This chapter is an update to Chapter 9 of the 2016 SFER – Volume I (Koebel et al. 2016). It focuses on the status of Kissimmee Basin projects during WY2016. The chapter also summarizes hydrologic conditions and water management during WY2016 and presents newly available data from evaluations of the KRRP and other monitoring and management activities from certain lakes in the KCOL.

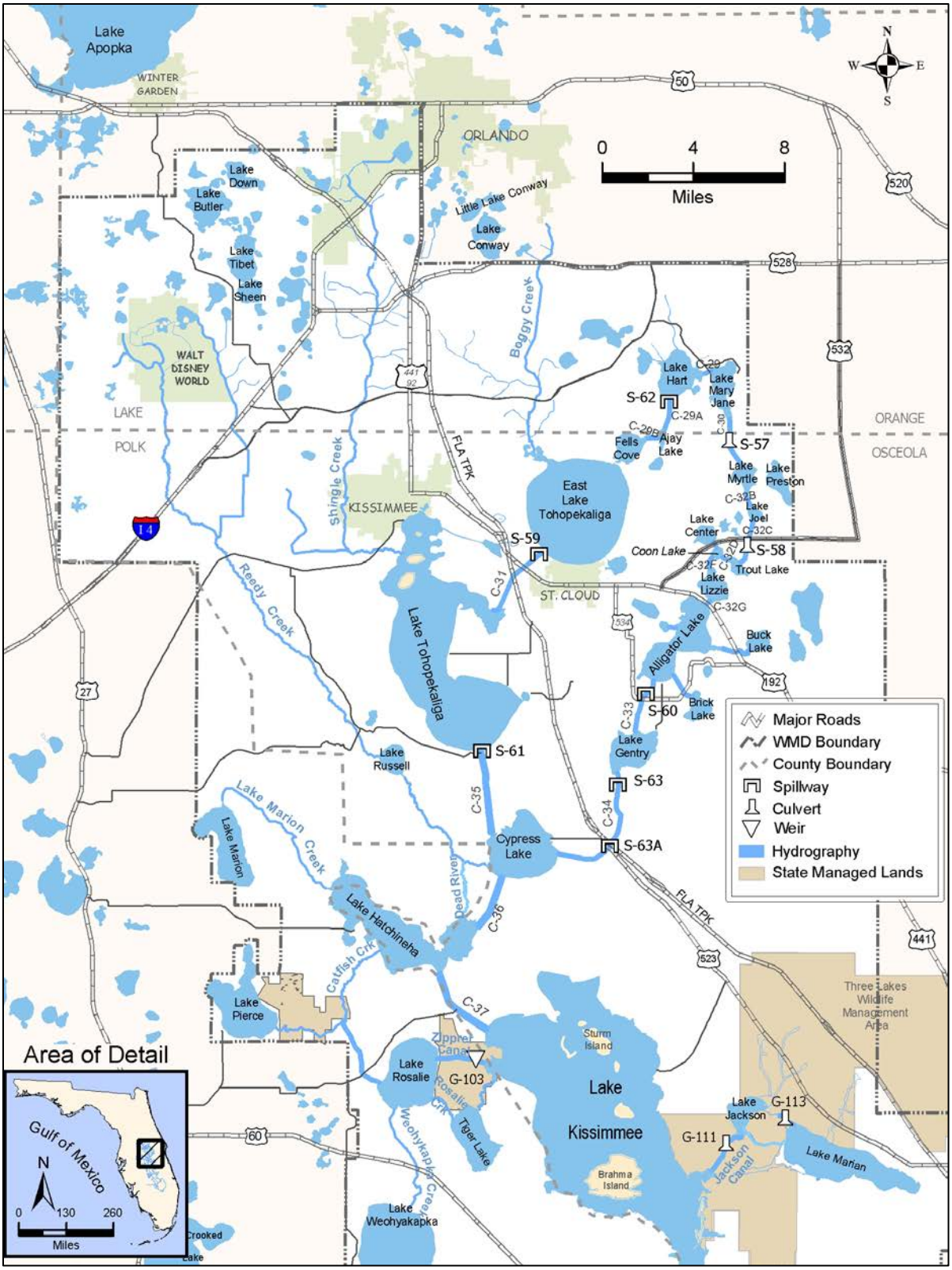

Figure 9-1. Upper Kissimmee Basin. (Note: WMD – South Florida Water Management District.)

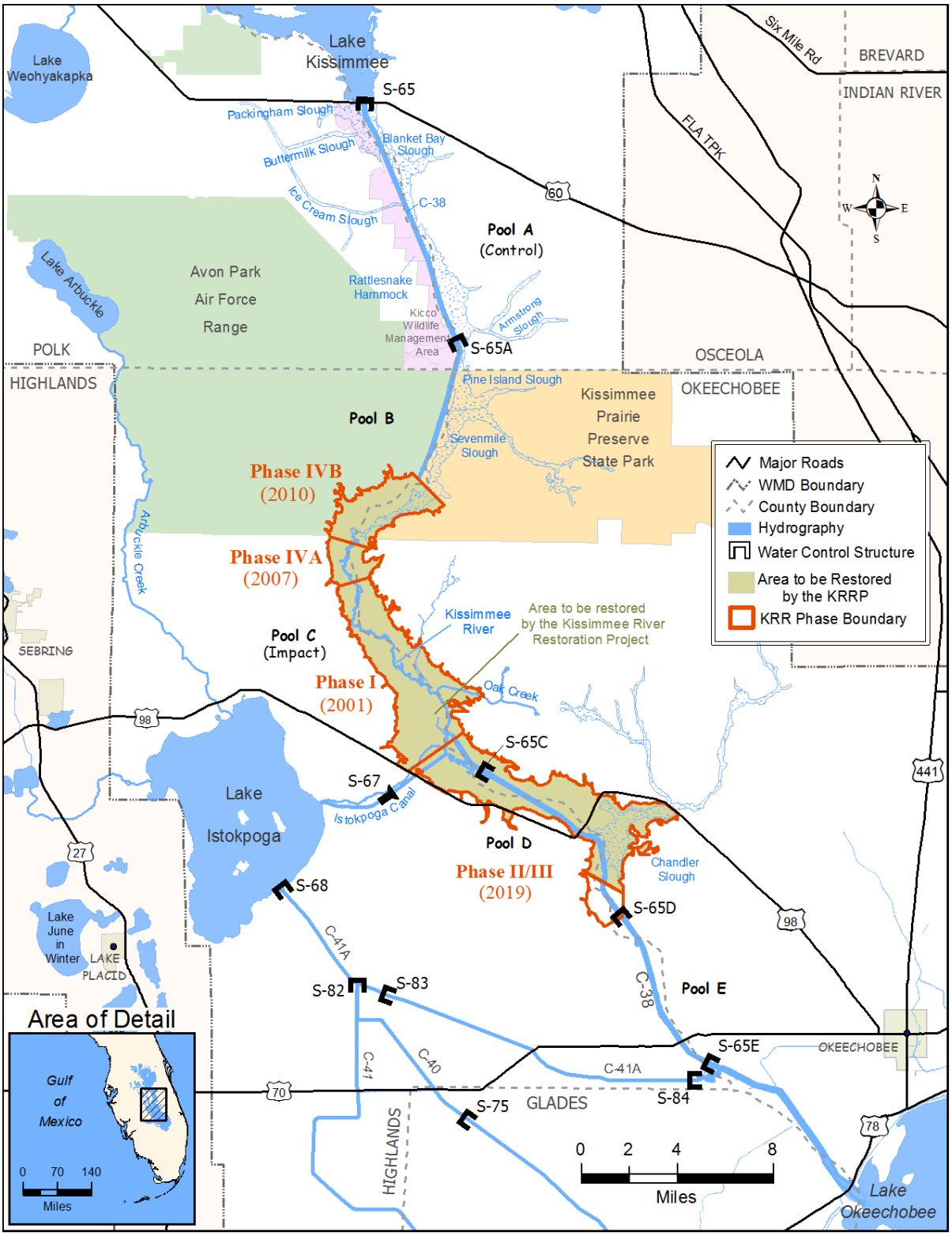

Figure 9-2. Lower Kissimmee Basin with actual and projected completion dates of construction phases. (Note: KRR – Kissimmee River Restoration.)

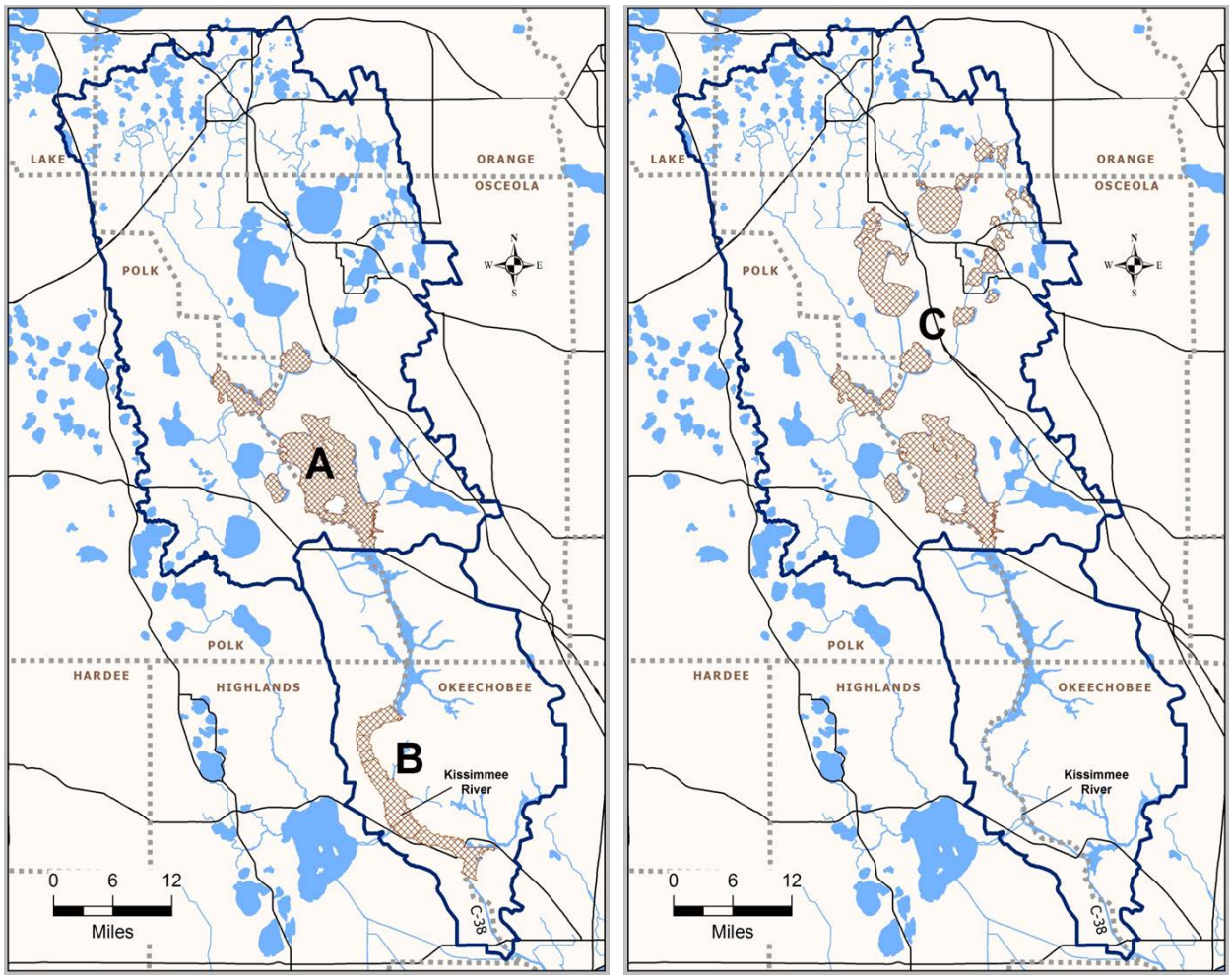

Figure 9-3. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) headwater lakes components of the KRRP, (B) KRRP, and (C) KCOL and Kissimmee Upper Basin Monitoring and Assessment Project.

KISSIMMEE RIVER RESTORATION PROJECT

Concerns about environmental degradation and habitat loss in the Kissimmee River and floodplain and the potential contribution of the channelized river to eutrophication in Lake Okeechobee were the impetus for the KRRP. The goal of the 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; USACE 1991; Koebel and Bousquin 2014). A headwaters component of the project is designed to allow additional storage capacity in the headwater lakes to provide discharge operations that can more closely approximate the prechannelized river's flow regime, including discharges with more natural timing, magnitude, and rates of change. The increase in 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 LKB, the KRRP is expected to restore ecological integrity to approximately one-third of the original river channel and floodplain, modifying a contiguous area of floodplain-river ecosystem of more

than 101 km^2. More than 51 km^2 of new wetlands will be established in areas that were drained by the canal, and 65 km of reconnected river channel will receive reestablished flow. In the UKB, more than 2,834 ha (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 SFWMD and USACE. Engineering and construction of the project are the responsibility of USACE, while SFWMD's purview is land acquisition, ecological evaluation, and hydrologic modeling for the restoration project.

RESTORATION CONSTRUCTION COMPONENTS

Restoration components include (1) acquiring 26,560 ha (65,603 ac) of land in the LKB, (2) backfilling approximately 35.5 km of the C-38 canal (more than one-third of the canal's length) from the lower end of Pool D north to the middle of the former 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 allow the additional storage volume needed to meet the hydrologic criteria for river-floodplain 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 (Reach 1) construction was completed in February 2001. This phase was followed by Phase IVA/IVB (Reaches 4A and 4B), which extends north from the Phase I project area and was completed in December 2010. Phases II and III (Reaches 2 and 3) are the last major phases of construction. Phase III began in 2015 and is projected for completion by the end of 2016. The Phase II contract was awarded in August 2016 with construction scheduled to begin by the end of 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 KRRP with selected benefits.

Construction Sequence	Name of Construction Phase	Timeline	Backfilled Canal (km)	River Channel Recarved (km)	River Channel to Receive Reestablished Flow (km)	Total Area (ha)	Wetland Gained (ha)	Location and Other Notes
1	Phase I Project Area	1999–2001 (complete)	12.9	1.6	22.6	3,849	2,345	Most of Pool C, small section of lower Pool B
2	Phase IVA Project Area	2006–2007 (complete)	3.2	1.6	6.4	547	207	Upstream of Phase I in Pool B to Weir #1
3	Phase IVB Project Area	2008–2010 (complete)	6.4	6.4	9.7	1,694	569	Upstream of Phase IVA in Pool B (upper limit near location of Weir #3)
4	Phase II/III Project Area	2019 (projected)	14.5	6.4	25.8	4,017	1,898	Downstream of Phase I (lower Pool C and Pool D south to CSX Railroad bridge)
Restoration Project Totals			**37**	**16**	**64.5**	**10,106**	**5,019**	

The construction phases completed so far have backfilled 22.6 km of flood control canal, recarved 9.7 km of river channel that had been obliterated during canal dredging, and demolished a water control structure (S-65B). These efforts reestablished flow to 38.7 km of continuous river channel and allowed intermittent inundation of 3,121 ha (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, the HRS, to operate the S-65 water control structure. The HRS will allow lake water levels to rise 0.46 m (1.5 ft) higher than the current S-65 schedule and will increase the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 120 million cubic meters (m^3) (100,000 acre-feet [ac-ft]). Ninety-nine percent of the 14,822 ha (36,612 ac) of land that will be affected by the higher water levels has been acquired, and all projects planned in the original project engineering to increase the conveyance capacity of UKB canals and structures are in place, although testing is needed in the early years of implementation of HRS to ascertain that the larger storage volume can be fully accommodated. 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, USACE authorized an interim regulation schedule that allows 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 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 during a drought in 2006–2007. While the use of Zone B releases has been beneficial, it does not provide the full benefits the HRS is expected to provide.

CONSTRUCTION STATUS

In recent years, the final backfilling contracts (Reaches 2 and 3) were on hold due to real estate and cost crediting issues. However, cost crediting issues, including authorization of credit for large acquisitions in the LKB and some evaluation activities have been resolved. All remaining real estate in the LKB has been acquired. As a result of these successes, USACE has accelerated the construction schedule. The new estimated completion date is 2019.

In WY2016, construction continued for backfilling of the MacArthur Ditch in the Phase I construction area. This small component of the KRRP will eliminate an artificial drainage feature in the floodplain created more than 50 years ago by the MacArthur family to protect part of their property from flooding. A small borrow canal resulting from the construction of a levee around the property grew to almost 5 km in length and up to 18 m wide after reintroduction of flow to the Phase I area in 2001 (**Figure 9-4**). This dated feature drains the floodplain quickly back into the C-38 canal while continuing to grow in length and width. If not backfilled, it would decrease the inundation depth and duration of water in the floodplain wetlands and impact the quality of fish and wildlife habitat. The ditch also disrupts the flow pattern in the southern portion of the Kissimmee River (seen in lower **Figure 9-4**). Construction under the contract broke ground in June 2015. In 2016, the contract was modified to backfill only the southernmost 2.4 km of the ditch because USACE concluded that backfilling that section will successfully eliminate the artificial drainage. The remaining section of the ditch will no longer facilitate flow. The project is scheduled for completion in October 2016.

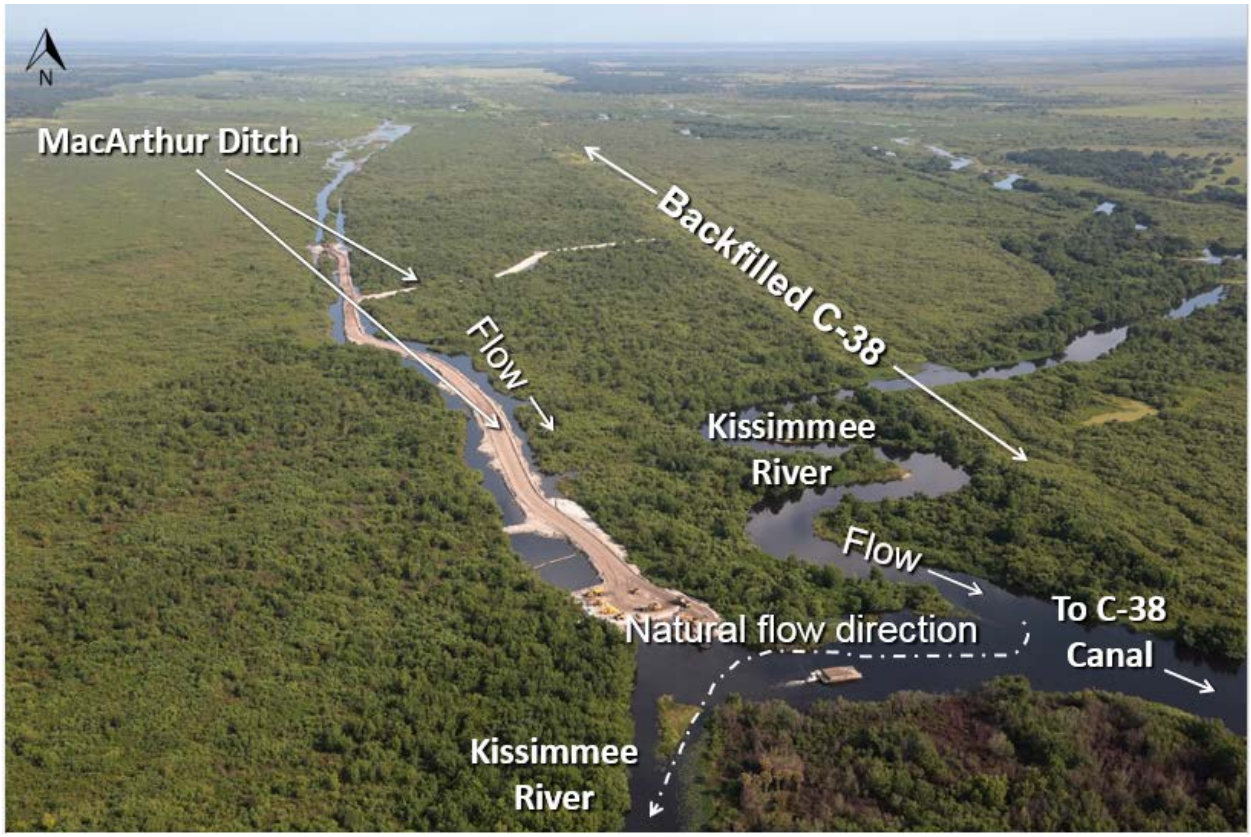

Figure 9-4 KRREP Phase I restoration area MacArthur Ditch Backfill Project.

WY2016 also marked the initiation of Reach 3 backfilling. The $4.7 million contract was awarded by USACE in September 2015 to backfill a 4-km long section of C-38 canal. Construction began in September 2015 and is scheduled for completion in September 2016. **Table 9-2** provides brief descriptions of current activities along with a chronological list of the KRRP construction activities.

Table 9-2. Chronology of KRRP construction.
(Note: Bold text within the cell body 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 million
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 million
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 million

Table 9-2. Continued.

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
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 the C-36 canal was enlarged to maintain the existing level of flood protection.	Complete		July 2001	$2.6 million
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 million
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 million
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 million**
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 canal portion of this contract was terminated before completion.	C-36 Complete C-37 Terminated		April 2003	$14.5 million
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 million
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 million
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 million
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 million
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 million
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**	**July 2006**	**October 2007**	**$29.8 million**
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	March 2007	June 2009	$13.5 million

Table 9-2. Continued.

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
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	January 2007	March 2010	$14.3 million
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**	**July 2008**	**December 2010**	**$18 million**
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 million
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 million
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 million
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 million
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 million
18B	Pool D Boat Ramp – A new boat ramp and small parking area will be constructed.	Complete	September 2011	October 2012	$0.9 million
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.	Complete	August 2012	October 2014	18.5 million
15A	River Acres Supplemental Work – Repair of S-65DX3 structure and miscellaneous construction features	Complete	July 2014	April 2015	$0.75 million
10B	MacArthur Ditch will be backfilled.	Under Construction	June 2015	October 2016	$4.7 million
12	**Reach 3 Backfilling – New channels will be dredged and 2.5 miles of the C-38 canal will be backfilled.**	**Under Construction**	**September 2015**	**September 2016**	**$4.7 million**
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.**	**Awarded August 2016**	**Not Yet Scheduled**	**December 2019**	**$26.1 million**

KISSIMMEE BASIN HYDROLOGIC CONDITIONS AND WATER MANAGEMENT IN WATER YEAR 2016

This section provides a description of hydrologic conditions in the UKB and LKB and their relationship to water management activities during WY2016. The narrative focuses on the timing and quantity of rainfall in the Kissimmee Basin and the water management and rainfall-driven temporal patterns of discharge and stage that resulted. In the LKB, SFWMD uses water control structures S-65, S-65A, and S-65C to manage flow to and water levels in the Kissimmee River and its floodplain, where USACE and SFWMD have completed three of five physical reconstruction phases of the KRRP since 2001. This work is designed to allow recovery of the river-floodplain ecosystem with appropriate water management per the authorized project objectives.

In the UKB, SFWMD manages water levels in the KCOL, which is divided into seven groups of one or more lakes interconnected by canals. Each group of lakes is regulated by a single water control structure (**Figure 9-1**). Surface water from the northern UKB flows to the Headwaters Lakes before being discharged through water control structures S-65 and S-65A to the C-38 canal, which flows to the reconstructed sections of the KRRP (**Figure 9-2**). Because the Kissimmee River and its floodplain slope to the south, it is not possible to store significant volumes of water in the KRRP area; most of the water discharged from S-65 leaves the Kissimmee Basin quickly at S-65E, where it enters Lake Okeechobee. Discharge from S-65 through S-65A therefore is the primary determinant of flow in the river channel, and the only way to generate the overbank flow needed to provide sufficient inundation of the floodplain for restoration is to provide prolonged, uninterrupted periods of discharge in excess of 1,200–1,400 cubic feet per second (cfs) through these structures.

Completion of restoration construction in 2019 and implementation of a revised regulation schedule for S-65 (HRS) are expected to provide additional upstream water storage for restoration of the Kissimmee River. However, appropriate water management during the Interim Period has the potential to realize substantial ecological benefits in the northern Phase I and Phase IV floodplain (**Figure 9-2**) where restoration construction has been completed, including improvements in reestablishment of long hydroperiod floodplain marshes and recovery of the fish and wildlife that depend on access to them and other wetlands. While it is not anticipated that the floodplain inundation targets can be fully met during the Interim Period, performance for these targets can be improved as discussed in the *Hydrology* subsection in the *Kissimmee River Restoration Evaluation Program* section below. S-65 (via S-65A) provides the dominant source of flow to reconstructed sections of the Kissimmee River and floodplain, but as water is released, stages in the Headwaters Lakes must decline unless rainfall balances discharge. For this reason, stage targets for the Headwaters Lakes may often conflict with the goals of KRRP, particularly when stages are targeted without consideration of discharge operations needed to address the hydrologic objectives of the KRRP given limited rainfall. Releases from other water bodies upstream of the Headwaters Lakes, especially Lakes Tohopekaliga and East Tohopekaliga (e.g., for flood control or to meet stage targets), also impact stage in the Headwaters Lakes; therefore, in addition to indirectly affecting operations for the KRRP, operations for upstream lakes may also inhibit meeting stage targets in the Headwaters Lakes.

The stage regulation schedules authorized by USACE for each water control structure in the KCOL have a strong influence on temporal hydrologic patterns in the Kissimmee Basin (**Figure 9-5**). Each water control structure controls stage in one or more lakes within a defined lake group (**Figure 9-1**); each lake group in the KCOL has a regulation schedule associated with its water control structure (e.g., **Figures 9-10** and **9-11** later in this chapter). All of the KCOL regulation schedules have a similar shape, declining in the spring to their lowest elevations ("low pool") on May 31 to create storage for wet season rainfall, rising to a plateau ("summer pool") on June 1 to accommodate early summer rainfall, and rising to their highest elevations ("high pool" or "winter pool") on November 1 (**Figure 9-5**) to provide additional storage for rainfall, which typically peaks in late wet season. Starting in February for the Headwaters Lakes, December for Lakes Myrtle-Preston-Joel, and mid-March for the other KCOL lakes, the schedules then

recede again to their low pool stages on May 31 to provide capacity for the upcoming wet season. The regulation schedule lines specify seasonally varying maximum water elevations that, when exceeded (Zone A in **Figure 9-5**), trigger mandatory flood control releases to bring lake stage back to or below the regulation lines. When lake stage is at or below the regulation line (Zone B in **Figure 9-5**), water can be discharged for environmental purposes. For example, S-65 (controlling the Headwaters Lakes) can be operated below its regulation line to release water to the KRRP to achieve restoration goals, or to allow lake stage recession or ascension objectives in the Headwaters Lakes to be addressed. For purposes of this discussion, discharge operations that release water to meet environmental goals when stage is below the regulation line are called discretionary releases (as opposed to mandatory releases for flood control when a regulation line is exceeded). Thus, stage regulation schedules do not represent required or desirable lake stages; they specify only the maximum stage at which the lake or lake group may be operated.

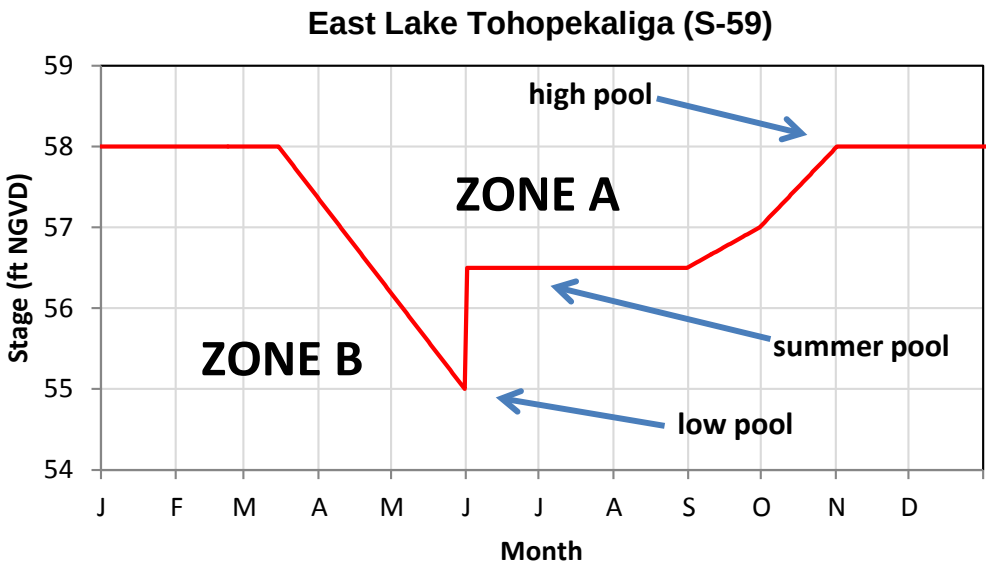

Figure 9-5. Example regulation schedule (East Lake Tohopekaliga) showing the regulation line (red) that separates Zone A (above the line) from Zone B (below the line). When lake stage is in Zone A, releases are mandatory for flood control; when stage is in Zone B, releases are discretionary for environmental purposes. All lakes in the KCOL have a similar schedule with a Zone A and Zone B. (Note: ft – feet and NGVD – National Geodetic Vertical Datum of 1929.)

The Kissimmee Basin is an ecosystem in which the progress and success of a federally authorized $800 million ecosystem restoration project with mandated hydrologic and ecological goals (KRRP), nesting habitat for an endangered species (the Everglade snail kite in the KCOL), demands from downstream ecosystems, and the sometimes divergent opinions of numerous stakeholders are factors in water management decisions. In addition to the hydrologic requirements of the KRRP, three of the UKB lake groups—the Headwaters Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga—are the focus of much of the discretionary water management in the Kissimmee Basin. To address these diverse demands, SFWMD conducts seasonal interagency coordination meetings in which Kissimmee Basin stakeholders discuss and seek to arrive at consensus given sometimes conflicting management objectives. The meetings have included staff from SFWMD, USFWS, FWC, USACE, the Florida Department of Environmental Protection (FDEP), county governments, and nongovernmental organizations such as Audubon of Florida. Concerns from other stakeholders (e.g., representing downstream water bodies, including Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries) are also considered in developing and implementing seasonal operational plans.

Planning meetings are hosted by a District team of scientists and hydrologists (Kissimmee Basin Operations) in coordination with KRREP staff, USFWS, and FWC, with support from the District's modeling and Water Control Operations groups. Planning meetings are held prior to the start of wet and dry seasons and may involve modeling or analysis requests, generally conducted by SFWMD, to address specific questions. A smaller interagency technical team focuses on scientific issues, water management tradeoffs, and refinement of operational objectives. A common topic of discussion is the tradeoffs involved when flow to the KRRP through the S-65/S-65A structures is balanced against requests to manipulate flow to the river-floodplain to target the prolonged, stabilized periods of high stage often requested for the Headwaters Lakes. Three of the lake groups in the KCOL—Lake Tohopekaliga, East Lake Tohopekaliga, and the Headwaters Lakes—provide important Everglade snail kite nesting habitat, although nesting and production in the KCOL have been declining since 2011 (see the *Everglade Snail Kite Population Monitoring* section of this chapter). In the dry season, alternative recession lines typically are requested for these lakes to moderate the rate at which lake stages are reduced to their seasonal low pools. During rainy periods, there can be concerns that discharge from S-65 (which enters Lake Okeechobee through S-65E), although small relative to the volume of Lake Okeechobee, may cause increases in discharge from Lake Okeechobee to the estuaries. The objective of the planning meetings is to develop consensus among stakeholders on a seasonal standing recommendation document, which provides joint agency water management recommendations to SFWMD Water Control Operations for the upcoming season. The standing recommendations provide generalized but comprehensive operational guidance for a particular season for S-65C, S-65A, S-65, S-61, and S-59, and in some cases other lakes/structures in the KCOL. The standing recommendations include discharge plans to balance stage in the Headwaters Lakes against discharge for KRRP restoration, KRREP limits on rates of discharge increase/decrease at S-65/S-65A, guidelines for rates of increasing and decreasing headwater stage at S-65C to manage water levels in the southern Phase I floodplain of the Kissimmee River, and requests for recession rates in dry season.

In this section, hydrologic conditions for WY2016 were quantified with data collected by the SFWMD hydrologic monitoring program at water control structures throughout the Kissimmee Basin (**Figures 9-1** and **9-2**) and stage monitoring locations distributed in the Kissimmee River channel and floodplain (**Figure 9-6**). This section follows the conventions of SFWMD and USACE water managers by reporting hydrologic variables in English units—inches for rainfall, feet National Geodetic Vertical Datum of 1929 (NGVD29) for stage and depth, and cfs for discharge.

Hydrology in the KRRP Phase I area floodplain is complex; its dynamics were characterized for WY2016 with two metrics—mean depth at floodplain BLM sites (here referred to as BLM depth) and mean depth on the Kissimmee River floodplain (referred to as mean depth). BLM depth is calculated as the average depth at five stations in the northern floodplain at which BLM vegetation occurred prior to regulation (pre-1962, before construction of the C-38 canal) and where BLM is expected to reestablish after restoration construction is completed (see *Hydrology* subsection of the *Kissimmee River Restoration Evaluation Program* section of this chapter). The five stations were selected because they are located in the northern floodplain of the Phase I area and are thus outside the direct influence of the headwater stage of the downstream water control structure (S-65C), and for concurrence with Expectation 3, also evaluated in the *Kissimmee River Restoration Evaluation Program* subsection. BLM was the predominant wetland plant community on the floodplain prior to channelization and with appropriate water management is expected to cover over 50 percent of the Kissimmee River floodplain after restoration construction is completed. BLM has very long hydroperiod requirements (see the *Expectation 3* subsection of the *Kissimmee River Restoration Evaluation Program* section). Mean depth is the average depth in the Phase I area floodplain, estimated using interpolations of mean daily stage measurements from a network of stage recorders covering most of the Phase I area. The interpolations are used to create a grid of water surface elevations, which are compared to ground elevations from a digital elevation model. Ground elevation is subtracted from the water surface elevation to obtain an estimated depth for each grid cell. Mean depth for the Phase I area is the average of depths of individual grid cells on a given date. Thus, mean depth provides an indication of conditions throughout the entire Phase I area, including the southern floodplain where depth

is influenced by a backwater effect of S-65C (Anderson 2014a). BLM depth and mean depth exhibit similar trends, but BLM depth exhibits a greater range of fluctuation.

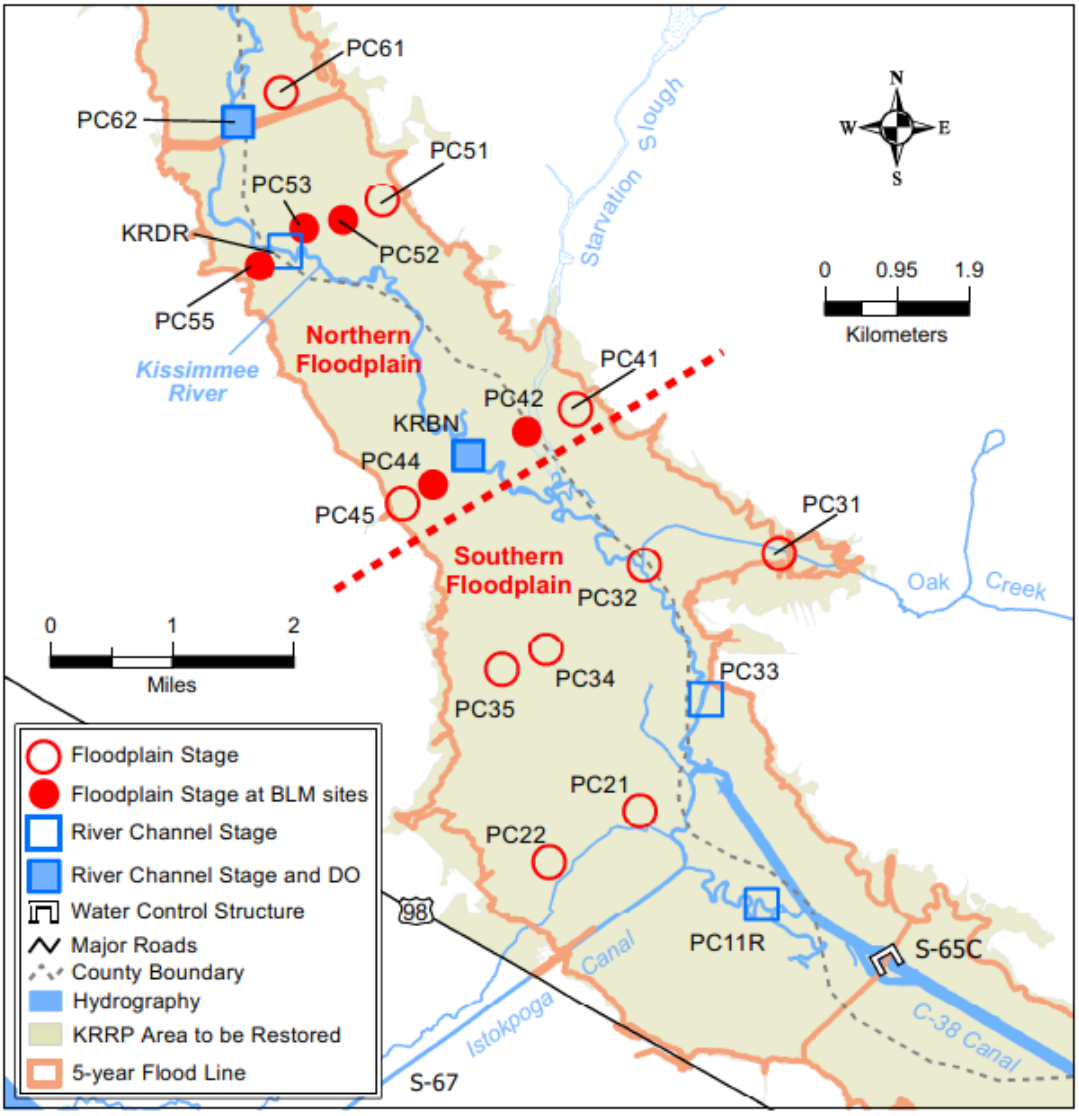

Figure 9-6. Locations of hydrologic monitoring sites in Pool C used to guide operations and evaluate restoration expectations.

RAINFALL

During WY2016, annual rainfall was above average for the third consecutive year in the UKB and the fourth consecutive year in the LKB. The UKB total of 52.2 inches was 2.9 inches above the long-term average (1981–2010); the LKB total of 52.8 inches was 6.8 inches above average. Most rainfall fell in the June–October wet season, but above average rainfall in the dry season (November 1, 2015–May 31, 2016) made an important contribution to the annual total, especially in January and March in the UKB and in January in the LKB (**Figure 9-7**). Wet season rainfall totaled 31.8 inches (3.6 percent above average) in the UKB and 30.2 inches (2.4 percent above average) in the LKB. Dry season rainfall in the UKB totaled 20.4 inches (9.3 percent above average) and in the LKB 22.6 inches (36.8 percent above average).

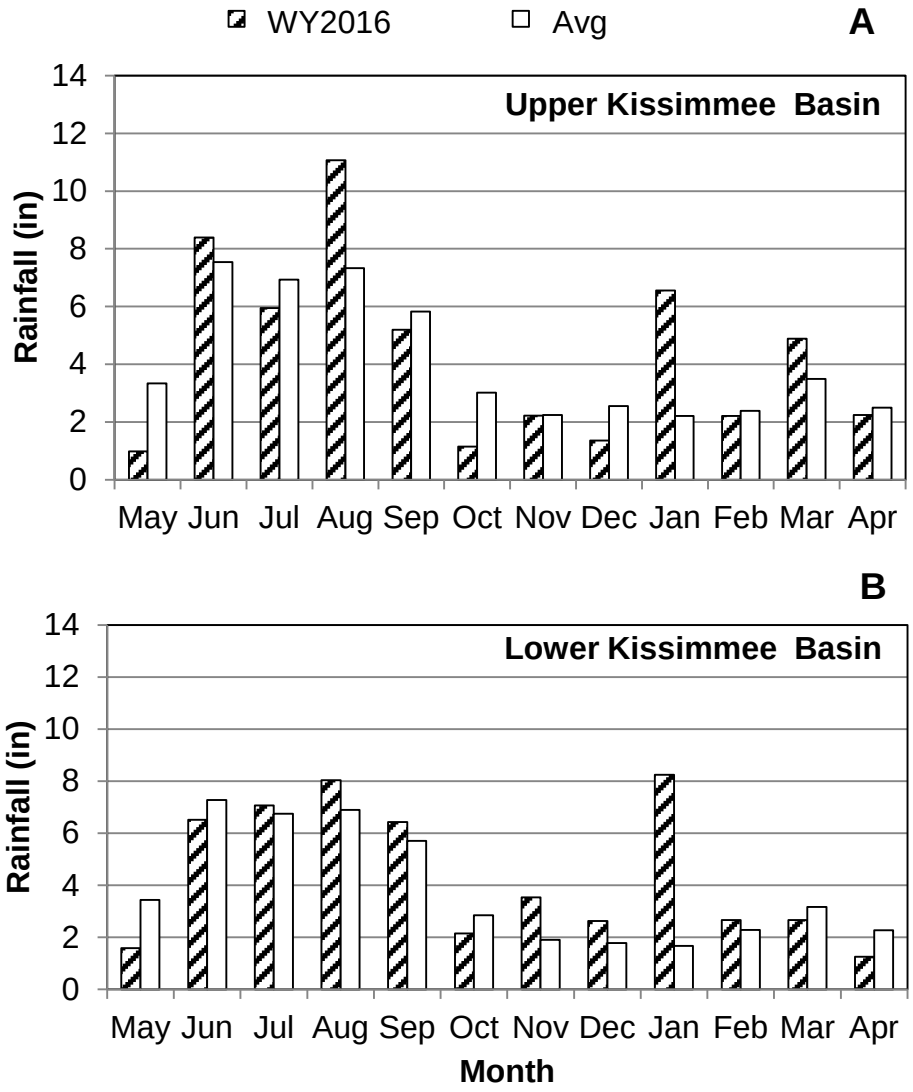

Figure 9-7. Monthly rainfall (in inches [in]) for WY2016 and average rainfall (1981–2010) in (A) the UKB and (B) the LKB.

OPERATIONAL REQUESTS AND OUTCOMES

The planning process described earlier was used to develop recommendations for water management operations in WY2016. The recommendations were made by KRREP scientists and staff from other agencies prior to the start of the wet and dry seasons. The following section summarizes the recommendations for the river (from the KRREP group) and requests for the lakes (from USFWS/FWC) for the 2015 wet season and the 2015–2016 dry season, followed by narratives of the outcomes of the water management actions designed to address these goals.

Wet Season 2015

KRREP Recommendations for Wet Season 2015

- Avoid discharge >1,500 cfs at S-65 from June–October if possible to reduce the likelihood of hypoxic events and fish kills, and to raise lake stage.
- Implement the 1,400 cfs/50.5 ft threshold discharge plan described below, which increases discharge to 1,400 cfs when lake stage approaches a 50.5-ft threshold, then holds 1,400 cfs (except during flood control events) unless stage declines below 50.5 ft. The plan also includes recommendations for limits on rates of change in discharge to the KRRP to address recurring problems of DO crashes (**Figure 9-8**).

USFWS/FWC Requests for Wet Season 2015

- Manage ascension rates as possible on East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes to not exceed 1.0 ft/month to benefit alligator, Everglade snail kite, and apple snail (*Pomacea paludosa*) reproduction and other lake-dependent wildlife.

1,400/50.5 Discharge Plan for Wet Season 2015

The 1,400/50.5 discharge plan (**Figure 9-8**) was developed to provide for more continuous inundation of the Kissimmee River floodplain during the 2015 wet season (June–October 2015) while addressing concerns about low lake stages by linking discharge to lake stage (and therefore to rainfall). Because the Kissimmee River floodplain slopes to the south, flooding fully depends on discharge from S-65 via S-65A (Anderson 2014a). In past years of the Interim Period, S-65 operations have tended to alternate (often multiple times per year) between brief periods of high discharge for flood control as stage in the Headwaters Lakes rose to or above the regulation line, followed by reductions in discharge to avoid subsequent stage declines in the Headwaters Lakes. The undesirable effect of such operations for the Kissimmee River, clearly visible in stage/discharge hydrographs (e.g., **Figure 9-9**), was sudden inundation of the floodplain followed by rapid termination of flood events as discharge declined below channel bankfull. The resulting intermittent pattern of floodplain inundation followed by rapid drying (often at the timescale of weeks) was quite different from the single long, continuous flood pulse that was characteristic of the natural flood pulse that occurred in the prechannelized system (see Koebel et al. 2016). Such sudden increases in stage and the ensuing depth reductions on the Kissimmee River floodplain are unnatural, contrary to restoration goals, interfere with fish reproduction and recruitment that depend on river channel/floodplain connectivity, and disrupt wading bird foraging on the floodplain, especially during the dry season. During both the wet and dry seasons, such operations cause periods of intermittent inundation separated by rapid drydowns of the floodplain, and are a basic reason for near annual failures since 2001 to improve performance for the KRREP hydroperiod performance measure even in wet years, as described in the *Kissimmee River Restoration Evaluation Program* section's *Hydrology* subsection below and in SFER 2016 (Koebel et al. 2016).

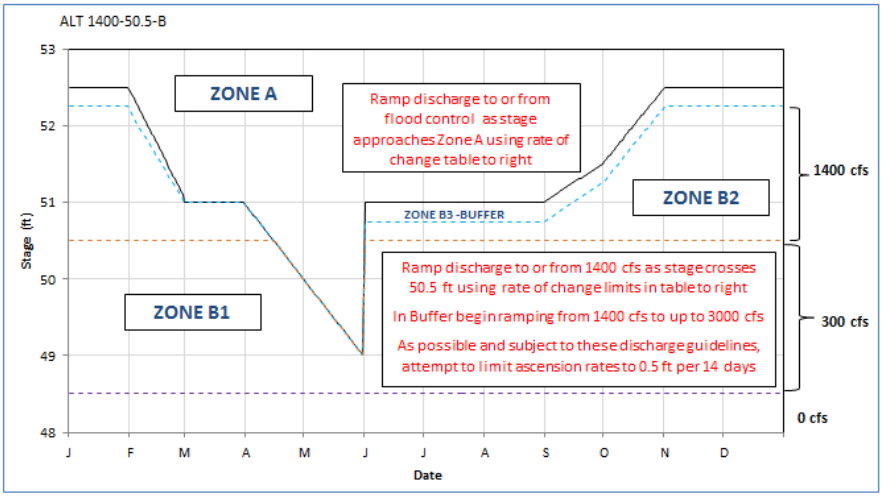

Table 1. Discharge Rate of Change Limits for S65/S65A
Rate limits apply only in Zone B

	Q (cfs)	Maximum rate of increase (cfs/day)	Maximum rate of decrease (cfs/day)
Zone B	0-300	50	-50
	300-1400	150	-75
	1400-2500	300	-300
	2500-3000	1000	-1000
Zone A	No limits		

Figure 9-8. The 1,400/50.5 discharge plan for Wet Season 2015. Inserted Table 1 specifies limits on rates of discharge increase and decrease at S-65 and S-65A. Source: 2014–2015 Kissimmee Basin Standing Recommendations.

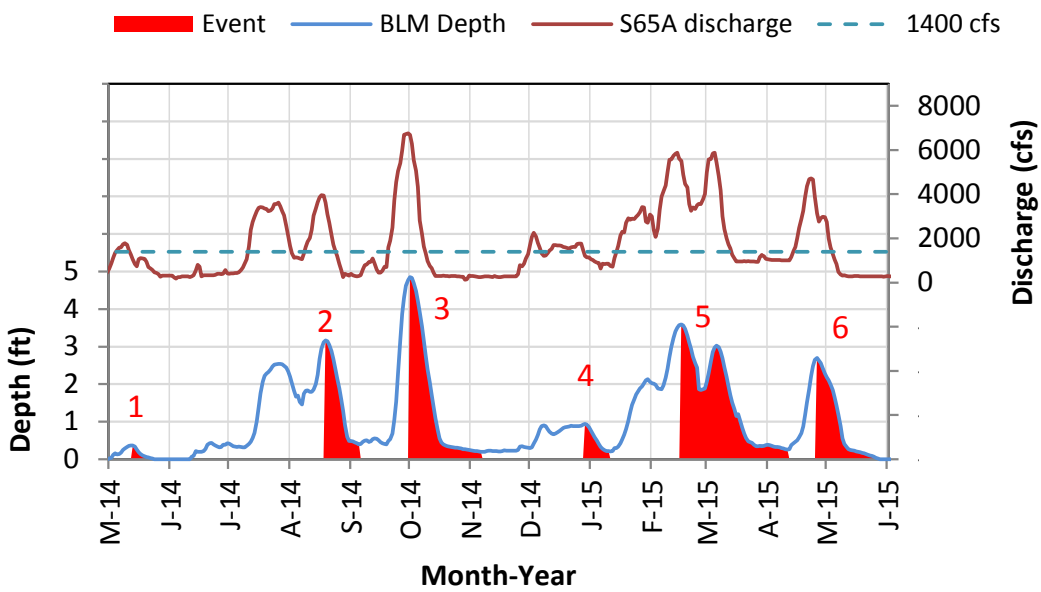

Figure 9-9. Large increases in S-65A discharge followed by decreases in discharge caused six floodplain inundation recession events during WY2015.

Discharge changes during the previous (2014) wet season can be used to illustrate the intermittent wet/dry pattern and the potential for improvement of hydroperiod duration (Koebel et al. 2016). Discharge was increased above full floodplain inundation (3,000 cfs) and reduced to within-bank levels three times over 88 days (July 12–October 7, 2014 in **Figure 9-9**). The total volume discharged during this interval was 344,960 ac-ft; a volume that is equivalent to a discharge of 1,400 cfs (above bankfull) for 124 consecutive days. Some of the discharge occurred at high levels that have no known benefit for the KRRP and actually may be harmful because of the resulting extreme depths. The 1,400/50.5 discharge plan changes the timing of discharge so that more of the volume of discharge occurs at levels that are beneficial to the floodplain, while reducing the duration and frequency of periods of below-bankfull discharge to the

extent possible given the rainfall that occurs in a given year, and overall has no net negative effect on the Headwaters Lakes stage.

The 1,400/50.5 discharge plan is shown in **Figure 9-8**. The plan is climate driven in that it does not increase discharge until rainfall has caused lake water levels to rise to 50.5 ft; and does not decrease discharge unless rainfall is not sufficient to keep water levels above 50.5 ft. Increasing discharge above 1,400 cfs occurs only if there is sufficient rainfall to raise lake stage to the buffer zone or above the regulation schedule, necessitating flood control releases. The plan includes limits on the rate of discharge increase and decrease as shown in the table insert in **Figure 9-8**. The range of discharges used in the plan are conservative relative to the hydrologic needs of restoration. The choice of 1,400 cfs as the discharge needed for floodplain inundation is based on the estimated bankfull discharge (i.e., discharge needed to fill and exceed the river channel) of 1,400 cfs in the prechannelization Kissimmee River (Warne et al. 2000). The plan is also conservative in that it ramps down to 300 cfs—a substantially lower level of discharge than the mean minimum discharge (500 cfs) that occurred during the prechannelization reference period (Anderson 2014a). The plan is a compromise between lake and river benefits: it was selected among several alternatives that differed primarily in the threshold elevation at which discharge would be increased from minimum flow (300 cfs) to 1,400 cfs. Modeling indicated that the use of lower thresholds (e.g., 50 ft or even 49.5 ft) allowed more water to be discharged from the Headwaters Lakes to the river and would increase the duration of discharge at or above 1,400 cfs, and therefore resulted in a longer duration of floodplain inundation; however, use of these thresholds in general resulted in lower stages in the Headwaters Lakes. Conversely, raising the threshold to 51 ft resulted in higher mean stage in the Headwaters Lakes, but shortened periods of floodplain inundation. Thus, the selected threshold of 50.5 ft is a compromise between goals for the Headwaters Lakes, which generally are stated as oriented toward high lake stages during the wet season, and river goals, which demand slowly varying discharge without repeated, unnecessary reductions of discharge to below-bankfull levels punctuated by brief high-flow events. The discharge plan is not intended to fully meet KRREP restoration targets for the Kissimmee River, which likely depends on the additional upstream storage that will be provided by the HRS. However, the 1,400/50.5 discharge plan significantly improves on prior operations and moves toward better performance in one crucial aspect of the hydrologic requirements for restoration – floodplain inundation.

Wet Season 2015 Water Management Outcomes

Rainfall was approximately average in June and July (**Figure 9-7**), which resulted in a steady rise in water levels in all of the UKB lakes. Variable discharge releases were made to slow the rate of water level ascension. Water levels in the smaller lakes reached the summer pool of their respective regulation schedules by the end of June. Water levels in East Tohopekaliga and Tohopekaliga reached their summer pool elevations around the beginning of August (**Figure 9-10**). The Headwaters Lakes reached summer pool in mid-August (**Figure 9-11**).

Ascension rates were evaluated by counting the number of days that the 14-day difference in lake water level exceeded 0.5 ft as requested by USFWS and FWC. During the June 1—August 15 window, East Lake Tohopekaliga had 0 exceedances of the requested rate, Tohopekaliga had only 2 exceedances, and the Headwaters Lakes had 21 exceedances (**Figure 9-12**). The higher frequency of exceedances in the Headwaters Lakes was expected beforehand and was due to the combination of the timing of rainfall, releases from S-61 (**Figure 9-10**, panel B) to control ascension upstream in Lake Tohopekaliga, limits on rates of discharge increase at S-65 to protect the Kissimmee River (see the *Hydrology* subsection in the *Kissimmee River Restoration Evaluation Program* section), and prioritization among the lakes as part of the USFWS/FWC requests (highest priority for controlling ascension was given to East Lake Tohopekaliga, then Tohopekaliga, and then the Headwaters Lakes). In early September (after the window of concern for ascension rate limitation), the 14-day difference in East Tohopekaliga exceeded 0.5 ft for 2 weeks and had a maximum value of 1.4 ft. Unusually high rainfall during this period was associated with remnants of Tropical Storm Erika. During this event, maximum releases were made from East Tohopekaliga for flood

control. This event illustrates the difficulty of controlling ascension rates and their dependence on the timing and magnitude of rainfall. During the pre-regulation period, when water levels were not managed, 14-day ascension rates frequently exceeded the 0.5 ft threshold (**Table 9-3**).

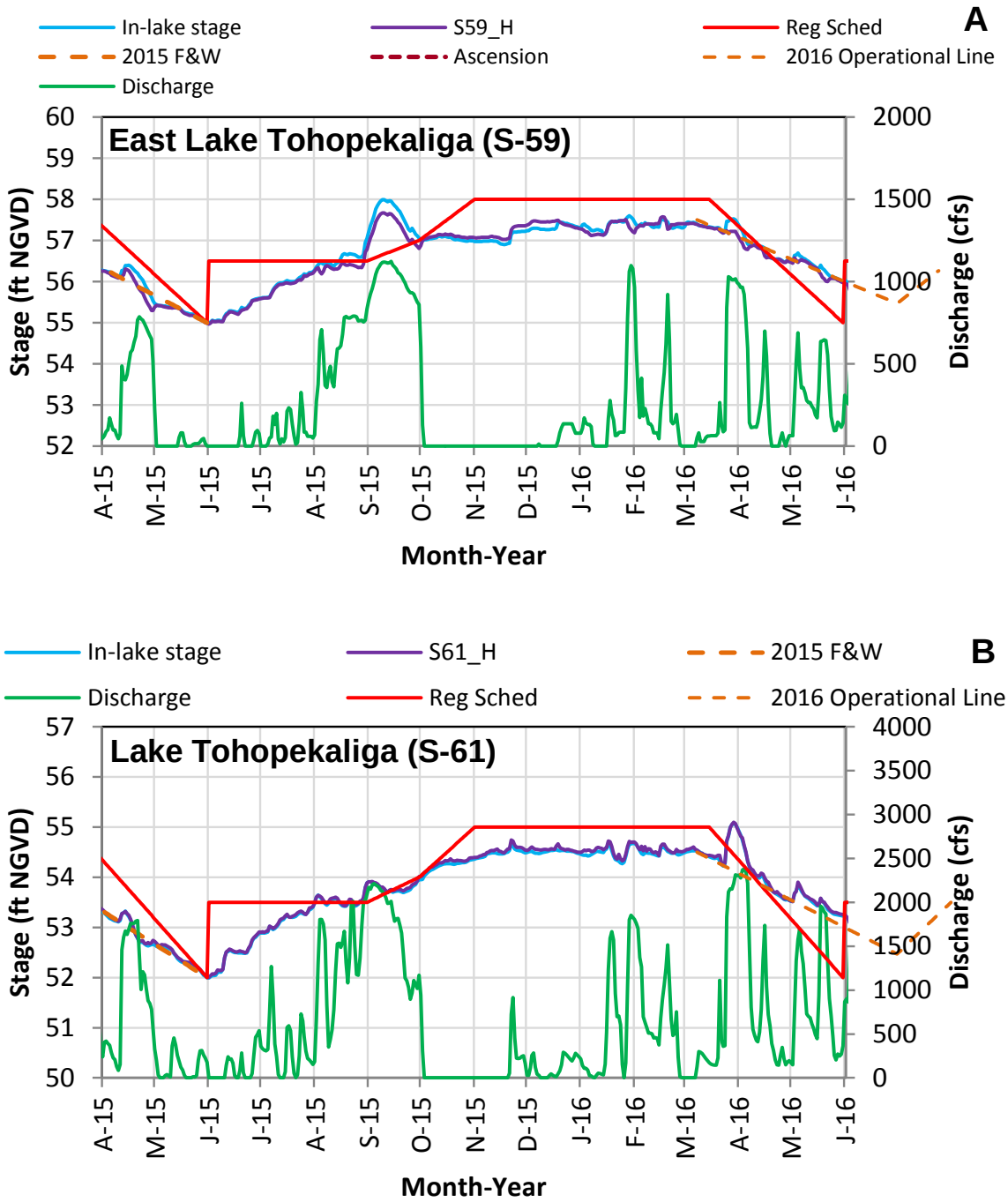

Figure 9-10. Regulation schedule (red line), water level (blue line), and discharge (green line) for (A) East Lake Tohopekaliga and (B) Lake Tohopekaliga during WY2016 and April of WY2015 and May of WY2017. Orange dashed lines are desired water level recession targets for Everglade snail kites in 2015 and operational guidance lines in 2016.

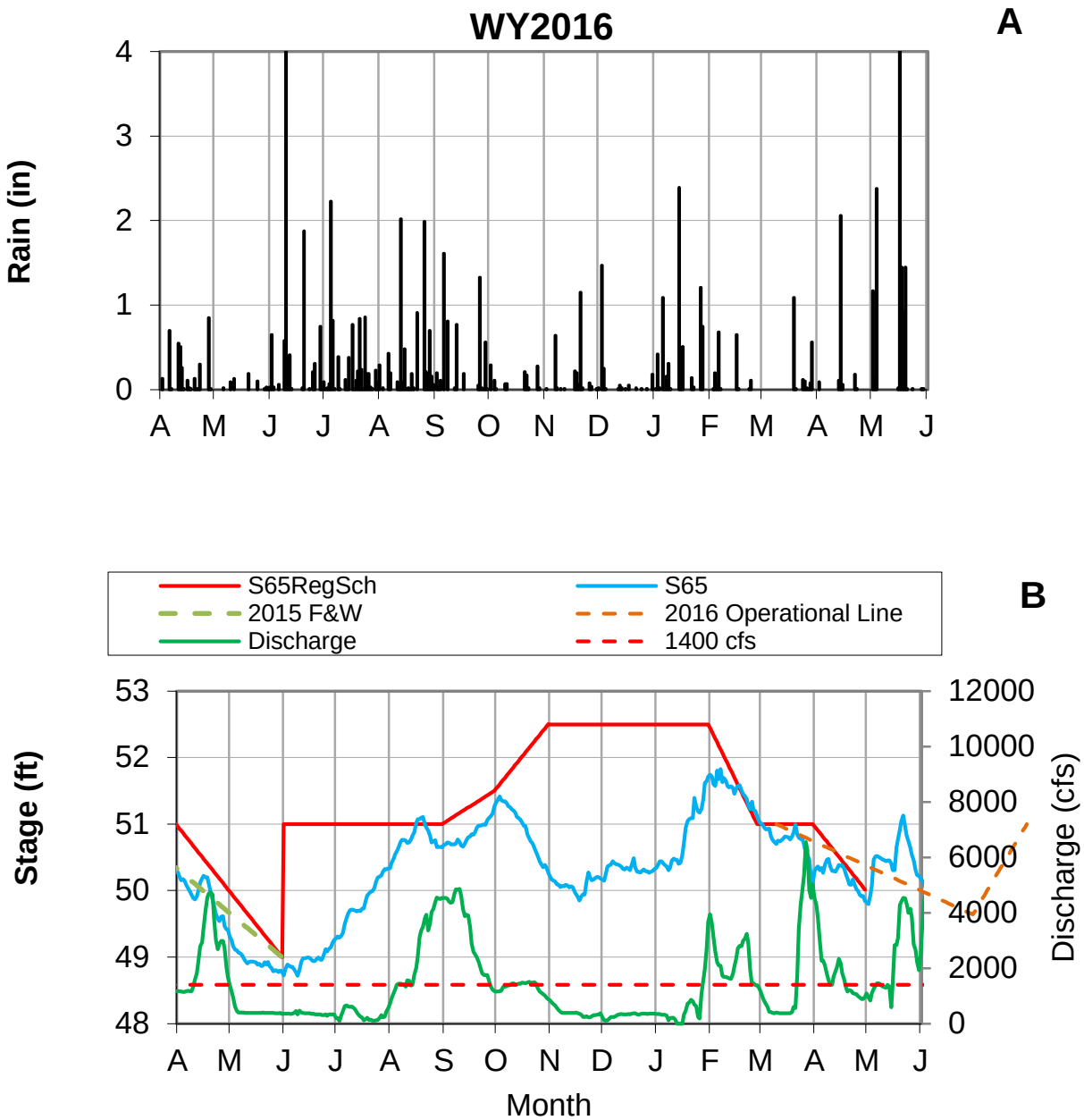

Figure 9-11. (A) Rainfall in inches (in) and (B) regulation schedule and water level in feet (ft) in the Headwaters Lakes, discharge in cfs at the outlet of Lake Kissimmee (S-65 structure) for WY2016 and April of WY2015 and May of WY2017. Panel B includes stage recession targets for F&W in 2015, and the 2016 operational guidance line.

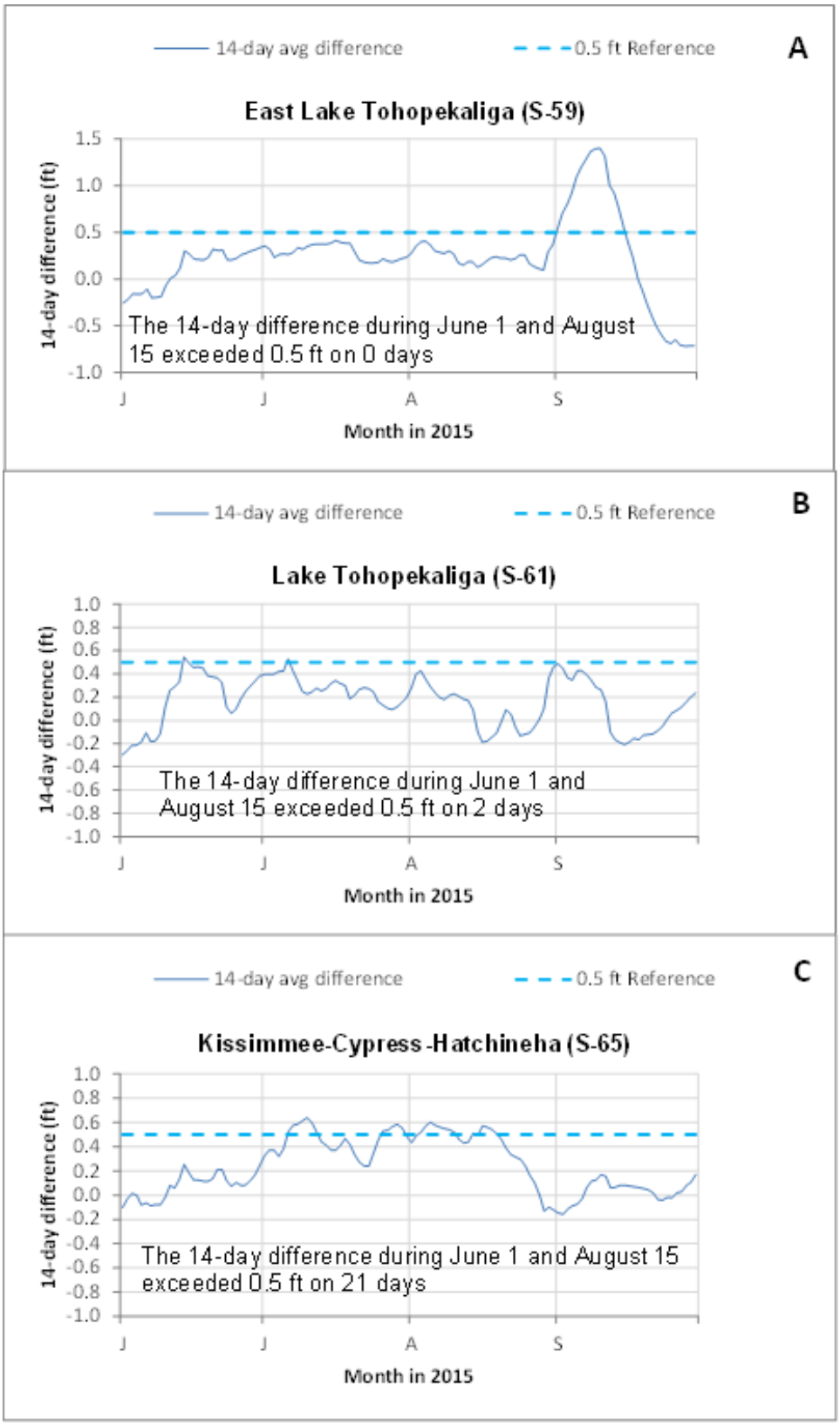

Figure 9-12. Stage ascension rate, measured as a14-day difference, in (A) East Lake Tohopekaliga, (B) Lake Tohopekaliga, and (C) the Headwaters Lakes during the June 1—August 15 window.

Table 9-3. Stage ascension rate metrics for the Headwaters Lakes calculated for three periods of record. Metrics are calculated for the June—September 10 window using the 14-day difference (amplitude). An exceedance occurs when the ascension rate is >0.5 ft/day for the 14-day difference method.

Period	Number of Calendar Years	Mean Frequency of Exceedance (days/year)[a]	Standard Deviation	Number of Years in Exceedance	Percent of Years in Exceedance
Pre-regulation	33	17	19	23	70
Regulated	26	15	13	21	81
Interim	14	25	7	14	100

a. Mean frequency also approximates the percentage of the 102 day window that is in exceedance.

As water in the Headwaters Lakes rose above 50.5 ft on August 4, per the 1,400/50.5 discharge plan, discharge was increased over several days, using the rate limits in **Figure 9-8**, reaching 1,400 cfs on August 8. Discharge remained at or above 1,400 cfs for 81 consecutive days (through October 27, 2015), resulting in the seventh longest inundation event since the Interim Period began in 2001 (see *Kissimmee River Restoration Evaluation Program* section's *Hydrology* subsection). Of the total volume (408,373 ac-ft) discharged from S-65 during this 81-day period, almost half (44 percent) was for flood control and therefore could not have been held in the Headwaters Lakes; only 56 percent was needed to maintain a mean daily discharge of 1,400 cfs. With the increases in discharge, water levels in the at the BLM sites in the northern Kissimmee River floodplain began to increase on August 11; mean depth at the BLM sites exceeded 1 ft on August 19 and remained greater than 1 ft through October 20, for a total of 63 consecutive days. Mean depth at the BLM sites decreased as discharge decreased. While discharge was held at 1,400 cfs, it slowed the rate of stage decrease but it was not adequate to sustain 1 ft of depth at the BLM sites. This indicated that a discharge >1,400 cfs will be needed to maintain depth of 1 ft.

Only three inundation events began in WY2016 (**Figure 9-13B**) compared with the six events that began in WY2015 (**Figure 9-9**), a substantial improvement. The first event was associated with the increase in discharge to 1,400 cfs as lake stage rose above 50.5 ft per the 1,400/50.5 discharge plan. As lake stage continued to rise into the buffer zone and then above regulation schedule, discharge was increased to a maximum of 4,500 cfs for flood control. The other two events occurred during the dry season and are discussed below in the *Hydrology* subsection.

WY2016 included an event in which the concentration of DO in the Kissimmee River declined below 1 mg/L (anoxia). In the Kissimmee River, DO concentrations <2 mg/L are stressful to centrarchids (largemouth bass and other sunfish); concentrations below 1 mg/L may be lethal (Furse et al. 1996). Hypoxic conditions also can affect other organisms, including many aquatic invertebrates, that depend on DO. A section summarizing current knowledge of the relationship of hypoxia to water management in the Kissimmee River was included in the 2015 SFER – Volume I, Chapter 9 (see *Hypoxia in the Kissimmee River: Consequences, Causes and Water Management* section in Cheek et al. 2015). The WY2016 hypoxic event was associated with the first period of floodplain inundation, lasted for 51 days (August 22—October 11, 2015) (**Figure 9-13**), and included an anoxic period of 38 days. DO declined to < 2 mg/L when discharge was greater than 3,000 cfs and BLM depth had increased to 1.5 ft. Recovery from this event happened as S-65A discharge approached 1,400 cfs and BLM depth declined below 2 ft. During the event, a small fish kill occurred in Pool C (August 27-28, 2015). Recorded were 209 dead fish—mostly sunfish (e.g., bluegill [*Lepomis macrochirus*], redear [*Lepomis microlophus*], warmouth [*Lepomis gulosus*]), some largemouth bass, and a few bullheads (*Ameiurus* spp.) and channel catfish (*Ictalurus punctatus*). The KRREP operational recommendation to use slow rates of change in discharge from S-65A (**Figure 9-8**) slowed the onset of these events (allowing time for sensitive species such as bass to adapt physiologically to the reduced oxygen condition) and reduced the duration of hypoxic conditions.

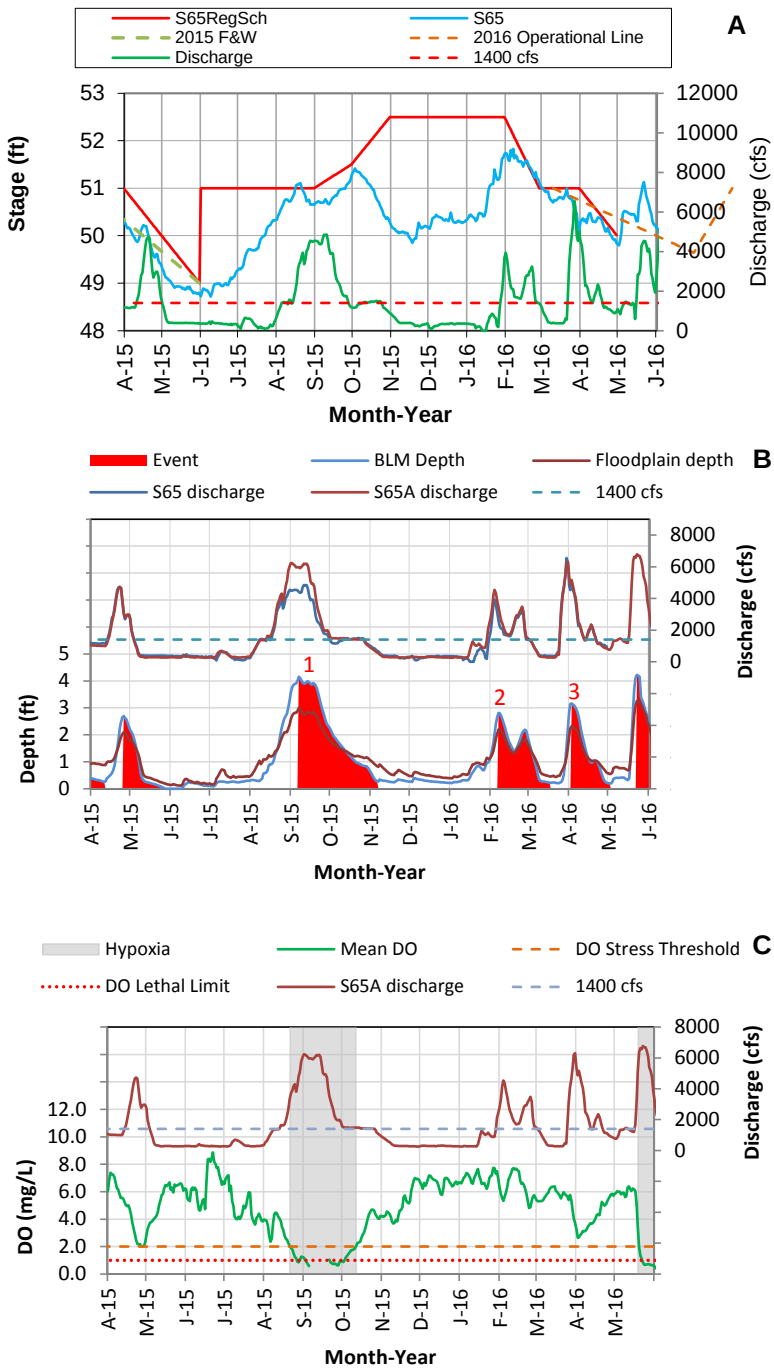

Figure 9-13. (A) Regulation schedule, lake stage, and discharge from the Headwaters Lakes; (B) floodplain depth and BLM depth at five stations (PC52, PC55, PC53, PC44, and PC42) in the northern floodplain where BLM occurred prechannelization and is expected to reestablish after restoration is completed in relation to mean daily discharge at S-65, S-65A, and S-65C during WY2016, April of WY2015, and May of WY2017; and (C) mean daily DO (calculated from 15-minute measurements) in the river channel at KRBN and PC62, and discharge at S-65, S-65A, and S-65C. Red numbers in panel B identify three events that began in WY2016 where the floodplain was inundated and rapidly drained as described in **Table 9-4**. See **Figure 9-6** for locations of hydrologic monitoring sites and the *Kissimmee River Restoration Evaluation Program* section's *Hydrology* subsection for more information.

Table 9-4. Characteristics of three events that began in WY2016 where changes in discharge caused increases and then decreases in BLM depth to very low levels for three numbered events shown in **Figure 9-13B**. For each event, the BLM depth is given at the start, the peak, and the end of the event.

Event	BLM Depth (ft)			Duration of Depth Decrease (days)	Interval between Events (days)
	Event Start	Event Peak	Event End		
1	0.37	4.16	0.28	60	74
2	0.23	2.82	0.23	39	59
3	0.33	3.16	0.22	27	11

Dry Season 2015–2016

USFWS/FWC Requests for Dry Season 2015–2016

- FWC and USFWS requested recession lines for East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes to benefit the Everglades snail kite. The recession lines were to begin after February 1, depending on lake stage, and had slopes of 0.62 ft per 30 days in East Lake Tohopekaliga and Lake Tohopekaliga and 0.63 ft per 30 days in the Headwaters Lakes.

KRREP Recommendations for Dry Season 2015–2016

- Continue the 1,400/50.5 plan into the first months of dry season until the recession lines were to be started. During follow-up meetings after discharge had been reduced to 300 cfs, the discharge plan was adjusted to raise the stage threshold for increasing discharge to 1,400 cfs from 50.5 ft to 51 ft. The one-time adjustment to a higher threshold during this portion of dry season was intended to ensure that discharge would not be increased and then decreased, which would have resulted in shorter intervals of floodplain inundation in the Kissimmee River.

District Seasonal Non-Standard Operations for Dry Season 2015–2016

- In anticipation of above-average rainfall during the November—May dry season due to a climatic outlook for very strong El Niño conditions, SFWMD water managers developed Seasonal Non-Standard Operations for the 2015–2016 dry season that would be implemented for as long as strong El Niño and wet conditions persisted. These operations were expected to hold water levels in the KCOL 0.2–0.5 ft below high pool (**Figure 9-5**) depending on water body. Holding water levels lower would allow some temporary storage during rainfall events and would make it easier to move water through known bottlenecks in the system by slightly increasing head differences between some lakes.
- In early February, following a declaration of a state of emergency by Governor Rick Scott due to high flows and its associated problems in the coastal estuaries, SFWMD decided to hold as much water as possible in the Headwaters Lakes to help alleviate flows to Lake Okeechobee. This meant departing from the requested F&W recession lines.

USACE Requests for Dry Season 2015–2016

- Operate S-65C to maintain the headwater stage from 33.7 to 34.2 ft NGVD to allow barging in Pool C for KRRP construction work.

Dry Season 2015–2016 Water Management Outcomes

Implementation of the dry season operating requests in the Kissimmee Basin were strongly influenced by rainfall conditions in the rest of the District. While the UKB had approximately average rainfall in November and December; the rest of the District had well-above average rainfall. The November–May dry season in 2015–2016 was the wettest District-wide since 1957–1958 and the second wettest since record keeping began in 1932. Concerns for the eastern (St. Lucie) and western (Caloosahatchee) estuaries resulted in an effort to hold as much water in the KCOL during the dry season and reduce inflow to Lake Okeechobee.

Water levels in the UKB lakes continued to rise with dry season rainfall and reached the seasonal non-standard operational lines in November in East Lake Tohopekaliga and Lake Tohopekaliga (**Figure 9-10**). Variable discharges were made to hold these lakes at the non-standard operational line. Although water levels in the Headwaters Lakes continued to rise during the first months of dry season, stage did not reach the non-standard operational line. Water level in the Headwaters Lakes rose to 51 ft (the dry season threshold for increasing discharge to 1,400 cfs), but on January 20, 2016, the Kissimmee Basin technical team recommended to temporarily bypass the 1,400/50.5 discharge plan and allow water level to rise to 51.5 ft (the February 1 recession starting stage) if conditions allowed, while continuing to follow KRREP discharge ramp-down guidelines.

In February, as discharge was being increased from East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes to begin F&W recessions, a decision was made to operate the lakes higher than the F&W lines or hold water levels steady. The decision to hold water in the KCOL was made to ease inflow, however slightly, to Lake Okeechobee and South Florida's coastal estuaries because of record rainfall across the District. Water levels in East Tohopekaliga and Tohopekaliga were held roughly steady through most of March, then efforts were made to follow new operational guidance lines developed by SFWMD that were intended to slow recession rates in East Lake Tohopekaliga, Tohopekaliga, and the Headwaters Lakes. The operational guidance lines were modified twice to accommodate changing conditions; the final versions are shown in the hydrographs (**Figures 9-10** and **9-11**). The operational guidance lines varied from the regulation schedules most significantly by lowering stages to 0.5 ft above low pool in East Tohopekaliga and Tohopekaliga and 0.64 ft above low pool in the Headwaters Lakes; the new low stages were reached a month later than in the regulation schedules on June 30. Consequently, these lines had a more gradual slope (0.52 ft per 30 days in East Lake Tohopekaliga and Tohopekaliga, and 0.36 ft per 30 days in the Headwaters Lakes) than the regulation schedules. The operational guidance lines were part of a strategy to hold as much water as possible in the KCOL to reduce the possibility of a need for additional releases from Lake Okeechobee.

When discharge from the Headwaters Lakes increased to begin the F&W recession in February, the second floodplain inundation event in WY2016 began (**Figure 9-13B**). When the F&W recession line was suspended, the Headwaters Lakes discharge was decreased using the rate limits in the 1,400 cfs/50.5 ft threshold plan. While discharge was being ramped down, stage in the Headwaters Lakes intersected the regulation schedule, necessitating increases in discharge for flood control. This series of events resulted in a reversal in BLM depth in the northern floodplain of 2.6 ft, which began the second inundation event of WY2016 (**Table 9-4**). The Headwaters Lakes regulation schedule flattens out in March, so discharge was again reduced, this time to 300 cfs for 10 days, during which time floodplain BLM depth declined to low levels. A subsequent increase in discharge in late March to lower the Headwaters Lakes water levels to follow the operational guidance line resulted in the third flood event with an increase in BLM depth of 2.8 ft, followed by the third recession event in WY2016 (**Figure 9-13B**).

WY2016 Water Management Summary and Conclusions

The 1,400/50.5 discharge plan was developed for S-65 to provide longer and more continuous periods of floodplain inundation. The plan was intended to improve on interim hydrologic conditions, rather than to fully meet the restoration hydrologic criteria described in the *Kissimmee River Restoration Evaluation Program* section's *Hydrology* subsection. The plan was implemented without difficulty by SFWMD water managers and improved on conditions in WY2016 by producing a single prolonged inundation event during the wet season, made possible by increasing the duration of discharge at 1,400 cfs (above bankfull) by about 1 month compared to what would have happened if discharge had ramped down to 300 cfs between flood control events. Had the reduction in discharge from flood control releases continued to 300 cfs, it likely would have resulted in at least a second inundation event for the Kissimmee River floodplain, similar to the two wet/dry events that occurred in WY2015 wet season.

Implementation of the 1,400/50.5 discharge plan provided insights into the relationship between S-65A discharge and BLM depth. Holding discharge at 1,400 cfs slowed the rate that BLM depth decreased, but 1,400 cfs was not sufficient to maintain a depth of 1 ft at BLM sites. Future implementation of the plan should consider using a higher discharge threshold than 1,400 cfs. Although pre-season analysis suggested this possibility, this is important information that could not have been extracted from the previous 15 years of interim period data because periods in which S-65A discharge was held constant at 1,400 cfs did not occur.

As reported in SFER – Volume I, Chapter 9 (Koebel et al. 2016), attempts to control early wet season ascension rates can—and often will—be overwhelmed by rainfall events; as shown earlier, ascension rates exceeding 0.5 ft using the 14-day difference method occurred frequently prior to regulation. In WY2016, although the 14-day difference exceeded the 0.5 ft threshold on 0 days in East Lake Tohopekaliga and only 2 days in Tohopekaliga, it was exceeded on 22 days in the Headwaters Lakes. The higher frequency of exceedances in the Headwaters Lakes reflects interactions between East Lake Tohopekaliga and Lake Tohopekaliga and the effects of discharge from those lakes on the Headwaters Lakes. Inflow into the Headwaters Lakes is increased by efforts to reduce ascension rates upstream in East Lake Tohopekaliga and Lake Tohopekaliga (S-59 and S-61, respectively) as well as by limits on rates of discharge increase downstream to protect KRRP. This finding illustrates the strong potential for operational conflicts between these three water bodies, complicating implementation of stage target requests, including ascension and recession rates.

The requested F&W recession lines for the 2015–2016 dry season were replaced by operational guidance lines that began the recessions in East Lake Tohopekaliga and Lake Tohopekaliga about one month later than requested and at a slower recession rate, and attempted to follow the operational guidance lines starting in early March. In the Headwaters Lakes, although stage rose in January, it did not rise to high pool and intersected the regulation line at 51.5 ft, at which point SFWMD released water to follow the descending limb of the regulation line until March 1, then attempted to follow the operational guidance line starting in mid-March. The guidance lines continued the recessions later into the following (2016) wet season but ultimately did not decline to as low a stage as the original F&W lines, which was intended to slow recession rates.

Following the dry season operational line for the Headwaters Lakes was observed to have negative effects on floodplain inundation in the Kissimmee River due to adjustments in S-65 discharge needed to prevent lake stage from moving too far above or below the guidance and/or regulation lines. Following the guidance line in WY2016 (2015–2016 dry season) resulted in two wet/dry events; the lines also caused at least one additional event at the beginning of WY2017 (May 2016). The effect of trying to follow the operational line very closely is similar to what has been seen in previous years when trying to follow F&W recession lines closely. Inundation of the Kissimmee River floodplain is almost fully dependent on discharge (Anderson 2014a) and responds dramatically to changes in discharge intended to control stages in the Headwaters Lakes. To lower lake stage along an operational line or F&W line requires increases in

discharge to limit stage increases after rain events, followed by a decreases to keep stage from declining below the line. The resulting discharge adjustments can inundate all or some of the floodplain then drain it rapidly. Ecological problems in WY2016 associated with rapid drawdowns and reversals, and their effects on project goals for the KRRP, are detailed in the *Kissimmee River Restoration Evaluation Program* section's *Hydrology* subsection.

KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM

A major component of the KRRP is assessment of restoration success by the KRREP, a comprehensive ecological monitoring program (Bousquin et al. 2005; Williams et al. 2007; Koebel and Bousquin 2014) mandated and designed to evaluate the ongoing status and ultimate success of the KRRP. Restoration evaluation was identified as SFWMD's responsibility in its cost-share agreement with USACE for KRRP (Department of the Army and SFWMD 1994). Initiation of the KRREP in the 1990s represented a pioneering effort to use scientific data from a set of rigorous and statistically valid monitoring studies to evaluate the success of one of the largest river-floodplain restoration projects in the world. Success is being tracked, in part, using 25 hydrologic, biotic, and abiotic performance measures (Anderson et al. 2005) to track project success and evaluate how well the project meets its goal of reestablishment of ecological integrity to the Kissimmee River and floodplain (Koebel and Bousquin 2014). 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 the 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 peer-reviewed and SFWMD technical publications, scientific conferences, and annual reports. Full realization of some aspects of the restoration expectations, particularly those related to floodplain responses in specific portions of the floodplain, are tied to removal of the S-65C water control structure during an upcoming phase of construction. However, targeted adaptive water management in the Interim Period prior to project completion can move parts of completed phases of the project in the direction required by project goals. Although final evaluations of project success will take place after all construction components are in place, the ecological and hydrologic 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 evaluation will continue for at least five years after construction is complete or until ecological responses have stabilized (USACE 1991).

Post-construction monitoring continued in the Phase I restoration area in WY2016, and the 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, aquatic invertebrates, herpetofauna, fish, and birds, have already documented changes consistent with those predicted by the expectations developed for the KRREP (Anderson et al. 2005), particularly in the river channel, with responses of floodplain hydrology and vegetation lagging substantially behind (see the *Hydrology* subsection below, Anderson 2014a, Spencer and Bousquin 2014). A comprehensive update of initial responses to Phase I reconstruction was first 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) and in Bousquin et al. (2007). **Table 9-5** provides a directory of KRREP monitoring study updates presented in the SFER since 2005.

Table 9-5 Directory of KRREP Phase I restoration response monitoring study updates in the 2005–2017 SFERs.[a]

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2017 SFERs — Volume I												
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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	9-27	9-29
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**	**9-37**	**9-38**
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**	**9-41**	**9-42**
Flow velocity	5	**11-25**					**11-35**	**11-37**	**9-24**					
Broadleaf marsh indicator	None					11-43						9-33	9-37	
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**	**9-45**	**9-47**
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	9-50	
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**		

Table 9.5. Continued.

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2017 SFERs – Volume I												
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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						
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**	**9-51**	**9-55**
Waterfowl	25		**11-67**	**11-35**		**11-73**	**11-52**		**9-37**	**9-42**	**9-55**	**9-59**	**9-54**	**9-57**
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	9-56	9-51
Threatened and Endangered Species	None	11-60												

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

To contain costs, most KRREP studies do not collect data continuously, with most studies active for two to five years during the Baseline (pre-restoration), Interim, and/or Post-construction 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 remaining construction phases and implementation of the HRS. During the Interim Period, the river's physical and hydrologic characteristics are only partially reestablished. Therefore, although substantial improvements can be made in the Interim Period by appropriate water management, the full array of hydrologic management options are not available. Therefore, the hydrologic conditions that are expected to lead to full restoration of the river and floodplain are not yet in place.

Only studies that collected new data in WY2016 are updated in this section. These new results from studies of floodplain hydrology, DO, and wading birds and waterfowl document the current status of these ecosystem components. Where applicable, the results are evaluated in relation to the associated restoration expectations.

Photos illustrating ecological conditions in the Phase I restoration area throughout WY2016 are available on SFWMD's website in the Library & Multimedia section at www.sfwmd.gov/library see Kissimmee River Restoration Environmental Conditions, Water Year 2016 (compiled by B. Anderson, SFWMD).

HYDROLOGY

Reestablishment of prechannelization hydrologic characteristics is the crucial driver for restoration of the Kissimmee River-floodplain ecosystem. This will be accomplished by reconstruction of the physical habitat template, reestablishment of lost hydrologic drivers by the KRRP, and adaptive water management operations guided by the results of studies conducted by the KRREP. The key hydrologic characteristics of the ecosystem were identified in five restoration criteria in USACE (1991). The criteria define the essential hydrologic drivers needed to achieve restoration of the habitat and ecological integrity of the river-floodplain. Meeting the hydrologic criteria is essential for achieving ecological integrity, which is identified as the project goal in the federal project documentation (USACE 1991, 1996). This goal is to be met by reestablishment of hydrology to ensure that the project addresses the level of the ecosystem rather than individual taxa (Bousquin et al. 2005); the project also requires monitoring and analysis of an array of specific biological and abiotic ecosystem components to evaluate their responses (Koebel and Bousquin 2014).

The hydrologic restoration criteria were expressed as five restoration expectations (performance measures) for evaluation of the status and ultimate success in terms of reestablishment hydrology (Anderson et al. 2005). The hydrologic expectations use long periods of prechannelization stage and discharge data to characterize prechannelization hydrology in terms of the magnitude, frequency, duration, timing, and rates of change of hydrologic variables, which form the basis (reference conditions) for the expected conditions in the future restored system (Anderson et al. 2005). After completion of the first phase of backfilling in 2001, the hydrologic expectations have been evaluated annually since 2005 to assess restoration progress (see 2005–2016 SFERs – Volume I [Williams et al. 2005b, 2006, 2007, Bousquin et al. 2008, 2009, Jones et al. 2010, 2011, 2012, 2013, 2014, Cheek et al. 2015, Koebel et al. 2016] and Anderson [2014a] for examples of evaluation of past hydrologic evaluations). Previous work has shown that while conditions in the Phase I area have improved in the Interim Period for some hydrologic criteria (e.g., more continuous flow in the river channel; longer, albeit intermittent periods of floodplain inundation), compared with the regulated Baseline Period conditions in the Interim Period they are neither meeting the restoration expectations nor showing a trend of improvement over time (Anderson 2014a).

Meeting or moving toward the hydrologic targets depends on rainfall but also appropriate water management to make best use of available water. However, in general, operations in the 16-year Interim Period thus far has not been focused on improvement of hydrologic conditions for the Kissimmee River

and floodplain. For the first time since 2001, a plan (the 1,400/50.5 discharge plan) was implemented in the WY2016 wet season to improve floodplain inundation and recession events while balancing effects on lake stages upstream. The basic feature of the 1,400/50.5 plan is that it maintains at least 1,400 cfs, an estimate of the bankfull discharge, when the Headwaters Lakes lake stage is above 50.5 ft; details of the plan are described in the section on WY2016 operational requests in the *Hydrologic Conditions* section earlier.

A challenge in past evaluations of the hydrologic criteria and in development of the original expectations was that the targets in the original hydrologic criteria were not necessarily stated in terms that could be readily translated into operational actions for recommendations and implementation. For example, a statement that flows should be reestablished that are comparable to prechannelization conditions requires considerable analysis of historic flows to determine the reference condition and a target value, and an evaluation comparing current operations to baseline conditions. To make water management recommendations in the Interim Period, hydrologic goals must be stated and quantified in operational terms (i.e., in terms of discharge and stage targets). To meet these needs, changes are being made to the expectations and analysis methods to define metrics that can be used to better guide adaptive water management operations during the current Interim Period and after the project is completed while retaining clear linkages with the original hydrologic criteria. The changes include realignment of the expectations with the original hydrologic criteria and addition of new metrics to more fully reflect the original criteria. Changes are based on new analysis of data from the Pre-channelization (Reference) and Interim periods and incorporate a better understanding of the hydraulics of the system (e.g., the extent of the backwater effect from the current downstream structure) gained over the 16 years of work since the Interim Period began in WY2002. This reorganization of the hydrologic expectations is intended to group metrics more logically and does not change their scope or the prechannelization hydrologic criteria that were the source of the expectations. Only the metrics and/or methods being used to evaluate them are being modified. Modifications of the expectations are ongoing; last year's chapter included a table (Table 9-5 in 2016 SFER, Volume I, Chapter 9) that provided a cross-walk to prior evaluation methodology.

This year's *Hydrology* section, as did last year's, focuses on Expectations 3 (hydroperiod) and 4 (recession events). These expectations have been challenging to address operationally in the Interim Period and are the most relevant to evaluating the effects of the 1,400/50.5 discharge plan that was implemented in the WY2016 wet season. Statements of the expectations are included. The section begins with a summary of the relationship of flood events to discharge and hydroperiod, especially in relation to the requirements of BLM, an important type of wetland that occurred historically in the Kissimmee River floodplain, and stage recession events, using the same information that was used to guide development of Expectations 3 and 4. The section summarizes calculations of targets for the expectations using data from the Reference Period (WY1932–WY1962), and evaluations of the Baseline (regulated) Period (WY1972–WY1999, during which the C-38 canal was in place) and the post- Phase I construction Interim Period (WY2002–WY2016). It concludes with recommendations for changes in discharge management that can improve performance for these expectations during the remainder of the Interim Period.

Flood Pulse, Hydroperiod, and Recession Event Background

Fluctuation of discharge resulting in seasonal inundation of floodplains (termed a flood pulse) is recognized as the dominant force organizing the habitat of floodplain-river ecosystems such as the Kissimmee River (Junk et al. 1989, Toth et al. 2002, Winemiller et al. 2014). Many characteristics of the historic ecosystem depended on the flood pulse, including floodplain wetlands, fish, wading birds and waterfowl, and numerous associated species and assemblages (USACE 1991, USFWS 1991, Toth et al. 2002). The flood pulse concept is embedded in the general literature of river-floodplain ecology as well as the KRRP hydrologic criteria, especially Criterion 1 (variable discharge comparable to pre-channelization records), Criterion 2 (seasonal and annual variability of floodplain inundation), and Criterion 3 (water level recession rate in the floodplain) (Table 9-5 in 2016 SFER, USACE 1991). The following subsection provides background on floodplain inundation as used in Expectations 3 and 4.

Floodplain hydroperiod requirements are based on the requirements of BLM, the most prevalent wetland plant community in the Kissimmee River floodplain prior to regulation. BLM covered approximately half of the floodplain's area (Spencer and Bousquin 2014). The BLM community is dominated by *Pontederia cordata*, *Sagittaria lancifolia*, or a mixture of both species, and may include substantial cover of the shrub *Cephalanthus occidentalis*. BLM is known to have relatively long hydroperiod requirements (Kushlan 1990, Toth 2010, Spencer and Bousquin 2014), estimated at >200 days of inundation per year. **Figure 9-14** shows the range of hydroperiods reported in the literature for BLM and another major wetland type occurring in the Kissimmee River floodplain. Kushlan (1990) described the hydrologic requirements of these marshes, including wet season water depths between 1 ft (0.3 m) and 3.3 feet (1.0 m), periods of inundation longer than 200 days per year, and a seasonal drying period. During the KRRP Demonstration Project, BLM reestablished from remnant BLM communities after 7 to 9 months (210 to 270 days) of inundation (Toth et al. 1998). Based on the review by Spencer and Bousquin (2014), the minimum hydrologic requirements for BLM hydroperiod are estimated as a minimum of 1 ft of depth for >210 days. The depth estimate of 1 ft is the lower end of the range given by Kushlan (1990); the flood duration of 210 days is the lower end of the range reported by Toth et al. (1998) for BLM response in the Kissimmee River floodplain, and is approximately the midpoint of the range of minimum hydroperiod estimates for BLM as estimated by Spencer and Bousquin (2014) (**Figure 9-14**). Pre-regulation stage data for the Kissimmee River were analyzed to verify that these conditions occurred in the pre-regulation system, and used to determine the seasonality of inundation and the frequency of years in which they occurred.

A recession event is defined as a period of time during which water depth is decreasing on the floodplain. A recession event can be characterized by its recession rate (rate of water depth decrease) or duration; both characteristics have important implications for patterns of inundation and are standard metrics used in other studies (Poff et al. 1997, Rood et al. 2005). Recession rates (the rate of decrease in water depth) and the durations of events are related to hydroperiod, with faster rates of recession or shorter durations of events resulting in shorter hydroperiods. The characteristics of recession events affect how and when organisms can use the floodplain, the ability of organisms to use the floodplain, and the exchange of organic and inorganic materials between the floodplain and river channel. Recession events in the prechannelization Kissimmee River typically were slow (<1 ft per 30 days) and of long duration (**Figure 9-20** later in this chapter) (USACE 1991, Anderson 2014a). Recession rate in the Kissimmee River is positively related to reductions in inflow discharge. Conversely, an increase in inflow during a recession event will cause an increase in water depth, called a stage reversal. Reversals can be disruptive of fish and wildlife foraging and reproductive activities in the floodplain (e.g., Frederick and Collopy 1989, Smith et al. 1995). In summary, the prechannelized system was characterized by much longer flood events, much slower recession rates, and fewer reversals than occurred in the Baseline and Interim periods.

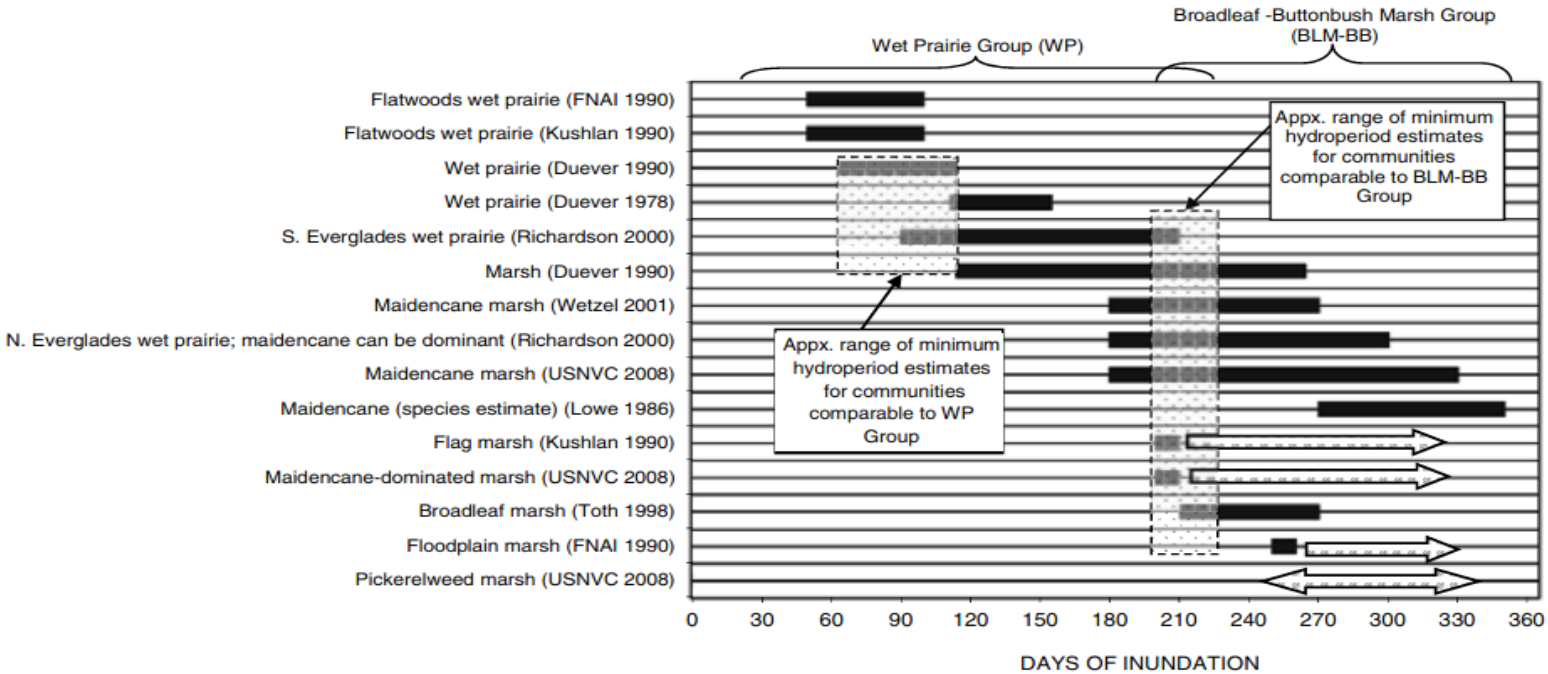

Figure 3. Published estimates of hydroperiods of Florida marsh plant communities comparable to major groups in the KR VCS BLM-BB, WP, and *Panicum hemitomon* (maidencane) (PhWP) groups. Nomenclature follows that of the cited sources. Grayscale bars with arrowheads indicate estimates for which only a minimum inundation duration was described or, in the case of pickerelweed marsh (USNVC 2008), a numerical estimate was not provided (inundation was described as "most of year"). The only sources that indicated inundation depth were Kushlan (1990, for flag marsh) and USNVCS (2008, for maidencane-dominated marsh); both estimated 0.3–1.0 m.

Figure 9-14. Estimates of hydroperiod durations for Florida marsh communities (Figure 3 from Spencer and Bousquin 2014; reproduced with permission).

Methods

Sources of stage data used to calculate the hydroperiod and recession rate metrics are summarized in **Table 9-6**. Reference Period stage data are from continuous stage recorders operated by the USGS (Parker et al. 1955). Data for the Baseline and Interim periods are from continuous SFWMD stage recorders. Mean daily stage was converted to water depth by subtracting the floodplain ground elevation at each station; negative (belowground) depths were converted to 0 ft. Measurements for calculations of depth were from locations where BLM occurred in the prechannelization Reference Period, termed here BLM depth. For the Reference Period, BLM depth was calculated by comparing stage measurements at stations located in the river channel with an average ground elevation for the floodplain immediately adjacent to the stage recorders (Obeysekera and Loftin 1990). These stations were located upstream or downstream of but not in the Phase I area. Water depth fluctuates in parallel at these sites (**Figure 9-15**), which indicates that depth dynamics during the Reference Period were comparable to those in the Phase I area during the same time period. Thus, depth measurements at these sites are appropriate for developing restoration performance measures and were used in the development of the previous versions of Expectations 3 and 4 (Anderson et al. 2005).

Table 9-6. Sources of stage used to calculate depth in the Reference, Baseline, and Interim periods.

Period	Station	Location	Period of Record (Water Year)	Floodplain Ground Elevation (ft NGVD29)
Reference	Fort Kissimmee	Upstream of Phase I	1943 – 1962	43
Reference	Fort Basinger	Downstream of Phase I	1933–1959	28.5
Reference	Lower Kissimmee River	Downstream of Phase I	1931–1962	21
Baseline	S-65B tailwater	Upstream of Phase I	1972-1999	*
Baseline	S-65C headwater	Downstream of Phase I	1972-1999	*
Interim	PC55	Phase I area	2002-2015	37.36
Interim	PC53	Phase I area	2002-2015	37.40
Interim	PC52	Phase I area	2002-2015	37.56
Interim	PC44	Phase I area	2002-2015	35.93
Interim	PC42	Phase I area	2002-2015	36.00

*Baseline Period stage data were compared to ground elevations at the five stations in the Interim Period.

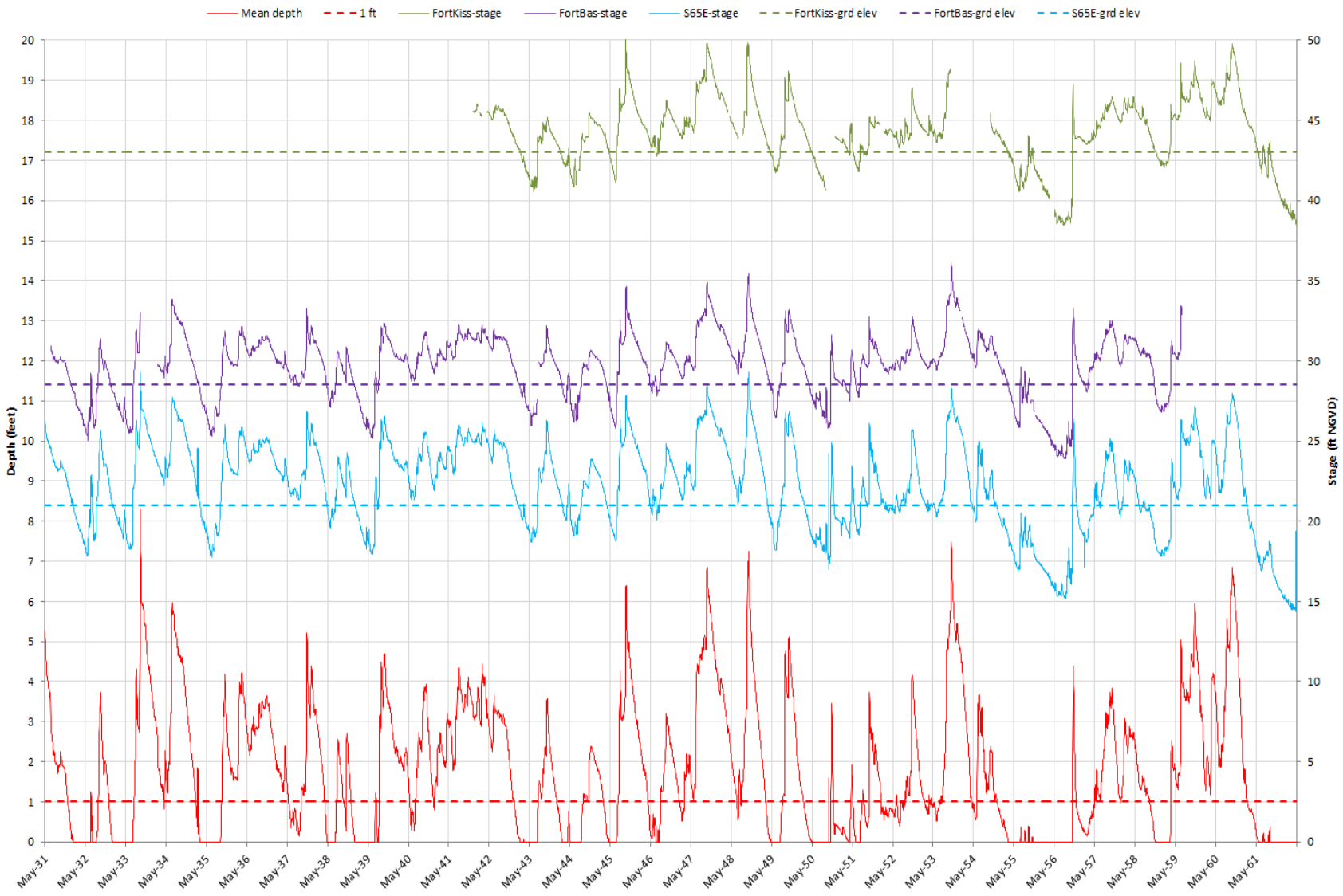

Figure 9-15. Stage at three sites relative to Kissimmee River floodplain ground elevations (dashed lines) and the resulting BLM depth averaged for three sites relative to a 1 ft reference line during the Reference Period.

For the Baseline Period, water surface elevation was calculated as the average of the tailwater stage at S-65B in the C-38 canal (near the upper end of the Phase I area) and the headwater stage at S-65C (near the lower end of the Phase I area). Water level in the C-38 canal between the two stations was essentially flat during the Baseline Period. Depth was calculated by comparing the mean water elevation in the canal with the ground elevations at the five BLM stations in the Phase I area.

For the Interim Period, water depth in the Phase I area was evaluated at five stations at which BLM occurred in the prechannelization vegetation map in the northern floodplain of the Phase I area (and which are unaffected by the backwater from S-65C). Ground elevation was calculated for each station by averaging the elevations within a 100-ft radius circle centered on the stage recorder. For the Interim Period, depth was determined using water surface elevations measured at each stage recorder minus its ground elevation. When Phase II/III of the restoration project is completed (including demolition of S-65C and its tieback levee), evaluation of hydroperiod and recession rate will be expanded to include sites in the southern Phase I area floodplain—which after the structure's removal will no longer be affected by the backwater from S-65C—and in the northern Phase II/III area floodplain downstream of the current location of S-65C. Hydroperiod was calculated by counting the number of consecutive days that BLM depth was at least 1 ft. Periods of time when BLM depth declined below 1 ft for no longer than 14 days, but stayed above 0.5 ft in BLM depth, were regarded as not resulting in a significant gap in the event's duration; these days therefore were included in counts of days for a single hydroperiod event.

A recession event is defined as beginning with a decline in water depth and ending when depth decreases to 0 ft, levels out, or the decline is interrupted by an increase in depth (a depth reversal) of at least 1.5 ft. A new recession event begins when depth begins to decrease following a depth reversal of at least 1.5 ft. The mean recession rate for an event was calculated by averaging the daily decrease in depth during the event. For convenience, the recession rate was multiplied by 30 days to provide a recession rate per 30 days. For purposes of counting the number of recession events in a water year, only those events that began in a water year were considered part of that year.

Results

Expectation 3 (Hydroperiod)

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

> *Component A: Percent of water years that mean depth at BLM sites is ≥1 ft for 210 days consecutively in a water year.*
>
> *Component B: Percent of water years that mean depth at BLM sites is ≥1 ft for 210 days consecutively in the August–February window.*

Hydroperiods during the Reference Period. During the pre-regulation Reference Period, BLM depth was ≥1 ft for at least 210 consecutive days in 19 of 32 water years, or 59 percent of water years. This provides a metric and target (59 percent of water years) for Component A, evaluation of hydroperiod durations. During the Reference Period, BLM depth exceeded 1 ft in almost every year for extended periods of time with a minimum of 120 consecutive days (**Figure 9-16**). Six water years in the Reference Period had 1 ft or more of depth continuously throughout all months (**Figure 9-16**). Several continuous hydroperiod events with BLM depth of at least 1 ft began in one water year and continued into the next; two began in one year, and continued through a second water year and into a third water year (**Figure 9-16**). BLM depth did not exceed 1 ft in only two water years, WY1956 and WY1962 (**Figure 9-16**); both years were classified as severe droughts in the Kissimmee Basin using the Palmer Drought Severity Index (Abtew et al. 2002).

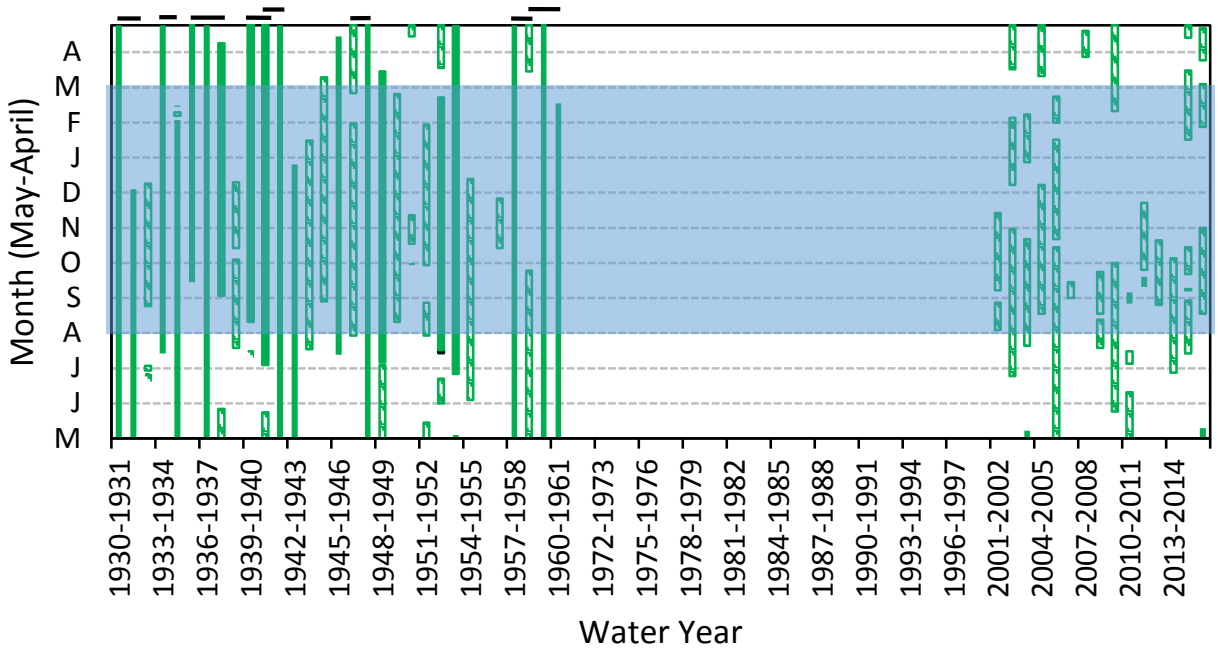

Figure 9-16. Periods and timing of Kissimmee River floodplain events with BLM depth ≥1 ft during the Reference Period (WY1931–WY1962), Baseline Period (WY1972–WY1999), and Interim Period (WY2002–WY2016). Continuous events are indicated by green bars; solid bars identify events that were at least 210 days long in a water year. Black bars at the top of the graph link years where an event began in one water year and continued into the next. Events were identified using a 14-day 0.5-ft buffer as described in the text. The shaded rectangle indicates the target window of August through February. The horizontal axis does not include WY1963–WY1971 or WY2000–WY2001, which were periods of construction for the C&SF Project and Phase I of KRRP, respectively. During the Reference Period, 59 percent of water years had BLM depth of at least 1 ft for at least 210 consecutive days. The Baseline Period never had BLM depth of 1 ft or more. During the Interim Period to date, BLM depth of at least 1 ft has occurred intermittently for relatively short intervals of time, and intervals of BLM depth of at least 1 ft were separated by long gaps, often a month or more.

Continuous periods of inundation at depths of at least 1 ft exhibited distinct seasonality (**Figure 9-16**) in the Reference Period. This is seen most clearly by plotting the median frequency of BLM depth ≥ 1 ft for each month of the Reference Period (**Figure 9-17**). The analysis indicates that BLM depth was 1 ft or more for a 7-month (212-day) window from August through February in at least 50 percent of water years, providing a dominant window of occurrence for evaluating Component A of Expectation 3. BLM depth was ≥ 1 ft for 210 days consecutively in the August–February window in 11 water years. Two additional years had more than 210 days but were short by less than 10 days of 210 days in the August–February window. Given the narrowness of the difference, it is reasonable to include these two additional years, which gives a total of 13 of 32 water years or 40 percent of water years. This provides a second metric and target for Component B of the hydroperiod expectation.

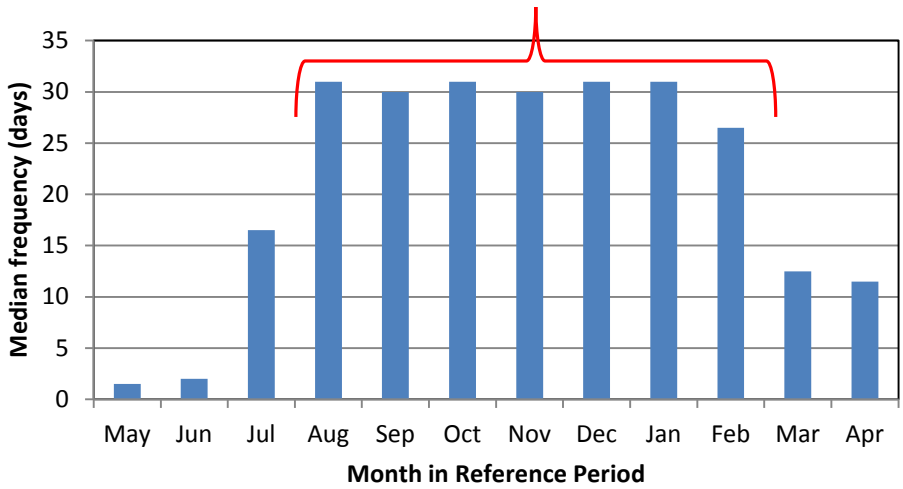

Figure 9-17. Median frequency of days in the pre-regulation Reference Period for the Kissimmee River floodplain that mean water depth was ≥1 ft in each month of the water year. Median values were calculated for 32 years (WY1931–WY1962). The red bracket encloses the dominant target window of August through February.

Hydroperiod Evaluation (Expectation 3) in the Baseline and Interim Periods. During the Baseline Period prior to backfilling of the C-38 canal, water levels in Pool C did not exceed ground elevations at any of the five BLM sites in the Phase I area (**Figure 9-18**). Consequently, there were no events in which BLM depth was ≥1 ft, and therefore the 210 consecutive day criterion hydroperiod duration was not met in any water year (Component A), nor in the August–February window (Component B) in the Baseline Period.

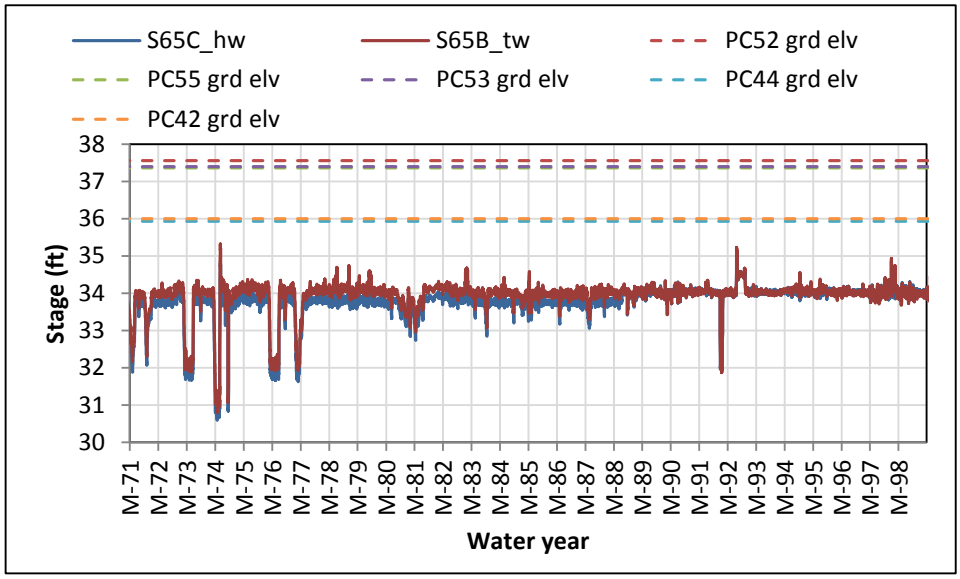

Figure 9-18. Baseline Period water surface elevation in the C-38 canal in relation to ground elevation at the Phase I area stage recorders used to calculate BLM depth for the Kissimmee River floodplain.

In the Interim Period to date, every year, including drought years, had one or more events in which BLM depth exceeded 1 ft (**Figure 9-16**); however, the longest event in the Interim Period was only 169 consecutive days, and in the large majority(12 of 15) of Interim Period water years, the longest events were

less than 120 days (**Figure 9-19**); therefore, none of the events in the Interim Period have met the 210-day criterion (Component A) and did not meet the criterion for the more restrictive August–February window (Component B). Only one year in the Interim Period (WY2006, in which Hurricane Wilma passed over the basin at the end of wet season) came close to meeting the criterion for that water year (Component A) or the seasonal window (Component B). However, for WY2006 to have met the 210 consecutive day criterion for Component A, the two longest periods of continuous BLM depth of at least 1 ft would have had to have been connected by disregarding a gap of 21 days (**Figure 9-16**). To have met the criterion during the August to February window (Component B), a second gap of 28 days also would have had to have been disregarded.

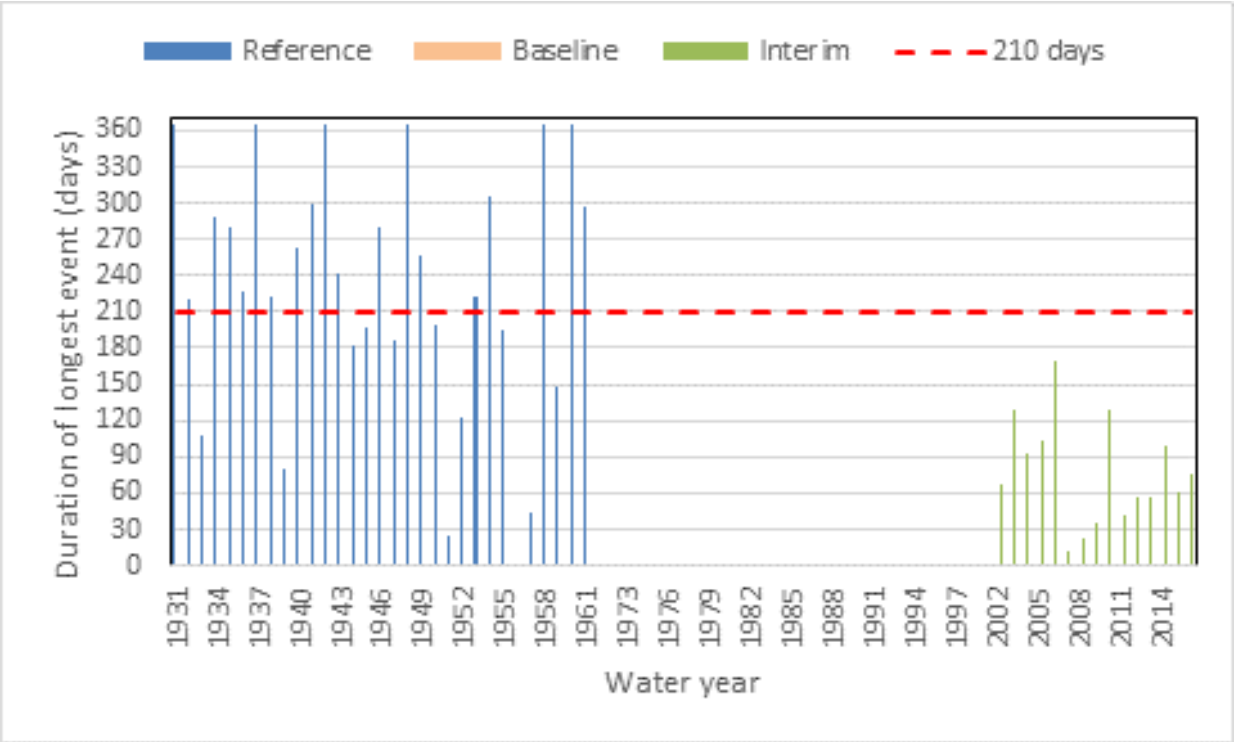

Figure 9-19. Kissimmee River floodplain duration of the longest event with BLM depth of least 1 ft in a water year during the Reference Period (WY1931–WY1962), Baseline Period (WY1972–WY1999), and Interim Period (WY2002–WY2016). The horizontal axis does not include WY1963–WY1971 or WY2000–WY2001, which were periods of construction for the C&SF Project and Phase I of KRRP, respectively. No events occurred in the Baseline Period.

WY2016 had three events with BLM depth of at least 1 ft (**Figure 9-16**). These events correspond roughly to the three inundation events characterized by discharge greater than 1,400 cfs that were described above in the *Kissimmee Basin Hydrologic Conditions and Water Management* section. The first event lasted 76 days (August 19–November 2), the second lasted 38 days (January 31–March 8), and the third lasted 28 days (March 30–April 26). The first event was the longest of the three in WY2016 and the seventh longest to have occurred in the Interim Period (**Figure 9-19**).While the first event and part of the second were within the August–February window, none of the events in WY2016 met the criterion of BLM depth of at least 1 ft for 210 days for the water year (Component A) or the August–February window (Component B). If the 91-day gap in WY2016 between the first and second events could have been closed (i.e., had sufficient discharge been maintained to keep BLM depth at 1 ft), it would have created a single 205-day event, almost meeting the BLM criterion. Although there was not sufficient water in the system to close this large of a gap, there was sufficient water to close the gap between the second and third events if a plan similar to the 1,400/50.5 discharge plan had been in use. The total volume discharged from S-65A during the 152-day

period between January 31 and June 30 was 806,979 ac-ft, or an average of 2,676 cfs per day, well in excess of the minimum discharge of 1,400 cfs per day called for in the plan. The benefits of using such a plan between January 31 and June 30 in 2016 would have included achievement of a flood pulse of approximately 150 days, the potential for release of less water to downstream systems, and a decrease in the number of stage reversals on the floodplain, which had substantial negative effects on wading bird foraging (see *Kissimmee River Restoration Evaluation Program* section's *Wading Bird Abundance* subsection).

Expectation 4 (Recession Events)

Stage hydrographs that result in floodplain recession events with rates of water level decrease, duration, and timing that are comparable to pre-channelization events, including seasonal and long-term variability characteristics.

Component A: Percent of events with a mean rate <1 ft per 30 days.

Component B: Percent of recession events with a mean rate <2 ft per 30 days.

Recession Events in the Reference Period. The Reference Period included 43 recession events, or a frequency of 1.3 events per water year (**Figure 9-20**). Only four Reference Period years had no events, although two of these (WY1932 and WY1943) had substantial portions of recession events that began in the previous water year. A single recession event occurred in 15 water years (47 percent), two events in 11 water years (34 percent), and three events in only 2 water years (6 percent). Recession rates ranged from 0.33 to 1.86 ft per 30 days and averaged 0.85 (± 0.2 standard error [SE]) ft per 30 days over all events (**Figure 9-20**). Recession events in the Reference Period averaged 146 (± 17 SE) days in length. Recession rates < 1 ft per 30 days occurred in 31 of 43 recession events, or 72 percent of events, which provides the basis for Component A. During the Reference Period, 100 percent of recession events had a mean recession rate < 2 ft per 30 days, which provides an upper limit on recession rates and the basis for Component B.

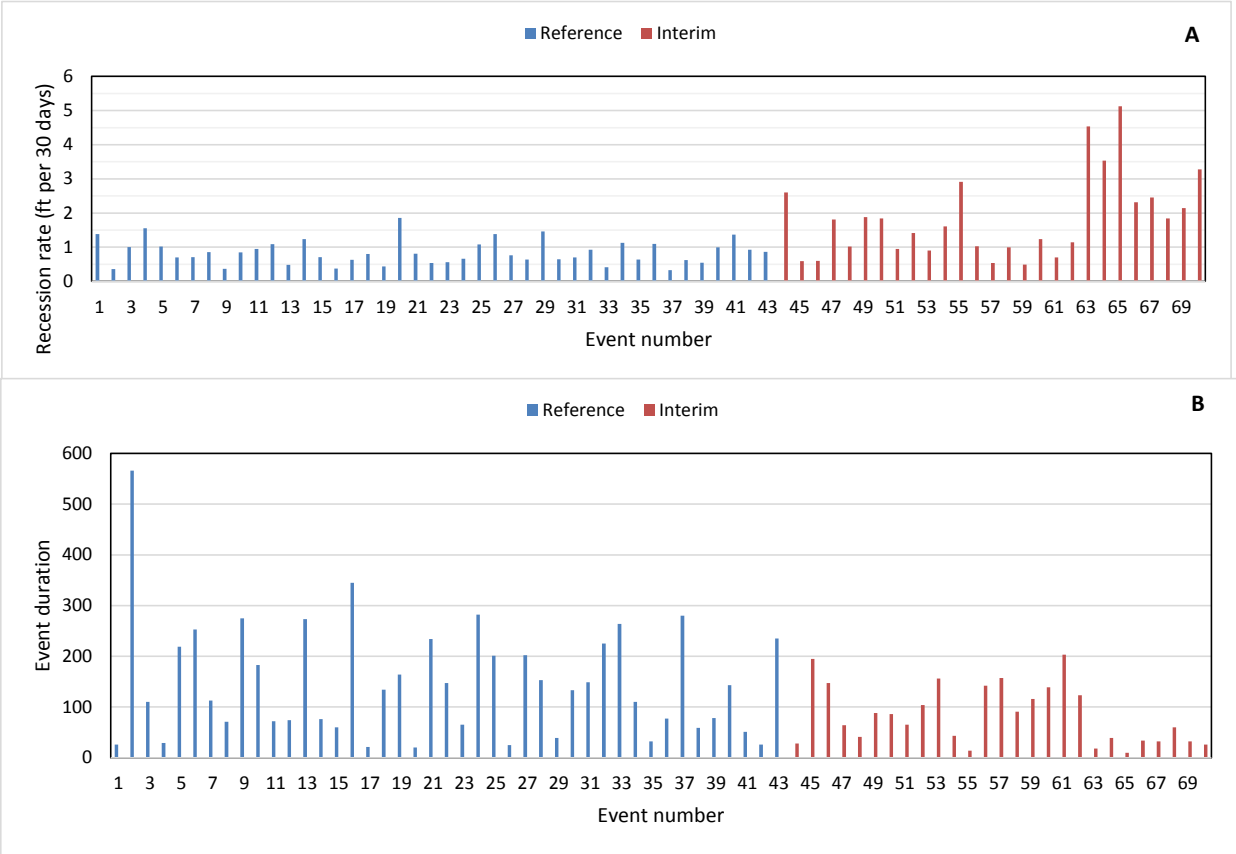

Figure 9-20. Recession rates (A) and event duration (B) for recession events during the Reference Period (WY1931–WY1962) and the Interim Period (WY2002–WY2016) in the Kissimmee River floodplain. The Baseline Period (WY1972–WY1999) is not shown because no recession events occurred.

Recession Events (Expectation 4) in the Baseline and Interim Periods. Water levels in the C-38 canal fluctuated very little during the Baseline Period and never exceeded ground elevations at the sites used for calculating BLM depth in the Phase I area (**Figure 9-18**). Consequently, there were no recession events during the Baseline Period. The addition of WY2016 to the Interim Period added three recession events to bring the total to 27 recession events, or 1.8 events per water year (**Figure 9-20**). Events had recession rates ranging from 0.49 to 5.13 ft per 30 days and a mean rate of 1.83 (±0.23 SE) ft per 30 days (**Figure 9-20**). Recession event durations were 10 to 203 days and averaged 83 (± 11 SE) days. Only eight events (30 percent of events) had recession rates less than 1 ft per 30 days; 18 events (67 percent) had rates < 2 ft per 30 days. WY2016 had three recession events (**Figure 9-20**); mean recession rates were 1.85 to 3.28 ft per 30 days. None of the WY2016 events had a rate < 1 ft per 30 days and only one had a rate < 2 ft per 30 days. The Interim Period had sufficient water level fluctuation and floodplain inundation to have had some recession events; therefore, the Interim Period was in a sense an improvement over the Baseline Period, which had no recession events; however, in the Interim Period, recessions have tended to be faster than those in the Reference Period. As a result, Interim Period values to date for the two recession rate metrics did not meet the expectation targets based on the Reference Period data (**Figure 9-21**). Nearly a third of Interim Period recession events were faster than occurred in the Reference Period.

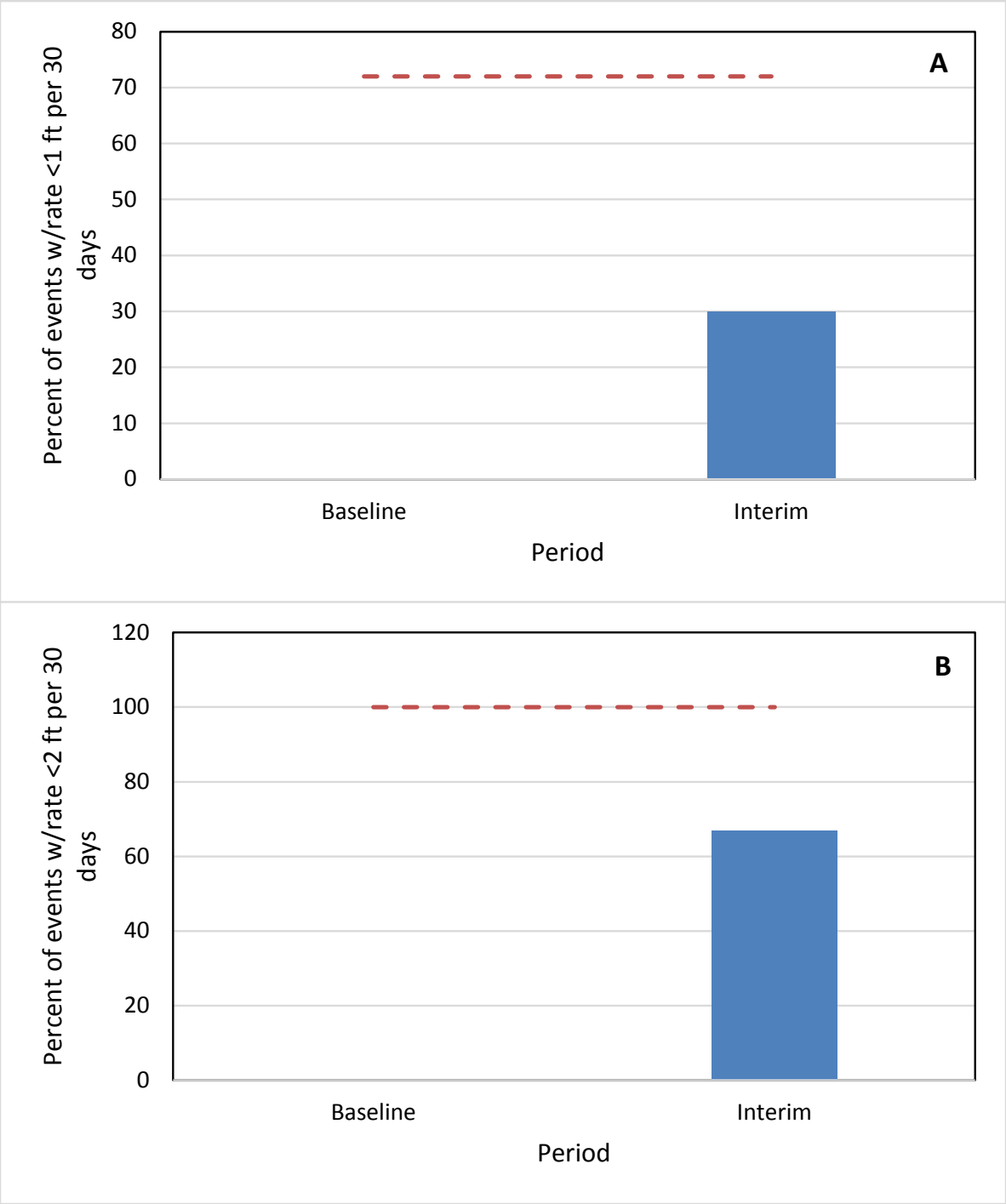

Figure 9-21. Comparison of the percent of Kissimmee River floodplain recession events that had rates <1 ft per 30 days (Component A) and < 2 ft per 30 days (Component B) during the Baseline Period (WY1972–WY1999) and Interim Period (WY2002–WY2016). Dashed red lines are the target percentages based on the frequency of events during the prechannelization Reference Period (WY1932–WY1962). Frequent reductions to low discharge result in disjunct floodplain inundation events separated by periods of floodplain drying.

To summarize, comparisons among the Reference, Baseline, and Interim periods indicate that recessions in the natural (Reference) system were prolonged, in sharp contrast to the absence of recessions in the Baseline Period and the multiple shorter recessions in the Interim Period. In recent years (events 63 to 70 in WY2015–WY2016) of the Interim Period, recession events have tended to be shorter and faster than earlier years of the Interim Period (**Figure 9-20**), likely due to a combination of above average rainfall, operations to keep the Headwaters Lakes stages high, and frequent schedule exceedances in the lakes due to proximity to the regulation lines, resulting in rapid discharge increases for flood control followed by decreases to maintain high lake stages upstream.

Excessively fast floodplain recession rates have important implications for restoration success. A slow recession rate was an important characteristic of floodplain inundation during the Reference Period, and interacted with other aspects of the hydrologic regime to produce the long hydroperiods or flood pulses typical of the unregulated ecosystem (i.e., slow floodplain recession rates were a consequence of the characteristic gradual decline in flow from the headwaters lakes). Faster recession rates, as seen in the Interim Period and especially in recent years, disrupt the continuity and duration of flood pulses, resulting in pronounced intervals of dry conditions that are unsuitable for the floodplain's signature marshes (Spencer and Bousquin 2014). Also characteristic of the Interim Period (**Figure 9-20**), extreme changes in Kissimmee River floodplain stage (stage reversals) due to rapid increases in discharge at S-65/S-65A to raise or maintain upstream lake stages, have been identified as a problem for restoration of the Kissimmee River (Cheek et al. 2014). Reversals as small as 0.3 ft (smaller than the 1.5-ft reversal used here to identify new recession events) have been associated with abandonment of nests by wading birds (Frederick and Collopy 1989, Smith et al. 1995).

Relationship of Expectations 3 and 4 to Discharge. BLM depth is influenced, to a small extent, by direct rainfall and associated LKB runoff, but it almost completely depends on inflow discharge through S-65 via S-65A (Anderson 2014a). Thus, the way these structures are operated directly influences floodplain inundation characteristics in the Phase I area as evaluated by Expectations 3 and 4. Therefore, recovery of the biota that depend on improvement in and eventual reestablishment of pre-regulation hydrology for recovery is strongly influenced by water management operations.

Last year's chapter noted that in WY2016, S-65 operations were expected to be modified for the first time to address these expectations and improve hydrologic performance for the KRRP, as required by USACE (1991,1996). Water operations in WY2016 involved implementation of the 1,400/50.5 discharge plan as described in the *Hydrologic Conditions* section. Although the plan is intended to improve the hydrologic performance of Expectations 3 and 4, it is not expected to fully meet the criteria for either expectation. How well the plan improves hydrologic performance in any given year until the HRS is implemented will be influenced by the quantity and timing of rainfall, but implementation of the 1,400/50.5 discharge plan in WY2016 resulted in promising improvements in the performance of Expectations 3 and 4 in the wet season to early dry season window relative to what would have happened had previous years' operations been followed. The plan produced a single floodplain inundation and recession event during the window that it was implemented. During this event, discharge was held at 1,400 cfs during the ramp down from flood control releases to lower discharge, which extended the period of time that BLM depth was at least 1 ft by about 3 weeks, an increase in duration of approximately 38 percent. While this increase moves closer to the target duration of 210 days, it still falls short of the target. Even so, this outcome suggests a promising direction for Kissimmee Basin operations when balancing the Headwaters Lakes stage against S-65 discharge to achieve benefits in both systems without harming either. Holding discharge at 1,400 cfs during the ramp down also improved hydrologic performance of Expectation 4 by increasing the duration of the recession event by approximately 21 days and slowing the recession rate from 2.84 ft per 30 days to 1.84 ft per 30 days. No negative effects on the lakes have been noted except slightly lower stages over the period of implementation.

The 1,400/50.5 discharge plan should continue to be implemented in future years, and consideration should be given to extending a modified version of it throughout the year. The plan is an example of

hydrologically and ecologically balanced operations designed to link discharge for KRRP to upstream lake stage to achieve mutually beneficial operations for these two connected parts of the Kissimmee Basin ecosystem. The plan does not attempt to fully meet the KRRP expectations for hydroperiod and recession events during the Interim Period, although implementation of the 1,400/50.5 discharge plan in WY2016 demonstrated that substantial improvements in performance for the hydrologic expectations can be made without the additional storage that will be provided by the HRS. Implementation of the plan will require that, in many circumstances, discharge not be decreased to low levels to reach higher or maintain stable stages in upstream lakes. In some years, this will mean lower average lake stages than would occur without use of a stage-discharge relationship. For the lakes, the resulting relationship of variation in lake stage with discharge would be more similar to what happened in the prechannelization system (see Figure 9-10 in the Hydrologic Conditions 2016 SFER) and is more characteristic of both the natural relationship of lake stage to flow and the natural variability in stage that is characteristic of healthy lakes (NRC 1992). Extension of the plan throughout the dry season would help address another issue identified in last year's chapter—that rapid changes in discharge needed to keep the Headwaters Lakes lake stage near the regulation schedule or to follow a stage recession line in the headwater, which can result in harmful depth fluctuations in the floodplain. Current guidelines allow maximum rates of discharge decrease and increase that are much faster than occurred in the Reference Period. Operations to maintain high stages near the regulation line in the Headwaters Lakes (and to a lesser extent in East Lake Tohopekaliga and Lake Tohopekaliga), or to precisely follow stage recession lines in these lakes, create conditions under which all or most inflow from rainfall events must be quickly discharged to the river, rather than balancing reversals between the lakes and the river. The resulting abrupt reductions and increases in depth on the Kissimmee River floodplain are harmful to the river and inhibit improvements in performance of the hydrologic goals of the KRRP.

Summary

- In WY2016, a new plan (the 1,400/50.5 discharge plan) designed to link S-65 discharge to the Headwaters Lakes lake stage was successfully implemented during the wet season and early dry season.
- Use of the plan resulted in marked improvements for KRREP Expectations 3 and 4 compared to previous water years. The wet season and early dry season period was characterized by a single floodplain inundation event and a single recession event, rather than the multiple events seen in previous years. Following the plan increased the duration of floodplain inundation for Expectation 3 and slowed the recession rate for Expectation 4.
- The targets for Expectation 3 were not met in WY2016 or in any year of the Interim Period thus far (WY2002–WY2016).
- Performance for Expectation 3 can be improved by implementing operations designed to increase the number of consecutive days that inflow discharge of 1,400 cfs or greater is maintained.
- The targets for Expectation 4 were not met in WY2016 or in any year of the Interim Period thus far (WY2002–WY2016).
- Performance for Expectation 4 can be improved by slowing the rate of recession, especially by eliminating the practice of decreasing discharge to low levels to hold the Headwaters Lakes stable at high stages for extended periods.

DISSOLVED OXYGEN

Expectation 8

Mean daytime concentration of DO in the Kissimmee River channel at 0.5 to 1.0 m depth will increase [a] from <1–2 mg/L to 3–6 mg/L during the wet season (June–October) and [b] from 2–4 mg/L to 5– 7 mg/L during the dry season (November–May). [c] Mean daytime DO concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50 percent of the time. [d] Mean daily (24-hour) DO concentrations will be >2 mg/L more than 90 percent of the time (updated from Colangelo and Jones 2005).

DO directly affects aquatic life through oxygen (O_2) availability and the metabolism of aquatic ecosystems (Hauer and Lamberti 2007; Colangelo 2007). DO concentration can influence growth, distribution, and structural organization of aquatic communities and impact the productivity of aquatic ecosystems (Wetzel 2001). For this reason, DO was chosen as one of the metrics used in expectations for evaluation of the status and success of the KRRP (Colangelo and Jones 2005). DO in the Kissimmee River channel is a function of the balance between primary production, reaeration, and respiration, which are influenced by many factors, including temperature, water depth, stage, and discharge at water control structures S-65A and S-65C (Chen et al. 2016). Operation of these structures thus has important implications for reduction of the severity and/or duration of hypoxic events (<2 mg/L) in partially restored sections of the Kissimmee River.

Based on reference and baseline data, restoration of the Kissimmee River is expected to improve DO concentrations in the river channel primarily by reintroducing flow to the river channel, which is expected to reduce the amount of organic matter that accumulated on beds of non-flowing (remnant) channels after construction of the C-38 canal (Colangelo and Jones 2005). To date, most components of Expectation 8 have showed positive responses in the Phase I area to reestablishment of flow, which was completed in 2001 (Colangelo 2014).

Data Collection and Analysis Methods

Reference and Baseline Data

DO data from the Kissimmee River were not available prior to channelization. For this reason, available daytime DO data from nearby free-flowing blackwater streams where DO had been measured frequently from 1973 to 1999 were used to estimate reference (prechannelization) conditions for the Kissimmee River. For some of these streams, more than 10 years of data were available (Colangelo and Jones 2005). Baseline (channelized period) DO data were obtained from monitoring stations in non-flowing remnant river runs of the Kissimmee River and the C-38 canal prior to Phase I construction. For these data, grab samples were collected monthly within a time window between 10 am and 2 pm from WY1996 to WY1999. Expectation 8 components [a], [b], and [d] were developed based on these reference and baseline data. Component [c] was developed based on weekly DO depth profiles sampled in Micco Bluff Run in the Phase I project area of the Kissimmee River from May to October 1999. Details and summaries of reference and baseline data and expectation development are available in Colangelo and Jones (2005).

Interim Data

DO monitoring has continued in the Phase I Interim Period (post-Phase I construction) at some of the stations that were used to establish reference and baseline DO conditions. The same or similar methods have been used to provide data for evaluating changes in DO before and after restoration construction. Grab samples used for evaluation of Components [a] and [b] were collected monthly from sampling stations KREA91, KREA92, and KREA97 in Pool A and KREA93, KREA94, and KREA98 in the Phase I area, between 10 am and 2 pm. Daytime DO concentrations within 1 m of the channel bottom were measured at

stations KREA94 and KREA98 in the Phase I area for evaluation of Component [c]. Daytime-only measurements were used for compatibility with the available reference data as described earlier and in Colangelo and Jones (2005).

For evaluation of Component [d] during the interim period, continuous monitoring of daily (24-hour) DO at stations KRBN, PC33, and PC62 (**Figure 9-6**) was conducted using stationary DO sondes at a depth of approximately 1 m from the water surface in the Phase I river channel. The data were collected continuously at a 15-minute interval, day and night. Data from these stations also were used to provide technical guidance for adaptive management of discharge at water control structures S-65, S-65A, and S-65C.

For statistical evaluation of a restoration effect on DO, the difference between the impact and control means (ICd) was calculated for daytime DO collected monthly at the KREA stations using a BACIPS sampling design (Bousquin and Colee 2014). The ICd data for DO were tested for autocorrelation using a Durbin-Watson test, which indicated no significant autocorrelation. A t-test was used to test the difference between the ICd means for daytime DO in the Before (baseline) and After (interim) periods (Stewart-Oaten et al. 1992). Statistical significance was evaluated at $\alpha = 0.05$.

Post-Construction DO through WY2016

Since completion of Phase I construction, DO in the Phase I area has averaged 2.8 ± 0.1 mg/L (1 SE) during the wet season and 6.4 ± 0.1 mg/L during the dry season (**Figure 9-22**). By comparison, post-construction DO in the control area (Pool A) was significantly lower at 1.7 ± 0.1 and 3.3 ± 0.1 mg/L during the wet and dry seasons, respectively ($p < 0.01$). Annual daytime DO has been significantly higher in the Phase I area, 4.9 ± 0.2 mg/L than in Pool A, 2.6 ± 0.1 mg/L for the 15 water years following completion of Phase I construction ($p < 0.01$) (**Figure 9-23**). A t-test on the ICd indicated that DO greatly improved in the Phase I impact area from WY2002 to WY2016 but did not change significantly in the Pool A control area. The ICd for DO was significantly higher for the post-construction period (2.3 ± 0.2 mg/L) than for the baseline period (-0.2 ± 0.2 mg/L) ($p < 0.01$).

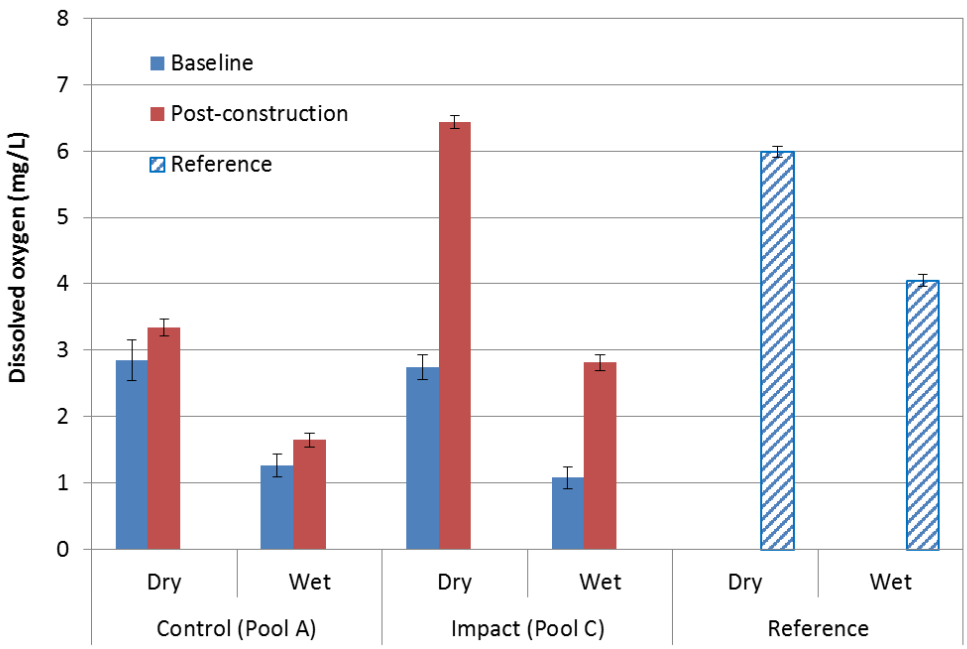

Figure 9-22. Daytime DO concentrations (mean ± SE) in reference streams (period of record = WY1973–WY1999) and control and impact

areas in wet and dry seasons during the baseline (WY1997–WY1999) and post-construction (WY2002–WY2016) periods. For evaluation of Expctation 8, Components [a] and [b].

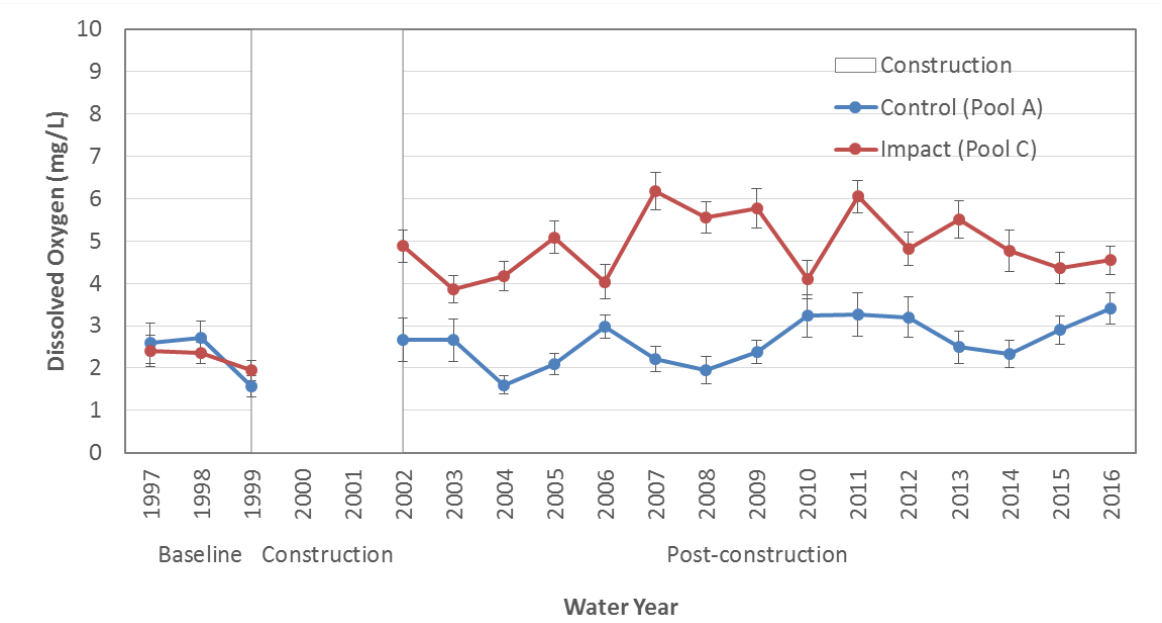

Figure 9-23. Daytime DO concentrations (mean ± SE) of sampling stations KREA91, KREA92, and KREA97 in Pool A and sampling stations KREA93, KREA94, and KREA98 in the Phase I impact area (Pool C) of the Kissimmee River for each water year during the baseline (WY1997–WY1999) and post-construction periods (WY2002–WY2016).

WY2016 DO Update

In WY2016, three of the four expectation metrics, Components [b], [c], and [d], were met (**Table 9-7**). However, daytime DO was 2.7 ± 0.4 mg/L in the wet season and therefore did not meet the Component [a] target of 3–6 mg/L. This outcome reflects a 51-day hypoxic event (August 22–October 11, 2015) that occurred in the wet season of WY2016, which coincided with a small fish kill observed in the restored Kissimmee River channel in late August 2015 (see the *Wet Season 2015 Water Management Outcomes* section). More than 3 inches of rain fell over the Phase I area during a period of 10 days from August 10–21, 2015, prior to the hypoxic event, and S-65A discharge was increased from 1,400 cfs to 3,300 cfs during that period (**Figure 9-13**). Continued increases in S-65A discharge up to approximately 6,000 cfs combined with local rainfall-driven runoff further increased water depth in the river channel and floodplain, likely the cause of a subsequent decline to an anoxic condition (<1 mg/L) for 38 days. Such events indicate that although Component [d], which is measured as an average, is being met, anoxic conditions continue to occur at a finer temporal scale and can be ecologically significant.

As in previous years, monthly daytime and continuous DO concentrations in WY2016 showed a common seasonal pattern (**Figures 9-24** and **9-25**) that was not seen prior to reestablishment of flow (Chen et al. 2016). Reestablishment of flow likely reduced sediment oxygen demand by eliminating the organic layer that had accumulated under the non-flowing, channelized conditions during the Baseline Period (Anderson 2014b); reaeration may have been a factor also.

Table 9-7. Restoration expectation component metrics and WY2016 values for DO.

Expectation Components	WY2016 Value	Metric Achieved in WY2016	Data Source
[a]. Mean daytime DO concentration in the river channel at 0.5–1.0 m depth will increase from < 2 mg/L to 3–6 mg/L during the wet season (June–October).	2.7 ± 0.4 mg/L	NO	KREA93, KREA94, and KREA98
[b]. Mean daytime DO concentration in the river channel at 0.5–1.0 m depth will increase from 2 to 4 mg/L to 5–7 mg/L during the dry season (November–May).	5.9 ± 0.2 mg/L	YES	KREA93, KREA94, and KREA98
[c]. DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50 percent of the time annually.	92%	YES	KREA94 and KREA98
[d]. Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90 percent of the time annually.	95%	YES	PC33 and PC62

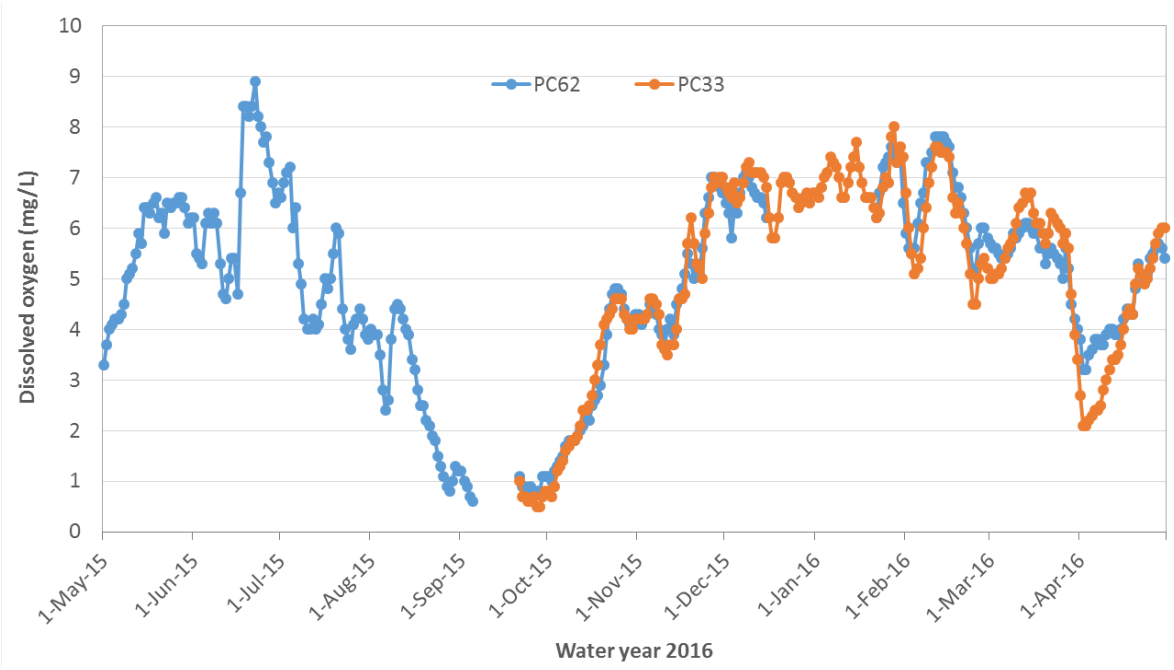

Figure 9-24. Daily DO concentrations in sampling stations PC33 and PC62 in the river channel of the Phase I impact area in WY2016. For evaluation of Expectation 8, Component [d].

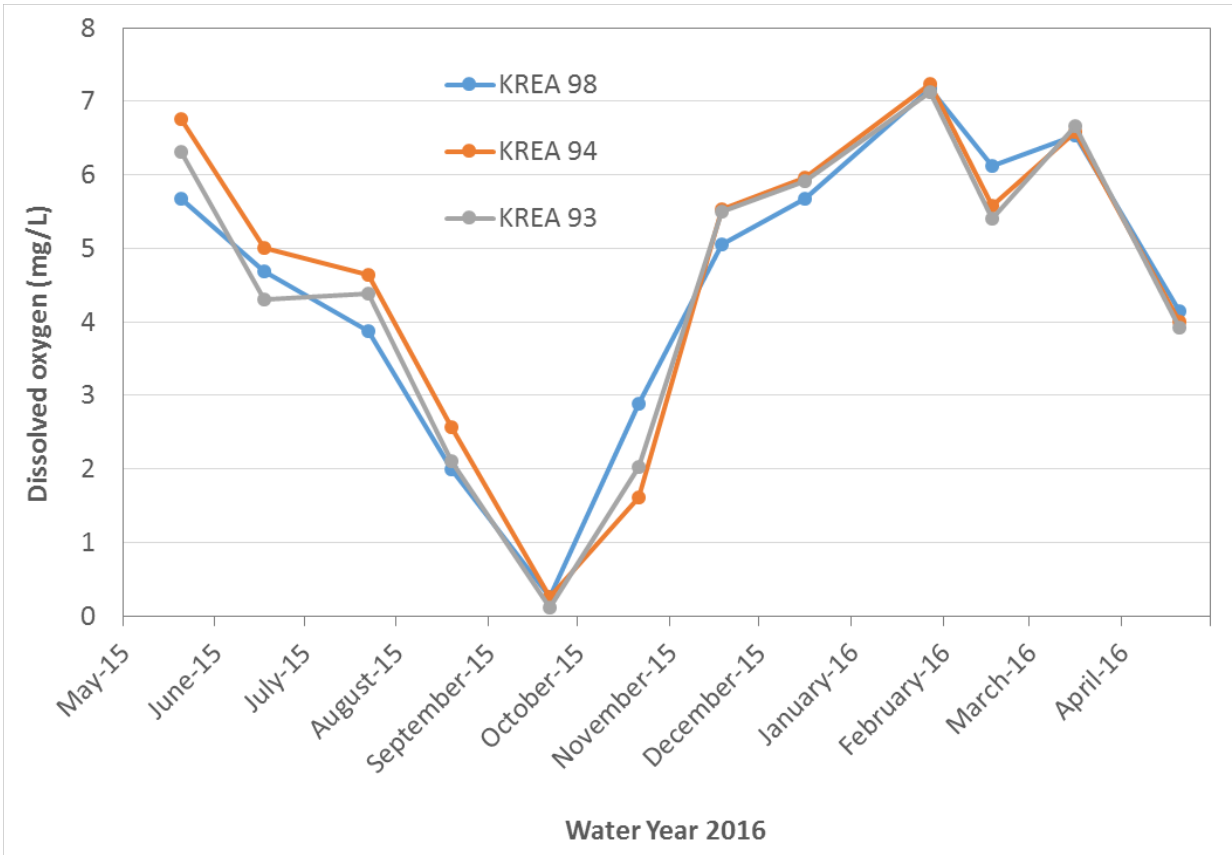

Figure 9-25. Monthly daytime DO concentrations in sampling stations KREA93, KREA94, and KREA98 in the river channel of the Phase I impact area in WY2016.

WADING BIRDS AND WATERFOWL

Birds are integral to the Kissimmee River floodplain ecosystem and highly valued by the public. While quantitative prechannelization data are sparse, available data and anecdotal accounts suggest that the system supported an abundant and diverse bird assemblage (National Audubon Society 1936–1959; FGFWFC 1957–1959). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Because 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* (described in 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 2015–2016, and compare recent data to restoration expectations.

Wading Bird Nesting Colonies

Expectation

No formal expectation has been established for wading bird nesting colonies.

As part of the KRREP, SFWMD performed three surveys (April 21, 27, and 28, 2016) to visit known wading bird nesting colonies in Lake Kissimmee, along the Kissimmee River, and in Lake Istokpoga. The survey intensity was reduced this season because flight time was utilized for more intensive weekly surveys

within the Kissimmee River Restoration Area (see the *Wading Bird Abundance* section) and there were several weather-related flight cancellations. Colonies within the UKB (with the exception of Rabbit Island) that have been surveyed in the past, and reported on here in the annual SFER, will no longer be surveyed for the reasons mentioned previously.

The colonies in Lakes Kissimmee (Rabbit Island) and Istokpoga (Bumblebee Island) and the River Ranch C-38 colony were surveyed from the air on April 21, and the Chandler Slough East and S-65C Structure colonies were surveyed during flights on March 2 and 30. Two flight-line direction count surveys were conducted from a boat near Bumblebee Island on April 27 and 28. The nest numbers reported here represent the maximum number of nests for each species observed, although the peak of nesting may not have been captured during the survey dates. 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 **Tables 9-8** and **9-9** are considered conservative. Nest fate and nesting success were not monitored.

Table 9-8. Peak (maximum) number of wading bird nests within the KRRP area[a], 2003–2016. Sites were surveyed during March and April 2016.

Year	Bird Species or Grouping[b]									Total Nests	Total Colonies	Nests of Aquatic Species
	CAEG	GREG	WHIB	GBHE	SMDH	GLIB	BCNH	SMWH	WOST			
2003	20									20	1	0
2004										0	0	0
2005		81								81	2	81
2006	500	133		9						642	4	142
2007	226				1					227	1	1
2008		2		4						6	1	6
2009	240	126		27	14					407	3	167
2010	891	35		31	37					994	2	103
2011	751	14		35	35			8		843	2	92
2012	1202			18	108			18		1346	2	144
2013	599	33		37						669	5	70
2014[c]	5	23		28	1					57	5	52
2015		94		31						125	4	125
2016[d]	291	316		20						627	4	336

a. Kissimmee River Restoration Project Area sites include Lakes Kissimmee, Cypress and Hatchineha, and colonies within approximately 10 km of the C-38 Canal/backfill, including: Multiple Kissimmee Prairie sites, Bluff Hammock, Cypress West, Oak Creek Marsh, C-38 Caracara Run, Chandler Slough East, Chandler Slough New, Chandler Slough, Cypress West, Orange Grove, Orange Grove NW, Orange Grove SW, Pine Island Slough, S-65C Boat Ramp, S-65C Structure, S-65D Boat Ramp, and Seven Mile Slough, Pool E Spoil Island, S-65E colony.

b. Key to Species and Groupings:

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 combined)

SMDH = small dark heron (little blue heron and tricolored heron combined)

GLIB = glossy ibis (Plegadis falcinellus)

WOST = wood stork (Mycteria americana)

c. Expanded survey effort in 2014

d. Reduced survey effort in 2016, but results from the Rabbit Island colony in Lake Kissimmee were added to the table this year.

Table 9-9. Peak (maximum) number of wading bird nests within Lake Istokpoga (Bumblebee Island), 2010–2015. Sites surveyed during April 2016.

Year	Bird Species or Grouping[b]									Total nests	Total Colonies	Nests of Aquatic Species
	CAEG	GREG	WHIB	GBHE	SMDH	GLIB	BCNH	SMWH	WOST			
2010	103	325	110	75						613	1	510
2011	381	200	50	45						676	1	295
2012	75	175		75						325	1	250
2013	250	343		55						648	1	398
2014	658	210	75	55						998	1	340
2015	434	180	829							1443	1	1009
2016	355	171	1296	25						1847	1	1492

b. See **Table 9-8** for a key to species and groupings.

Five colonies were active during the 2016 season within the KRRP area and Lakes Istokpoga and Kissimmee (see **Tables 9-8** and **9-9**, and **Figure 9-26**). All colonies combined were dominated by white ibis nests (1,296), followed by smaller numbers of cattle egret (646), great egret (487), and great blue heron (45). The largest of these colonies was Bumblebee Island in Lake Istokpoga (1,847), followed by Rabbit Island (526), Chandler Slough East (85), River Ranch C-38 (12), and S-65C Structure (4)(**Figure 9-26)**.

Similar to last season, none of the colonies occurred within 3 km of the partially restored portions of the Kissimmee River, but several occurred in unrestored portions of the river, north, east, and south of the restoration area (**Figure 9-26**). The Kissimmee River Restoration Area is within the potential foraging range of nesting waders at both the S-65C Structure colony (4.3 km) and the Chandler Slough East colony (13.3 km), while the Bumblebee Island colony is approaching the farthest limits of regular foraging for most species at approximately 15 km away. The Rabbit Island and River Ranch Island colonies (40.6 km and 23 km, respectively) are too far to the north of the restoration area for regular foraging by nesting species there.

Most nesting of aquatic wading bird species and cattle egrets continues to occur outside of the KRRP area on islands in the UKB and Lake Istokpoga. To date, only one colony of aquatic bird species (S-65C Boat Ramp colony) has formed within 5 km of the partially restored portion of the Kissimmee River, and during most years it has contained fewer 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. Another possible factor preventing breeding colony site formation within the restoration area is lack of suitable habitat conditions during the January–June breeding season (e.g., woody substrate surrounded by water, nesting materials, and nearby foraging areas) (White et. al. 2005).

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 currently is not optimal for rookery formation due to constraints and other demands on water management. 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. Survey efforts next season will focus primarily within 10 km of the KRRP area and the Headwaters Lakes.

Figure 9-26. Nesting colony locations in Lake Kissimmee, Lake Istokpoga, and within the KRRP area (i.e., within approximately 10 km of the C-38 canal backfill) during 2016.

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/km² (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 (±SE) 3.6 ± 0.9 birds/km² in 1997 and 14.3 ± 3.4 birds/km² in 1998. Since completion of Phases I, IVA, and IVB of restoration construction in 2001, 2007, and 2009, respectively, annual abundance has ranged from 102.3 ± 31.7 birds/km² to 11.0 ± 1.9 birds/km² (mean [2002–2016] = 42.3 ± 6.3 birds/km²) (**Figures 9-27** and **9-28**). The annual three-year running mean (2002–2016) is 41.7 ± 4.3 birds/km², significantly greater than the restoration expectation of 30.6 birds/km² (t-test, p = 0.03) (SAS Institute 2011, Williams and Melvin 2005a). However, each three-year running mean was not significantly different from the restoration target of 30.6 birds/km² when examined on an annual basis (t-test, SAS Institute 2011). Mean monthly wading bird abundance within the restored portions of the river during the 2015–2016 season was 40.1 ± 7.4 birds/km², bringing the three-year (2014–2016) running average to 40.9 ± 9.6 birds/km².

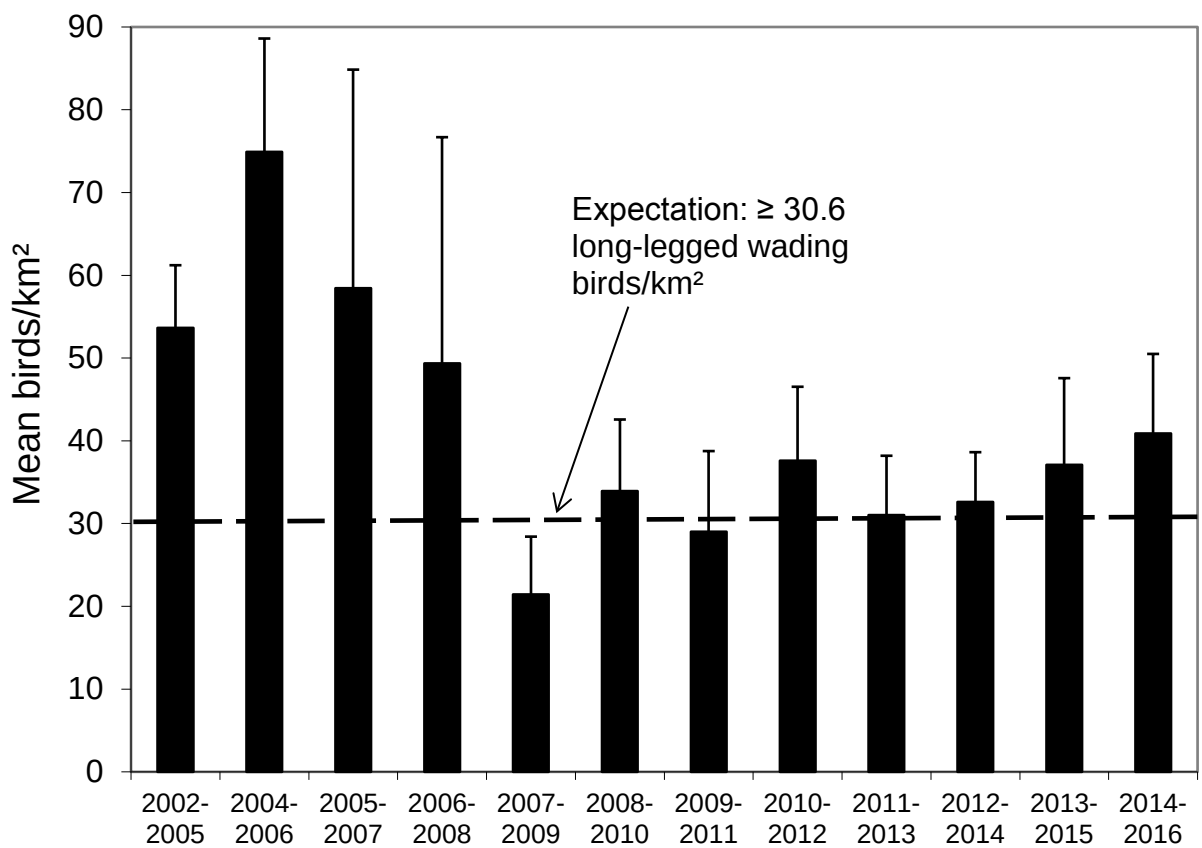

Figure 9-27. Post-restoration abundance as three-year running averages ± SE of long-legged wading birds/km², excluding cattle egrets, during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River. Each three-year running mean was not significantly different from the restoration target of 30.6 birds/km² when examined on an annual basis, TTEST, SAS Institute 2011.

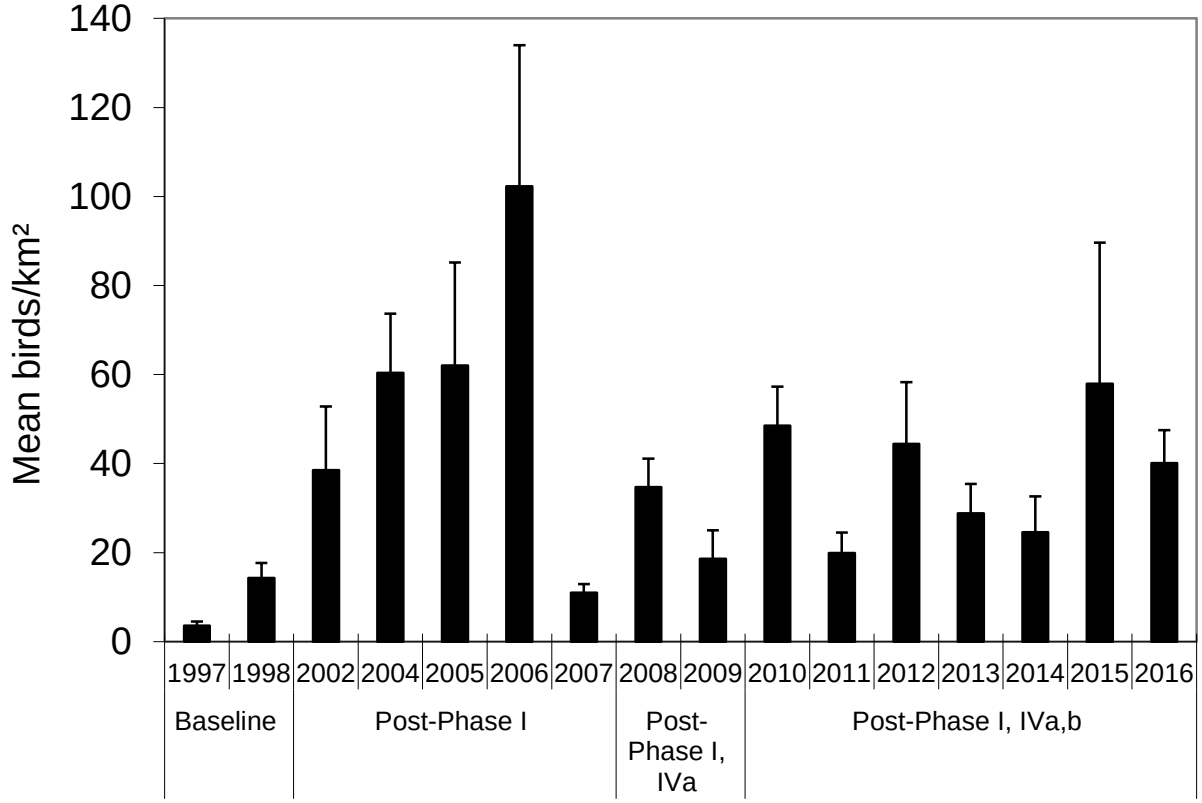

Figure 9-28. Baseline and post-Phases I, IVA, and IVB mean abundance ± SE of long-legged wading birds/km^2,excluding cattle egrets, during the dry season (December–May) within the 100-year floodline of the Kissimmee River.

Rainfall during the 2016 dry season was well above average in the UKB and LKB (151 percent and 190 percent, respectively), resulting in above average floodplain depths and four significant reversals in water depth > 0.15 m. Reversal of declining water levels during the dry season is thought to decrease prey availability for wading birds by redistributing prey over a larger area and decreasing prey density, thereby decreasing foraging suitability and leading to fewer nest initiations or nest abandonment when sufficient food cannot be captured to feed young. Wading bird abundance was high during the initial fall recession in November and December, with more than 210 birds/km² observed during the November 20 survey (**Figure 9-29**). Bird numbers then declined from 74.3 birds/km² on December 30 to 23.8 birds/km² on January 13, when floodplain stage began to rise to greater than 0.61 m deep by February 7 during the first dry season reversal of water depth. Bird numbers remained relatively low from January 13 through March 2, when water levels were too deep (> 0.40 m) for foraging over most of the floodplain. Bird numbers increased to 52.4 birds/km² when water depths receded to approximately 0.21 m on March 9, then declined to 4.4 birds/km² on April 6 when floodplain depths increased to over 0.67 m. Bird numbers reached a final peak of the season of 28.7 birds/km² by April 27 as water receded to 0.16 m on May 4, before rising to its greatest depth of the dry season at > 0.98 m deep on May 24.

White ibis dominated numerically (61 percent), followed in order of abundance by glossy ibis (14 percent), great egret (8.0 percent), small white heron (snowy egrets [*Egretta thula*] and juvenile little blue heron) (6.5 percent), great blue heron (4.0 percent), small dark heron (tricolored heron and adult little blue heron) (2.0%), roseate spoonbill (*Platalea ajaja*) (1.2 percent), black-crowned and yellow-crowned night herons (1.1 percent), and wood stork (*Mycteria americana*) (0.8%).

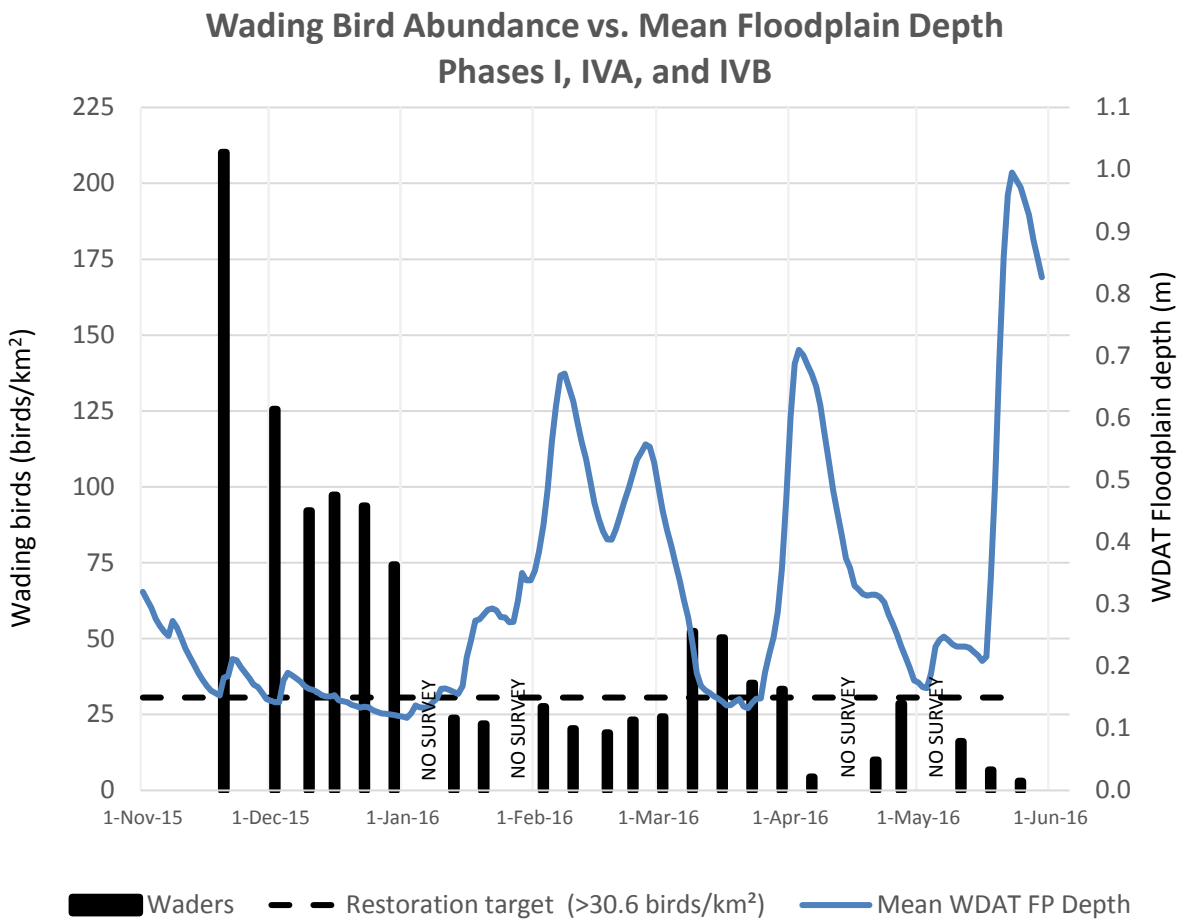

Figure 9-29. Wading bird abundance and mean floodplain depth in the Kissimmee River Restoration Area (Phases I, IVA, and IVB) during the dry season (December–May) 2016. Floodplain depth is obtained from the South Florida Water Depth Assessment Tool (SFWDAT 2016).

Waterfowl Abundance

Expectation 25

Winter densities of waterfowl within the restored area of the floodplain will be ≥3.9 ducks/km². 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 ± SE 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 mean annual three-year running average (2002–2016) of waterfowl abundance is 10.4 ± 1.1 birds/km², significantly greater than the restoration expectation of 3.9 birds/km² (TTEST, $p < 0.0001$) (SAS Institute 2011, Williams and Melvin 2005a). However, when examined on an annual basis, only the period 2011–2013 was significantly greater than the restoration target of 3.9 birds/km² (TTEST, p-value = 0.05, SAS Institute 2011).

Waterfowl abundance during the 2015–2016 survey was 12.1 ± 4.6 ducks/km², bringing the three-year (2014–2016) running average to 8.5 ± 1.9 birds/km² (**Figures 9-30** and **9-31**). Since 2001, annual duck

abundance has ranged from 37.0 ± 22.5 birds/km^2 to 1.3 ± 1.3 birds/km^2 (mean [2002–2016] = 10.9 ± 2.2 birds/km^2) **(Figures 9-30** and **9-31**).

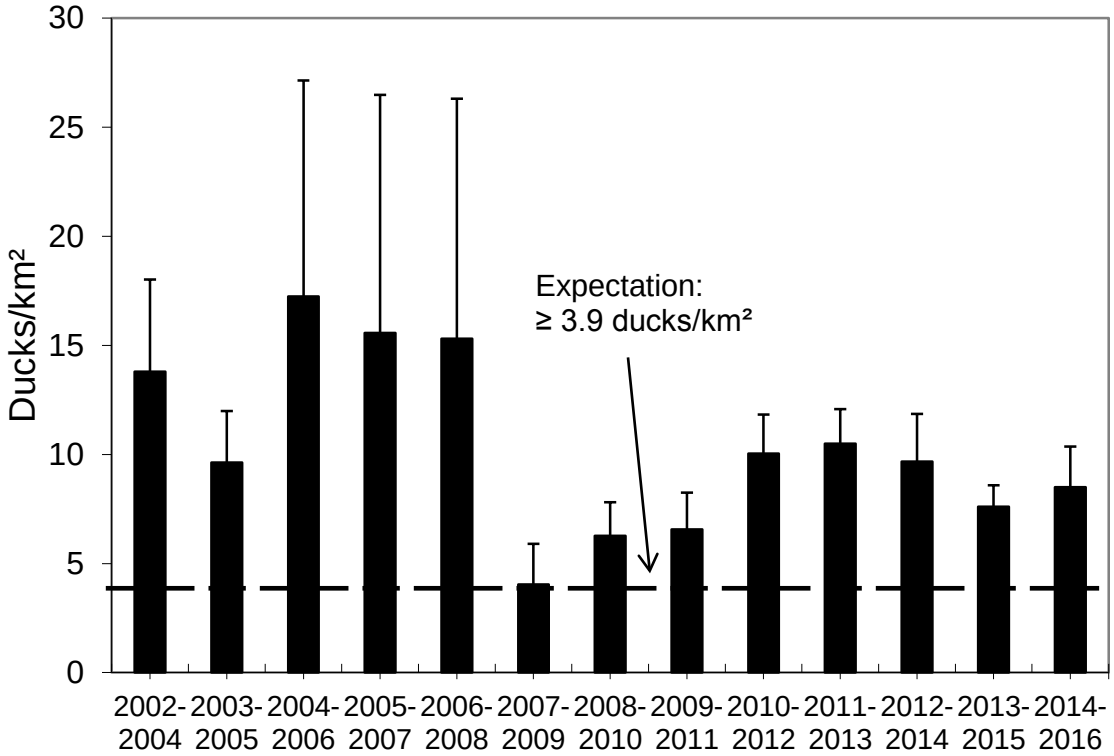

Figure 9-30. Post-restoration abundance as three-year running averages ± SE of waterfowl (ducks/km^2) during the winter (November–March) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

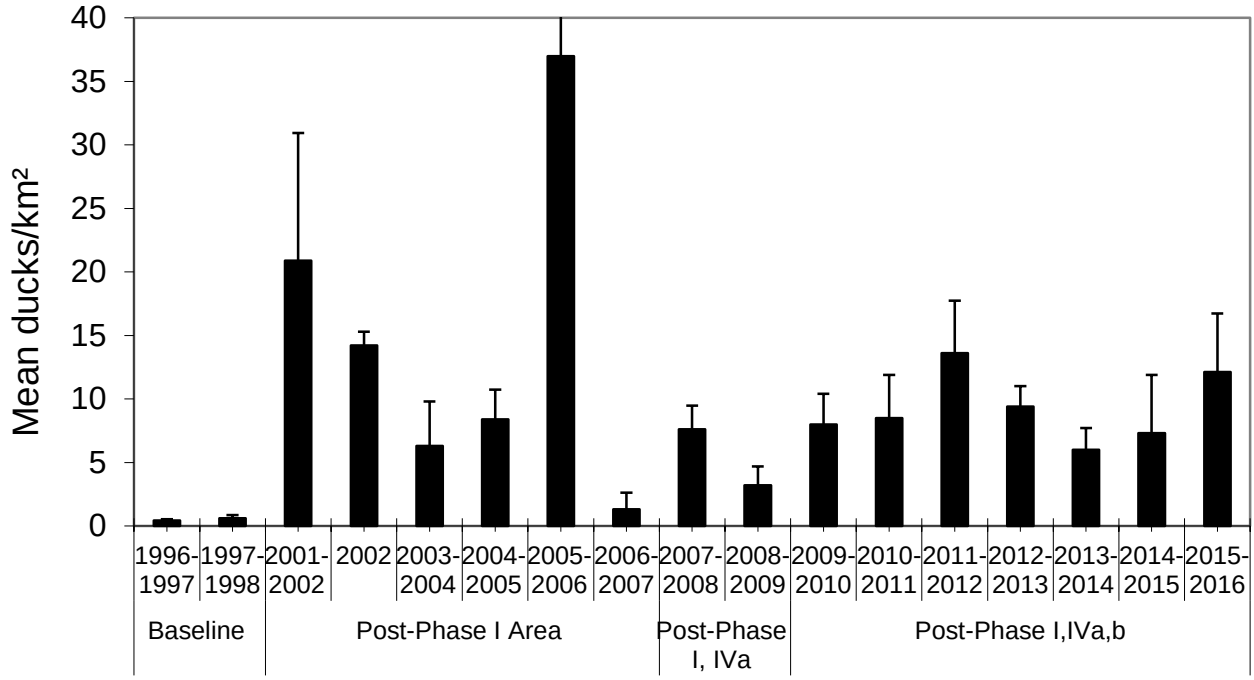

Figure 9-31. Baseline and post-Phases I, IVA, and IVB mean abundance ± SE of waterfowl during winter (November–March) within the 100-year floodline of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately nine months following completion of Phase I.

As with wading birds, waterfowl abundance was high during the initial fall recession in November and December, when floodplain water depths were below 0.18 m (SFWDAT 2016) (**Figure 9-32**). Waterfowl numbers remained above the restoration target through the end of January before declining to 2.7 birds/km² by February 3, when floodplain water depths quickly increased to 0.43 m. Water depths >0.3 m are relatively deep for the two most common species of ducks occurring on the river, teal (*Anas* sp.) and mottled ducks, both dabbling species that prefer shallower water. Waterfowl numbers remained low until the March 9 survey, when 3.8 birds/km² were observed as water levels receded quickly from 0.67 to 0.21 m during the preceding four weeks. Numbers remained above the restoration target until the April 6 survey, when 1 bird/km² was observed and water depths had climbed rapidly to 0.67 m during the preceding week. Survey numbers remained low through May.

Teal (*Anas* sp.) dominated numerically (77.9 percent), followed in order of abundance by mottled duck (17.6 percent), black-bellied whistling duck (*Dendrocygna autumnalis*) (4.0 percent), and <1.0 percent each wood duck, northern pintail (*Anas acuta*) and American wigeon (*Anas americana*).

Despite relatively rapid changes in water level and deeper-than-average floodplain depths this dry season due to effects of the El Niño weather pattern, waterfowl numbers were, on average, above the restoration target during the November–March survey period. Diving ducks, which prefer deeper water (usually>0.30 m) and require more open water habitat for access to prey, have not been prevalent on the river floodplain during the interim restoration period (2001–2016) (Cheek et al. 2014). This is likely due to insufficient inundation depth and duration to support significant open water habitat, submerged aquatic vegetation, and large invertebrate populations.

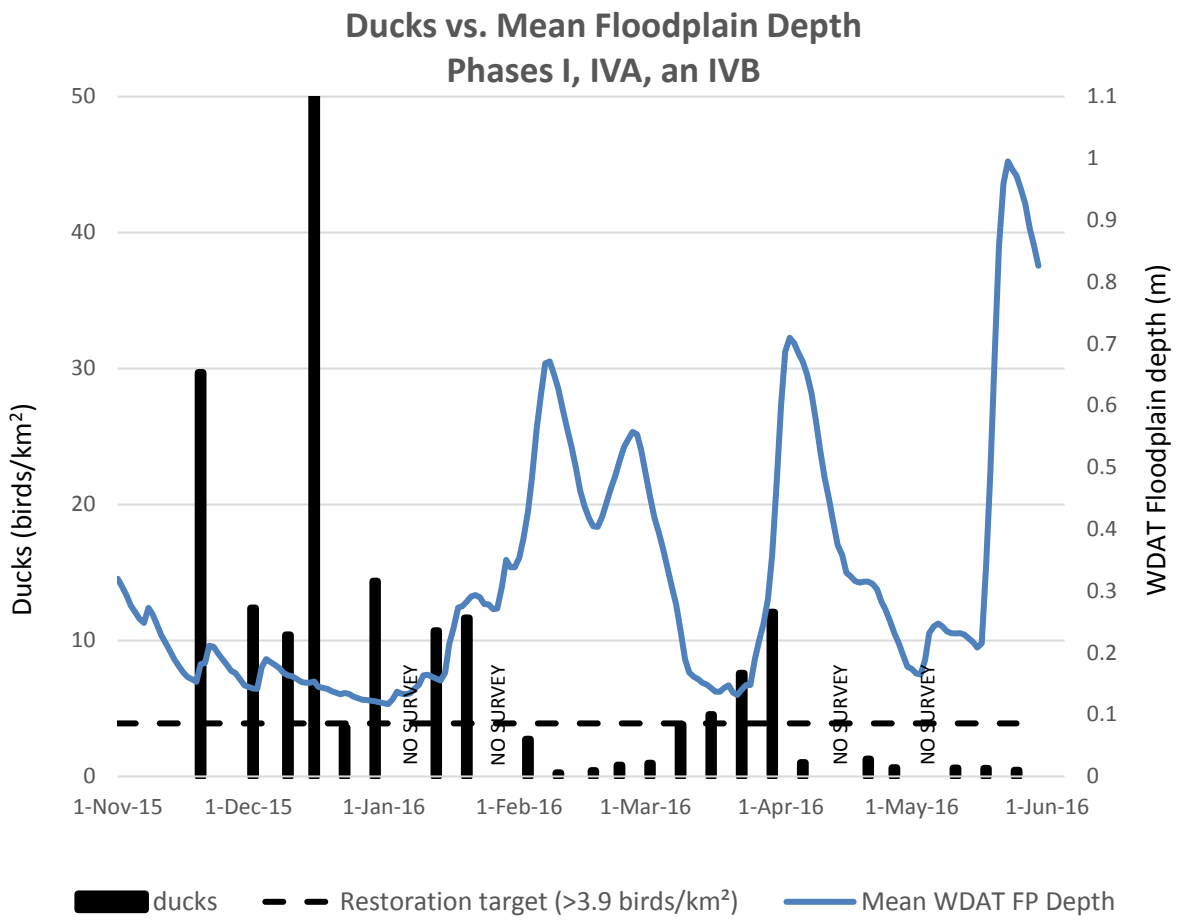

Figure 9-32 Waterfowl abundance and mean floodplain depth in the Kissimmee River Restoration Area (Phases I, IVA, and IVB) during the dry season (December–May) 2016. Floodplain depth is obtained from SFWDAT (2016).

The American wigeon, northern pintail, northern shoveler (*Anas 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 more than 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.

UPPER KISSIMMEE BASIN PROJECTS

KCOL AND KISSIMMEE UPPER BASIN MONITORING AND ASSESSMENT PROJECT

The KCOL and Kissimmee Upper Basin Monitoring and Assessment Project includes data collection, evaluation, and reporting to support SFWMD's mission to manage and protect water resources. Project products support management decision making and are used to determine whether management intervention is required or whether the ecosystem is responding as intended to management actions. Key focus areas include the following:

- Data collection and evaluation to define linkages/relationships between hydrology and fish and wildlife resources, and between hydrology and the lake littoral vegetation response to seasonal water level conditions.
- Lake and watershed water and nutrient budget development to document directions in basin water quality and lake assimilative capacities.
- Coordination with agency and environmental stakeholders to ensure non-redundant and complementary data collection and evaluation, to annually report on ecological conditions within the KCOL and UKB, and to facilitate information sharing and identification of emerging issues and concerns.

The scope of this year's report includes an overview of watershed assessment, monitoring, and research results. The results provide an overview of ecological conditions and water quality trends in the basin by combining data and information from SFWMD's monitoring activities with those of KCOL partner agencies.

KCOL WATERSHED MANAGEMENT PROJECTS

Osceola County Project Updates

LiDAR Survey

Osceola County received a cost-share grant from USGS to acquire detailed elevation data (1-ft contour LiDAR) for the entire county footprint, including the municipalities of Kissimmee and St. Cloud, and the portion of Reedy Creek Improvement District that lies within Osceola County. The three jurisdictions, SFWMD, and many local partners will share the cost-match financially and/or with in-kind services to produce this very valuable product. Similar elevation data are already available for many areas in the state, including most of the surrounding counties. These 1-ft contour lines across the county will allow emergency managers, county planners, natural resources staff, and engineering staff to better plan for development impacts, emergency response to flooding, and many other important functions.

The data were collected in the spring/summer of 2016 via flights over the county, and are being edited by the vendor. The finished product should be available to the county before November 2016. This product will be a complete map of 1-ft contours in Osceola County. During the flights, data were collected that provide for the ability to estimate vegetation density and other interesting information as well.

Lake Tohopekaliga Nutrient Reduction Plan

Osceola County completed its fourth year of study for the nutrient reduction plan, which was presented to FDEP and at the annual Lake Okeechobee Basin Management Action Plan meeting in Okeechobee. Osceola County has completed two water quality treatment systems on the west side of Lake Tohopekaliga

that provided 150 percent of the required treatment. The City of Kissimmee completed the rain garden portion of its comprehensive Kissimmee Lakefront Park water quality treatment system.

The eight-year average of total phosphorus concentration for Lake Tohopekaliga (WBID 3173A) continues to decline, but has had spikes of 0.08 mg/L, depending on a variety of conditions. Osceola County is waiting for the next FDEP assessment of Lake Tohopekaliga under the Impaired Water Rule, sometime before December 2016, to see how the lake fares after four years of effort.

Lakes Management Plan

The county is actively implementing its Lakes Management Plan. They have conducted debris removal and aquatic plant management in Boggy Creek and Shingle Creek to improve safety and mitigate navigation hazards along these very popular water ways. They also are working on logistics of removing a shoal/sandbar in Lake Tohopekaliga at the mouth of Shingle Creek. The county continues to apply for grants to help expand and improve boating access and to construct water quality treatment areas to meet the goals of the Northern Everglades and Estuary Protection Program as well as the Central Florida Water Initiative.

KCOL ASSESSMENT, MONITORING, AND RESEARCH

Monitoring Headwaters Revitalization and the UKB

The Headwaters Revitalization Project (HRP) was designed to increase storage in the headwater lakes of the Kissimmee River in order to provide appropriate flow patterns to the restored floodplain upon completion of restoration (expected date 2019/2020). The increased storage, or higher maximum regulatory stages, also are expected to improve the quantity and quality of littoral habitat in the headwater lakes as well. The HRP will increase regulatory stages and change the operating schedule on three major water bodies in the KCOL, including the Headwaters Lakes (USACE 1996). Monitoring vegetation within the existing littoral zones and up to future lake regulation elevations is necessary to determine the effects of the HRP (USACE 1996) on the headwater lakes. The need for vegetation monitoring was identified in the Kissimmee Upper Basin Monitoring and Assessment Project (initiated in October 2010) to address data gaps and knowledge uncertainties that were identified during the development of the KCOL Long-Term Management Plan (SFWMD et al. 2011). By combining monitoring efforts between these projects, expected improvements from HRP can be better isolated from other management activities in the basin, and monitoring efforts can be expanded to include wildlife responses in the future.

Currently, there are two vegetation monitoring studies on the KCOL that can help fill these needs. The first is a District project that involves tracking changes in specific plant community types over time and documenting any distributional shifts up or down slope if they occur. The second is an FWC project and involves quantifying specific littoral communities via aerial imagery on a 3 to 5-year rotation in the major KCOL water bodies. Below is a summary of each of the projects.

Permanent SFWMD Monitoring Stations

Long-term permanent monitoring stations were established on three of the major water bodies in the KCOL in 2015; East Tohopekaliga, Tohopekaliga, and Lake Kissimmee. Lake Kissimmee is the only lake that will have a different regulation schedule under the HRP, while Lakes Tohopekaliga and East Tohopekaliga will serve as control lakes for comparison. Additional monitoring stations may be added to other headwater lakes in the future, including Lakes Cypress or Hatchineha. The permanent monitoring stations include circular plots that are stratified by water depth and community type throughout the littoral zone, as well as belt transects set perpendicular to shore in the upper reaches of the littoral zone.

Methods. The circular plots were established using a stratified-random sampling approach (Baker et al. 1987), placing sampling stations randomly within selected communities and depth strata (Day et al.

1988, Walker et al. 2003). This approach focuses sampling within clear patterns of plant zonation, allowing the monitoring of responses of vegetation along the depth gradient (Dale 1999). Using repeated measures (i.e. resampling the same monitoring stations over time) focuses variance within sites in order to more effectively detect trends or differences in impact between sites (Green 1993).

Using the above methodology, sampling stations were placed in communities from medium (Shallow Marsh) and long hydroperiod (BLM) depth classes, as well as two deepwater (5–7 ft when lake is at high pool) communities (Floating Leaf, Deep Grasses) that represent different "energy" environments (**Figure 9-33**). For example, lilies and floating leaf aquatics are representative of more stabilized water levels or sheltered/lower-energy areas (Day et al. 1988, Wisheu and Keddy 1992), whereas deepwater grasses/emergents are more representative of dynamic water levels and/or higher-energy environments (Johnson et al. 2007). Additionally, these two communities respond differently to periodic lake drawdowns, and can be an indicator of long-term drying cycles (Moyer et al. 1989, Paillisson and Marion 2006, Johnson et al. 2007).

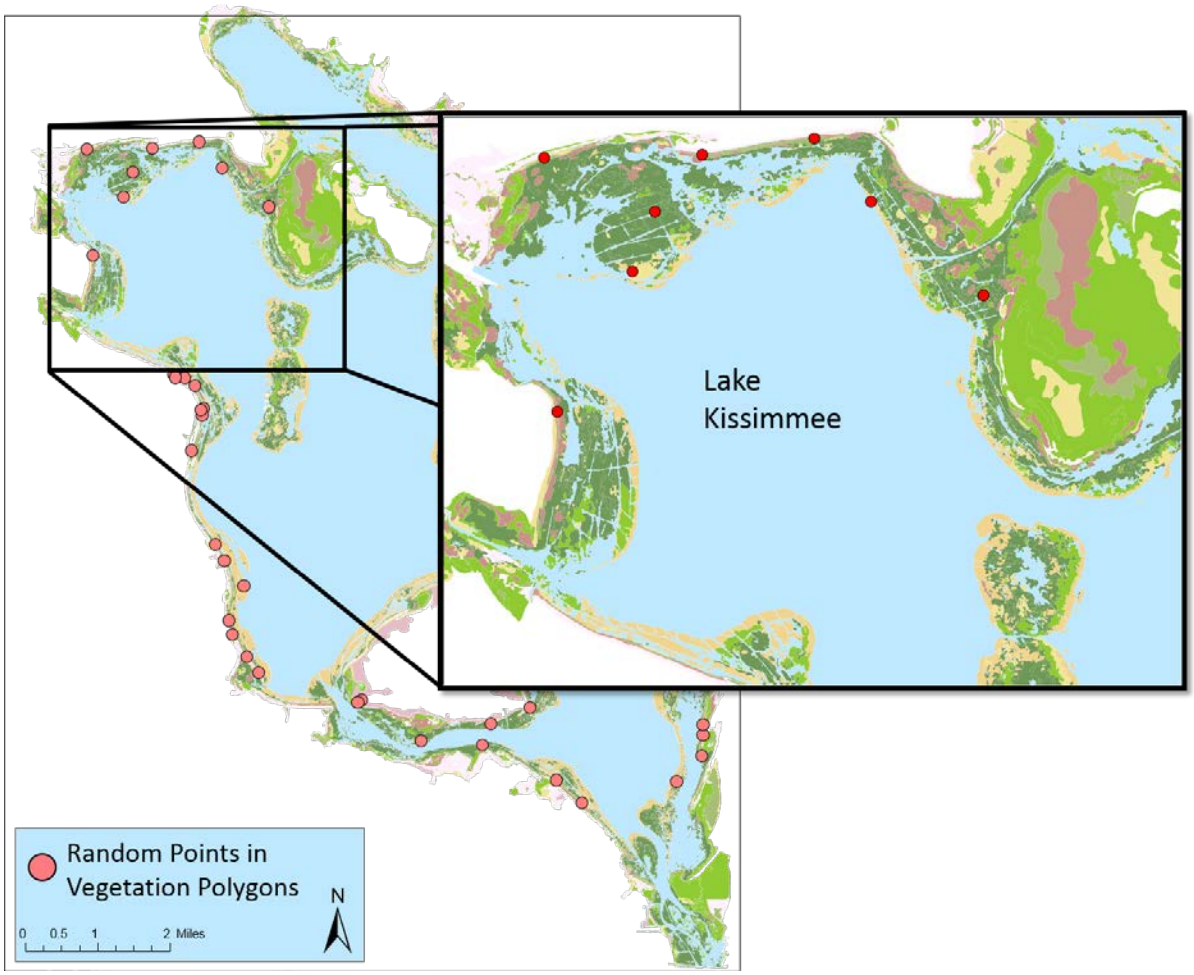

Figure 9-33. Examples of randomly generated sample locations (red circles) in different depth categories (colored polygons), which were used to select permanent monitoring stations for percent cover estimates.

Within each of the four depth categories described above, ten sample locations (40 per lake) are monitored annually in the late summer/early fall, which coincides with the peak of the growing season and when many species are flowering, aiding identification (Toth 2005). Percent cover is visually estimated at each location for a 5-square meter (m^2) circular quadrat, using Daubenmire (1959) cover classes (Bousquin and Colee 2014).

In addition to percent-cover plots, three interrupted belt transects (Baker et al. 1987) were established perpendicular to shore between the low and high water elevations of the current lake regulation schedules, and on the headwater lake (Lake Kissimmee) they extend upslope to what will be the high water elevation under the HRP regulation schedule (**Figure 9-34**). Perpendicular to each transect, two rectangular, 1 × 2 m quadrats (Bousquin and Colee 2014) are sampled 1 m from the transect at each 0.5-ft elevation break (e.g., Frahn et al. 2014), totaling seven sampling locations on each transect, an equal sampling effort regardless of total length (**Figure 9-34**). Plant species abundance is visually estimated using Daubenmire (1959) cover classes (Bousquin and Colee 2014) in the late summer/fall each year.

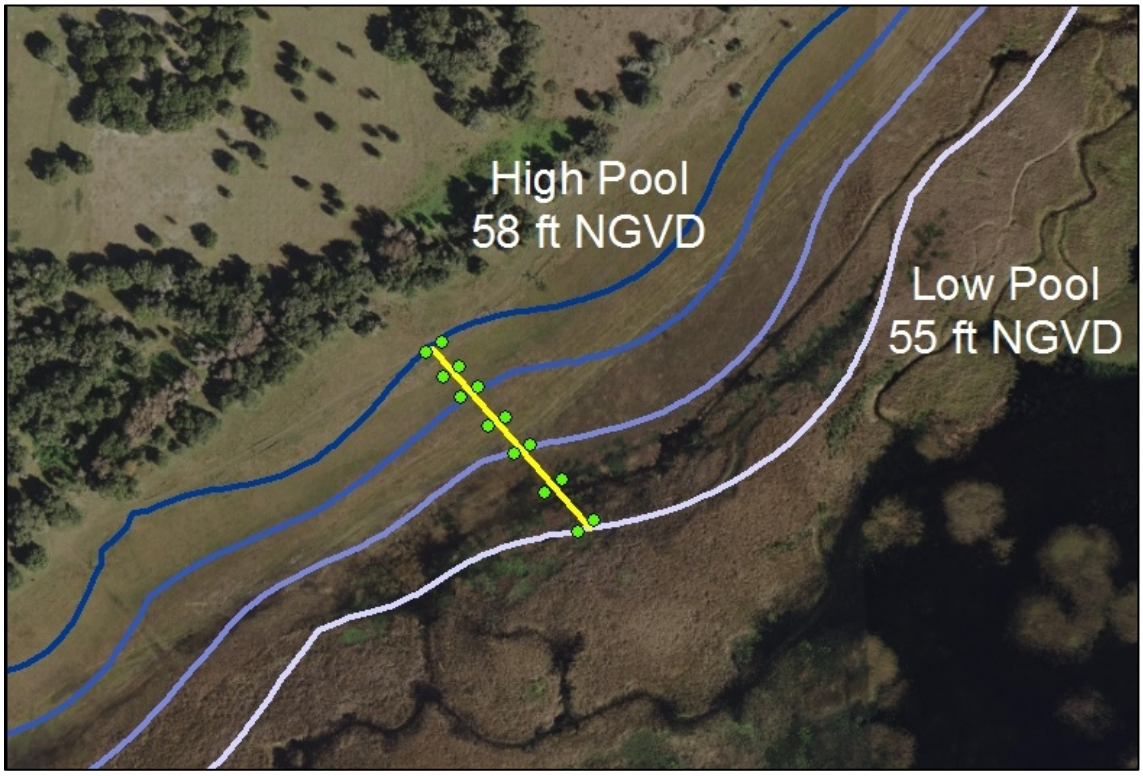

Figure 9-34. Example of line transects (yellow) and subsamples (green circles) are shown to demonstrate approximate locations spanning 58–55 ft NGVD29 elevation contours on East Tohopekaliga, or the maximum and minimum of the annual regulation schedule.

Results and Discussion. For the plots and transects, samples were grouped via cluster analysis, using Sorenson distance measure and flexible Beta of -0.25; and species representative of each cluster were identified via indicator species (ISA) analysis (Tichý and Chytrý 2006). The number of clusters was chosen based on the ISA with the lowest average p-values and highest number of significant indicator species (McCune and Grace 2002). The relative dissimilarity of the samples (in terms of species composition) were displayed via a non-metric multidimensional scaling ordination, with individual samples color-coded to the groups identified in the cluster analyses.

The community plot data showed the distinct differences between the groups, which were distributed along a water depth gradient ($R^2 = 0.89$) (**Figure 9-35a**). This was expected because sample locations were randomly placed in distinct community types apriori in order to monitor changes in those specific types over time. However, in the year between establishing sample locations and collecting the initial data, four plots were grouped with a different community than they were originally established in. In other words, their species compositions had become more similar to a different community than they were originally established in one year prior. For example, one of the samples originally placed in the BLM community type was grouped with the Shallow Marsh community in the cluster analysis, two of the Deep Grasses community samples were grouped with the Floating Leaf community type, and one of the Floating Leaf community samples was grouped with the Deep Grasses via the cluster analysis. These types of shifts in species composition are precisely what the monitoring program is established for, and each future sample will provide insight as to whether these shifts are temporary or happening on a larger scale.

The cluster and ISA analyses resulted in three communities distributed along a depth gradient that was strongly correlated to the average annual continuous hydroperiod of each sample location ($R^2 = 0.84$) (**Figure 35b**). While there were seven to eight samples located along transects at every 0.5-ft elevation break from the regulation high to the regulation low on each of the three lakes, these samples were only grouped into three distinct community types via cluster and ISA analyses. The shallowest group's indicator species were several grasses and sedges (*Schizachyrium* spp., *Andropogon* spp., *Axonopus* spp., and *Rhyncospora* spp.), which transitioned into a less diverse community dominated by the grass *Luziola fluitans*, and finally into a BLM community near the annual low pool, which was dominated by *Pontederia cordata* and *Sagittaria lancifolia*. There was considerable overlap between these three community types, as well as within each, as evidenced by the vertical spread of points along Axis 1. This is due to the considerable diversity of species along these ecotones, which often exceeded 15 species/m^2, as well as some variation between water bodies and transects. However, over time monitoring will show whether these community types shift up or down slope, if their composition changes from additions of new species, and whether changes vary by water body.

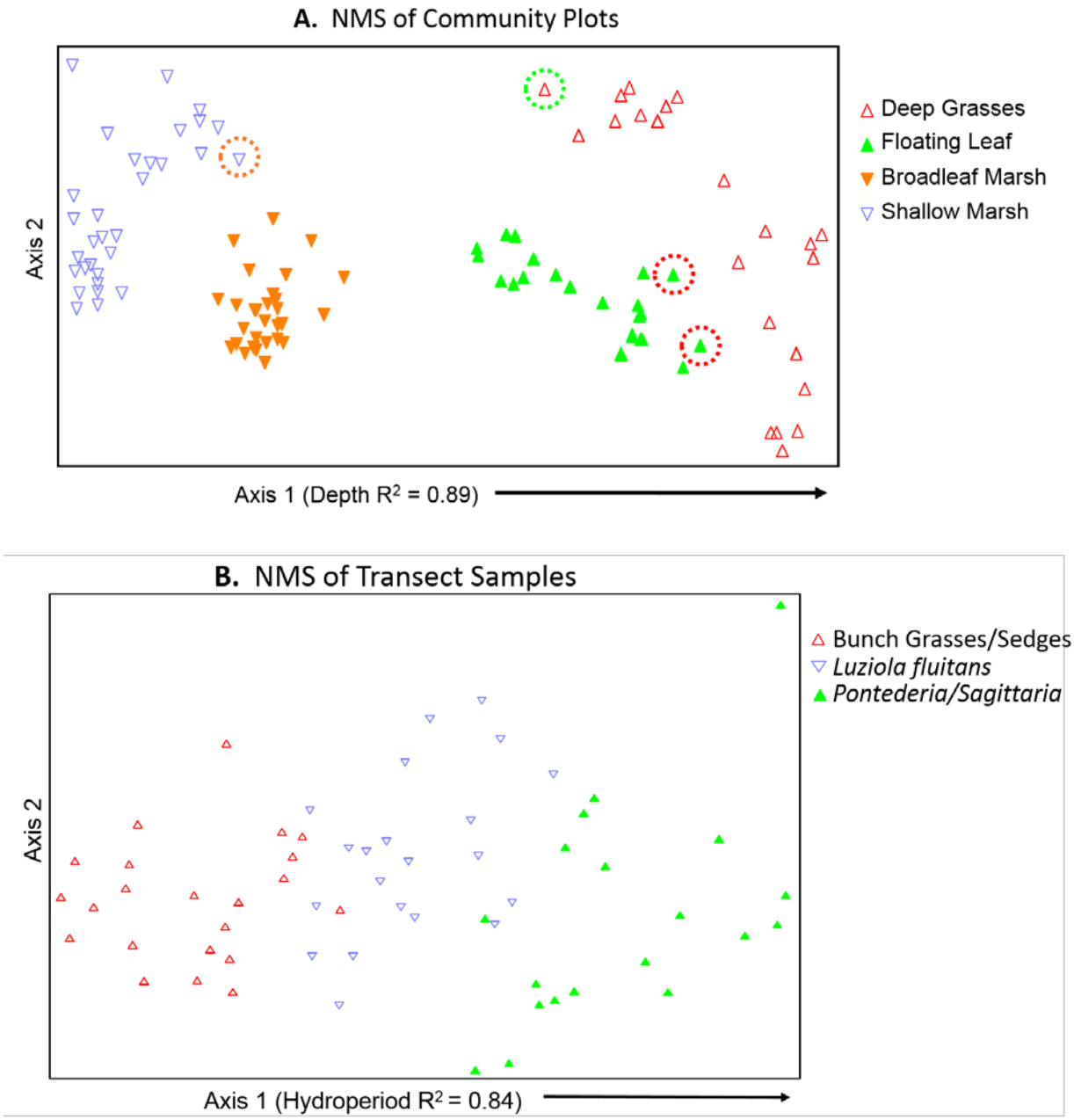

Figure 9-35. Non-metric multidimensional scaling ordination of (A) community and (B) transect data. Colors represent different community types, as identified by cluster and ISA analyses. (A) Water depth of each plot relative to the minimum of the regulation schedule in each waterbody was correlated to Axis 1 (R^2 = 0.89), with samples increasing in depth from left to right. Dashed circles represent plots that were originally established in a community type other than what the cluster analysis placed them in, as identified by the color of the dashed circle. (B) Five-year average annual continuous hydroperiod of each sample was correlated to Axis 1 (R^2 = 0.84).

Aerial Imagery Classification

FWC has been creating vegetation community maps from aerial imagery of the major waterbodies in the KCOL (and Lake Istokpoga) since 2005. The monitoring effort was initiated to develop lake management plans using quantifiable habitat targets for a suite of representative wildlife species. In order to better assess littoral vegetation conditions and to monitor efficacy of management actions, FWC developed a classification system using vegetation types that were common and/or representative of specific habitat value for fish and wildlife. The classes were based on an amended version of the Florida Land Use, Cover and Forms Classification System (FDOT 1999), and also contained estimates of plant coverage (sparse, medium, or dense) for each.

The resulting vegetation classifications were then assigned values according to their relative habitat value for a variety of fish and wildlife taxa, including alligators, imperiled species, sportfish, wading birds, and waterfowl. For example, a dense floating mat of vegetation might be scored low as sportfish foraging habitat but high for alligator nesting habitat. The rankings provide an estimate of available habitat for each of the focal wildlife taxa on each lake as well as where it occurs. These efforts allow lake managers to balance habitat needs among a variety of fish and wildlife and to focus management in specific areas to maximize efficiency and reduce costs.

Aerial imagery for Lake Kissimmee was collected in the spring/summer of 2015 and classified into community types described previously. Two community types of interest to managers are deepwater emergent grasses and floating leaf, or lily pads. Generally, floating leaf communities are less desirable for fisheries and recreational access, and typically are representative of fairly stable water levels and deeper organic sediment (Nohara 1991, Whyte et al. 1997). For the last several years, lake managers have observed an apparent increase in lily pad/floating leaf communities on several lakes in the KCOL, including Tohopekaliga and Kissimmee.

While Lake Tohopekaliga imagery was collected in the spring/summer of 2016, it will not be classified until the end of 2016. The latest classifications for Lake Kissimmee, however, show a marked increase in communities dominated by lily pads/floating leaf species (e.g., *Nuphar advena, Nymphaea odorata, Nymphaea mexicana,* and *Nellumbo lutea*) and a decrease in those dominated by deepwater grasses/emergents (e.g., *Paspalidium genimatum, Panicum hemitomon,* and *Schoenoplectus californicus*). **Figure 9-36** shows the lily pads community increased from 21 percent of the total emergent littoral zone in 2012 to 29 percent in 2015, while the grasses decreased from 18 percent to 11 percent.

While the communities co-dominated by both grasses and lily pads stayed relatively constant (7 to 9 percent), it is evident that many areas that were classified as mixed in 2012 have shifted to lily pad-dominated in 2015 (yellow to green on map), and that many of the areas classified as grasses in 2012 have shifted to mixed in 2015 (orange to yellow on map). This imagery shows that the deepwater grass communities are being replaced by floating leaf/lily pad communities. These are the kinds of habitat shifts that typically prompt lake managers (e.g., FWC) to conduct extreme drawdowns in order to expose, desiccate, and oxidize the organic sediments that the floating leaf communities occur in, and to simultaneously stimulate germination and expansion of the grass communities. Further information regarding the mapping results for individual lakes, methodology, or habitat classifications can be found by contacting Craig Mallison with FWC at craig.mallison@MyFWC.com.

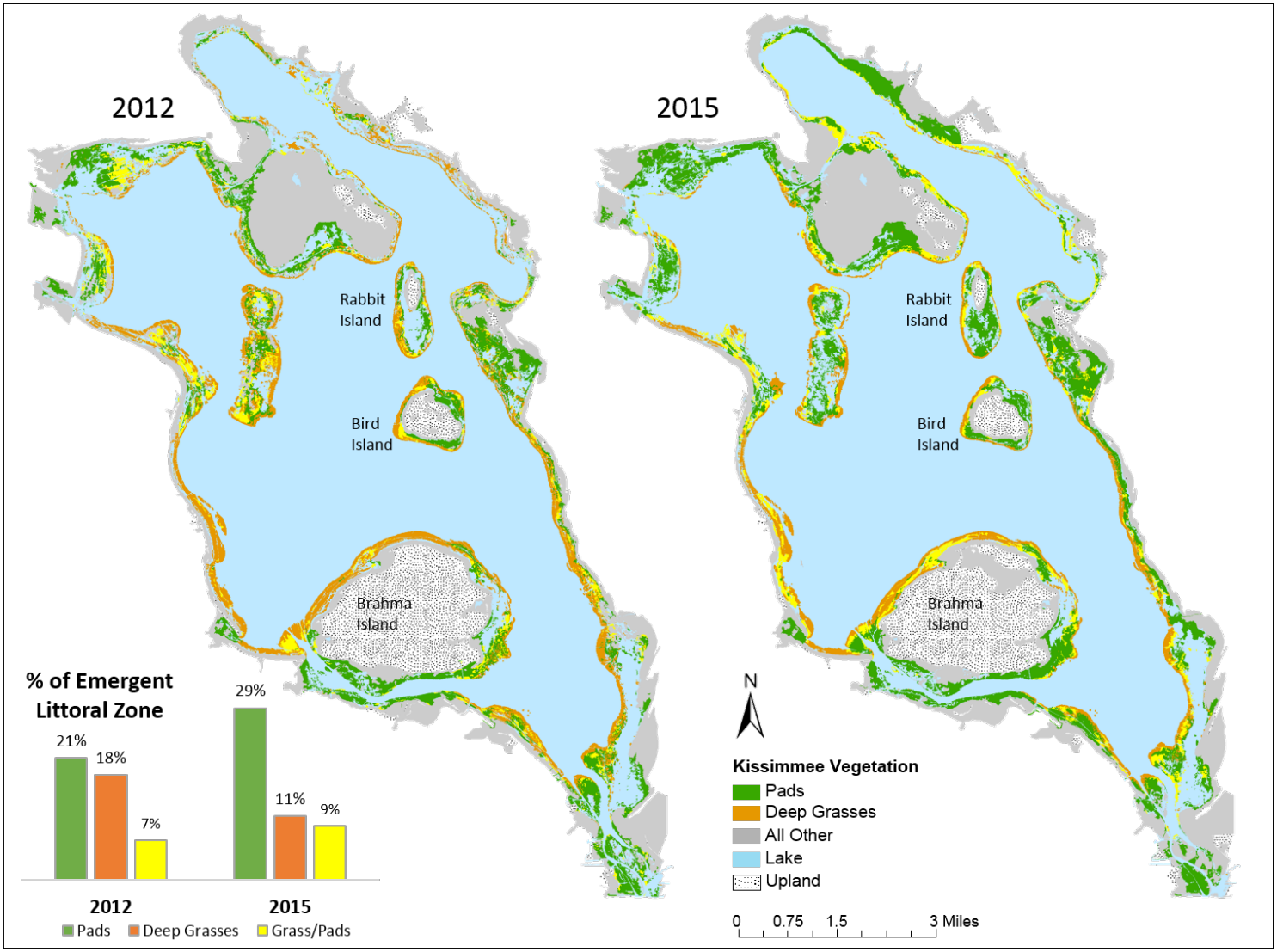

Figure 9-36. Vegetation classifications of Lake Kissimmee aerial imagery showing locations of dominant lily pad, deepwater grasses, and a mix of the two communities in 2012 versus 2015. Bar graph on lower left shows percent of total emergent littoral zone each community represented in the given year.

Fish Population Monitoring

The status of the fishery in the KCOL is monitored on a regular basis by FWC via electrofishing and creel surveys. Electrofishing surveys provide an opportunity to assess the size distribution of the largemouth bass populations as well as their relative health based on established relationships of length:weight ratios. These surveys occur in the spring every 2–3 years on the major lakes in the chain, with the most recent conducted on lakes East Tohopekaliga, Tohopekaliga, Cypress, Kissimmee, and Marian, in the spring of 2015. Catch per unit effort ranged from 21.7 bass/hour on East Tohopekaliga to 43.4 bass/hour on Lake Marian (**Table 9-10**). Mean relative weights were recorded for largemouth bass on Lakes Tohopekaliga and Kissimmee, and were 99 on each lake (scale of 0–100, with 90–100 representing healthy weights), meaning the fish populations appeared healthy (**Figure 9-37**). Results indicate all of the surveyed lakes support good bass populations, but lakes Cypress, Kissimmee, and Marian may have a greater number of large bass (>498 mm [19.7 inches] total length [TL]) than East Tohopekaliga or Tohopekaliga.

Table 9-10. Mean catch per unit effort (fish/hour) values by length group for largemouth bass collected by electrofishing from random transects in lakes East Lake Tohopekaliga (n = 31), Tohopekaliga (n = 31), Cypress (n = 20), Kissimmee (n = 18), and Marian (n = 13) in spring 2015. Each transect was sampled for 15 minutes. SE and coefficient of variation values are denoted in parentheses and brackets, respectively.

Lake	<201 mm TL	201-355 mm TL	356-498 mm TL	499-598 mm TL	>599 mm TL	Total
East Tohopekaliga	9.3	8.5	3.9	0.0	0.0	21.7 (3.5) [91]
Tohopekaliga	11.2	13.3	5.3	0.7	0.3	30.7 (4.2) [66]
Cypress	5.2	14.4	13.0	1.8	0.8	35.2 (6.7) [81]
Kissimmee	8.9	11.8	10.7	1.6	0.2	33.1 (3.9) [50]
Marian	1.5	12.3	23.4	5.8	0.3	43.4 (5.0) [42]

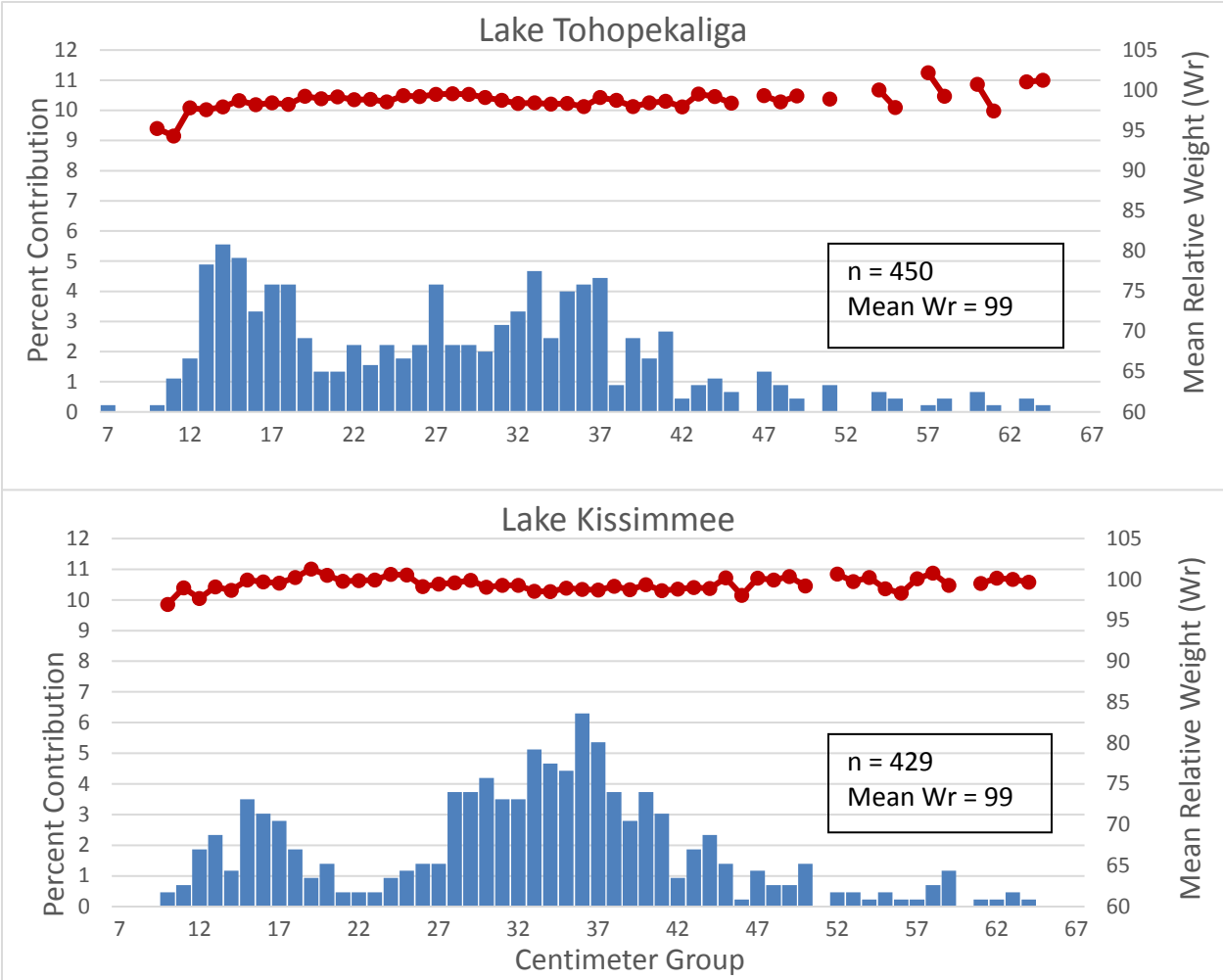

Figure 9-37. Length-frequency distribution (bars) and mean length-specific relative weight (Wr, red points) for largemouth bass collected by electrofishing at Lakes Tohopekaliga (top) and Kissimmee (bottom) during spring 2015. Fish lengths were placed into centimeter groupings (e.g., 10 cm group = 10.00–10.99 cm TL).

Everglade Snail Kite Population Monitoring

Statewide Everglade snail kite nesting effort, distribution, and population size are systematically monitored by the University of Florida on an annual basis (see Fletcher et al. 2014). This monitoring effort covers all wetlands in which breeding activity has been observed within the last decade or more, statewide. In the KCOL region, surveyed water bodies include East Lake Tohopekaliga, Lake Tohopekaliga, Lake Runnymede, Lake Jackson, Lake Cypress, Lake Hatchineha, and Lake Kissimmee. The number of Everglade snail kites observed in each water body are counted and identified by their alpha-numeric leg bands, if possible. Survey crews also record nesting information, including the location, status (building, incubating, nestlings, failed, or successful), leg-bands of parents (if possible), and other important characteristics. Following the first survey in January, each nest is revisited on subsequent surveys at about 3-week intervals until it is no longer active. Alpha-numeric leg bands are put on most nestlings when they are 24 days old for future identification and for estimating population size.

Survey crews located a total of 445 active nests (i.e., containing eggs or nestlings) throughout the Everglade snail kite's range in Central and South Florida in the breeding season of 2015 (roughly January to September). As has usually been the case since 2005, a large proportion of the nests (133 total) were

located in the KCOL, accounting for 30 percent of the range-wide nesting effort in 2015. The total number of active nests and the total number of successful nests in the KCOL were up from at least a seven-year low in 2014 (**Figure 9-38A**). For the second year in a row, however, the KCOL did not have the most active or successful nests of any region; the "Other" region had more active and successful nests than the KCOL, while the stormwater treatment areas had more successful nests but fewer active. The Other region consists of any wetlands that are not encompassed by the KCOL, Okeechobee, stormwater treatment areas, or Everglades regions. In 2015, the Other region was bolstered by a record amount of nesting effort in Lake Istokpoga (37 active nests) and a new area in Brevard County called Mary A Mitigation Bank (94 active nests). In fact, Mary A alone contributed 21 percent of the range-wide nesting effort, 34 percent of the range-wide successful nests, and 37 percent of the range-wide fledgling production.

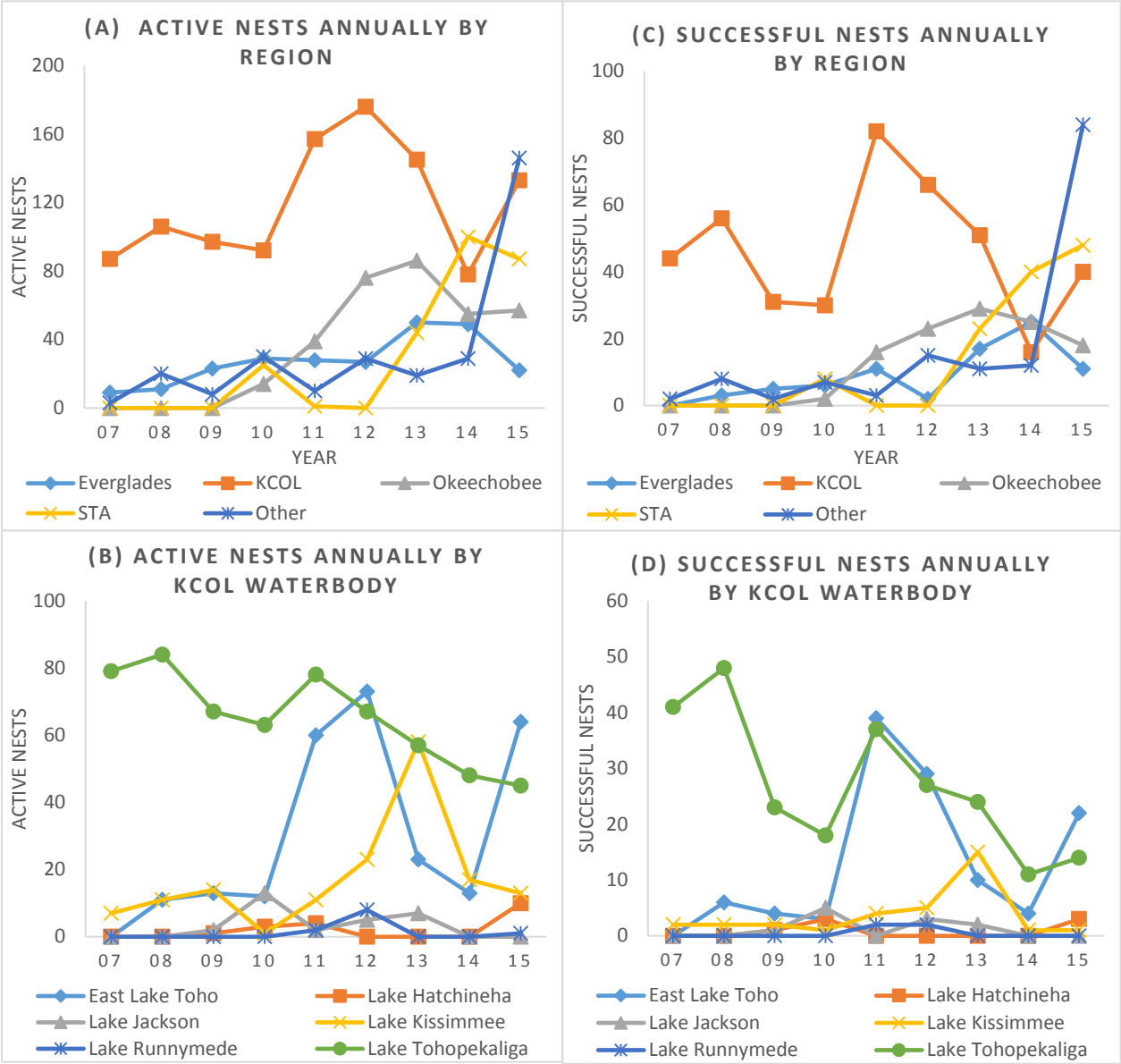

Figure 9-38. Active Everglade snail kite nests for (A) each region from 2007 to 2015 and (B) each major water body in the KCOL region, and (C) total successful Everglade snail kite nests annually and (D) for each KCOL water body from 2007 to 2015.

Within the KCOL, there were 45 nests located on Lake Tohopekaliga in 2015, which accounted for 10 percent of the statewide nesting effort. Lake Kissimmee had 13 nests (3 percent of the statewide nesting effort) and East Lake Tohopekaliga had 64 nests (14 percent of the statewide nesting effort). Lake Hatchineha had 10 nests (2 percent of the statewide nesting effort) and Lake Runnymeade had 1 nest (<1 percent of statewide nesting effort) (**Figure 9-38B**). Of the 133 total nests in the KCOL, 40 (20 percent) were observed to be successful (fledged at least one young) (**Figure 9-38C** and **D**).

In summary, the KCOL region had a rebound year after a couple consecutive years of declining nest effort and success. Total active and successful nests in the KCOL were higher in 2015 than in 2014 but still below their averages from 2011–2013. The resurgence in Everglade snail kite nesting was mostly due to the second highest nesting effort ever documented on East Lake Tohopekaliga. East Lake Tohopekaliga also had the third highest number of successful nests and fledglings ever documented on the water body, while the other KCOL lakes, including Lake Tohopekaliga, had similar numbers to the previous year.

Alligator Population Monitoring

FWC conducts alligator monitoring studies in many public water bodies throughout the state to obtain relative abundance of their populations (Hutton and Woolhouse 1989). Alligator activities vary seasonally (Lutterschmidt and Wasko 2006), so night-light surveys are conducted from May through mid-June (spring surveys) and July through mid-August (summer surveys), and are analyzed separately. Survey routes are standardized and follow the perimeter of a lake along the open water-shoreline/marsh interface (Woodward and Marion 1978), or middle/centerline of a river/canal section, depending on width. Spotlights (200,000 candlepower) are used to locate alligator eye reflections and sizes are estimated to the nearest 1 ft, if possible. In cases where the exact size cannot be determined, broader size categories (0–2 ft, 2–4 ft, 4–6 ft, ≥ 4 ft, ≥ 6 ft, and ≥ 9 ft) are used, or they are recorded as "unknown size".

For trend analysis by year, counts are summed in each size category, and average date, water level, and water temperature within replicates are determined for each year. FWC uses Turnbull's (1976) approach for interval censored data via the "%ice" SAS macro (So et al. 2010) in order to allocate counts into size categories. A modified version of this macro is used to produce an overall probability distribution function describing the estimated proportions of unit-interval lengths for each replicate-unit-year sample. The probability distribution function is summed for specified portions of the alligator size range to produce the cumulative distribution function for each replicate-unit-year. SE and 95 percent confidence intervals for the cumulative distribution function are determined via the macro as well, and these are multiplied by the total number of alligators counted for each replicate-unit-year sample to estimate the total count, its SE, and confidence limits.

FWC models year trends in the natural logarithms of the estimated counts using the generalized additive modeling (GAM) package of the R statistical environment (Hastie 2009). Akaike's information criterion is used to select the best of six models with the following predictors plus intercept: (1) linear year effect; (2) 4 knot spline for year; (3) linear year and linear water level; (4) linear year and 4 knot spline for water level; (5) linear water level and 4 knot spline for year; (6) 4 knot spline for year and 4 knot spline for water level. A fixed detectability coefficient of 0.14 is applied to survey counts to generate population estimates from the GAM analyses (Woodward et al. 1996).

Lake Kissimmee

Total population estimates on Lake Kissimmee have continued to stay strong in recent years. The 2015 estimated population was 13,053, which is an increase of approximately 183 percent since population monitoring began in 1991 (**Figure 9-39a**). The estimated number of juvenile (1–4 ft) alligators was 7,666, which is a 372 percent increase over the 1991 estimated population. The adult (≥ 6 ft) segment of the alligator population also increased, and was estimated at 3,761, a 60 percent increase since 1991.

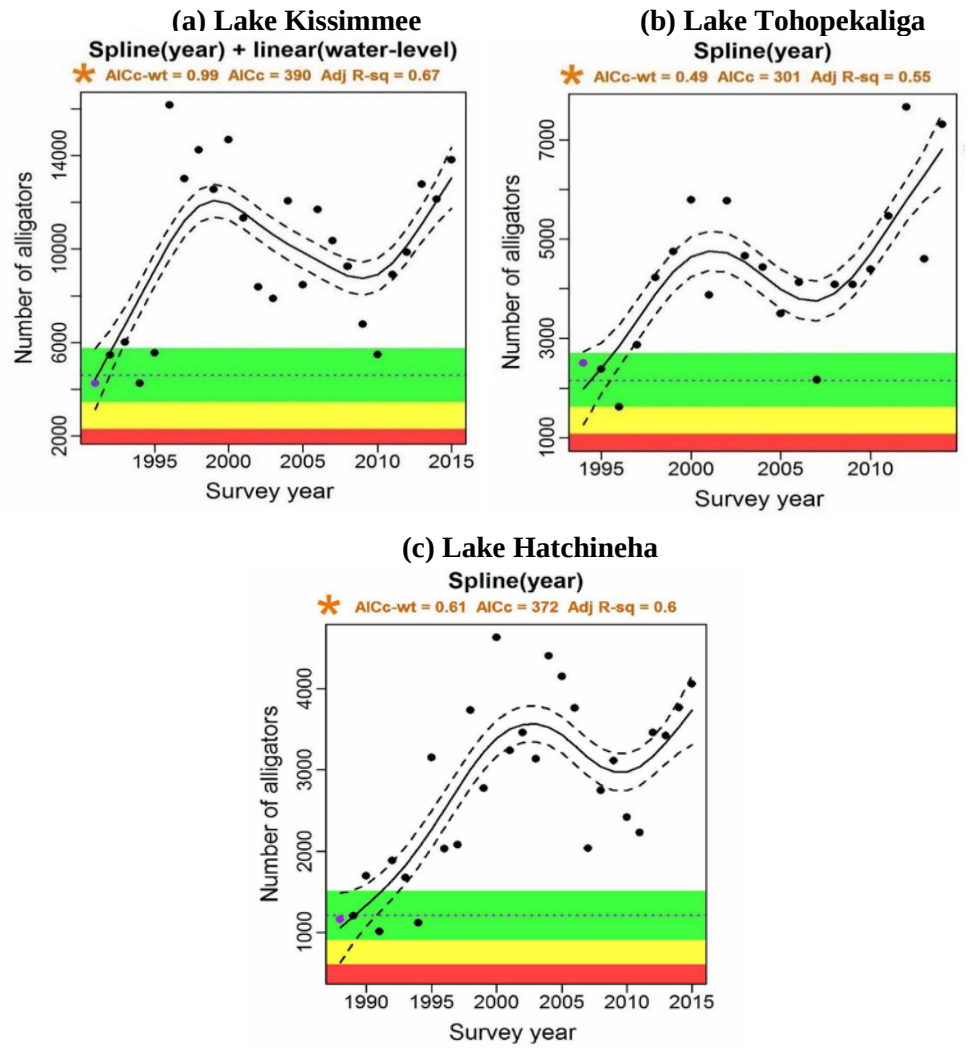

Figure 9-39. Alligator population trends on (a) Lake Kissimmee, (b) Tohopekaliga, and (c) Hatchineha, based on night-light surveys conducted between 1988 and 2015. Green shaded area represents ±25 percent of the starting population estimate; yellow shaded area represents a 25–50 percent decline; and the red shaded area represents a >50 percent decline. Dashed lines represent 70 percent confidence intervals around the solid trend line. Note that the scales on both the X and Y axes vary between figures.

Lake Tohopekaliga

Total population estimates on Lake Tohopekaliga have continued to stay strong. The 2015 estimated population was 6,816, an approximate increase of 216 percent since population monitoring began in 1994 (**Figure 9-39b**). The estimated number of juvenile (1–4 ft) alligators was 4,936, a 185 percent increase over the 1994 estimated population. The adult (≥ 6 ft) segment of the alligator population has also increased, and was estimated at 1,372; an 86 percent increase over the 1994 estimated population.

East Lake Tohopekaliga

Total population estimates on East Lake Tohopekaliga have remained relatively stable over time. The 2015 estimated population was 104, an increase of approximately 6 percent since population monitoring

began in 2003. The estimated number of juvenile (1–4 ft) alligators was 20, a 33 percent decline from the 2003 estimated population. The adult (≥6 ft) segment of the alligator population was 83; a 60 percent increase over the 2003 estimated population.

Lake Hatchineha

Total population estimates on Lake Hatchineha have remained strong. The 2015 estimated population was 3,734, an increase of approximately 209 percent since population monitoring began in 1988 (**Figure 9-39c**). The estimated number of juvenile (1–4 ft) alligators was 2,277, a 263 percent increase since 1988. The adult (≥6 ft) segment of the alligator population also increased and was estimated at 932, a 129 percent increase over the 1988 estimated population.

Cypress Lake

Total population estimates on Lake Cypress have remained stable over time. The 2015 estimated population was 1,023, a 5 percent increase since population monitoring began in 2000. The estimated number of juvenile (1–4 ft) alligators was 186, while the estimated number of adult alligators was 529. Those estimates represent a 24 percent decline and a 22 percent increase from the 2000 estimated population, respectively.

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