ANNEX E
REPORTS PROVIDED BY RECOVER TO SUPPORT THE LAKE OKEECHOBEE STORAGE RESERVOIR SECTION 203 STUDY

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REstoration COordination and VERification (RECOVER) Support to LOCAR
MEMORANDUM FOR THE RECORD & TRANSMITTAL LETTER

January 5, 2024

To: Elizabeth Caneja, Project Manager
Lake Okeechobee Component A Reservoir (LOCAR)

RECOVER SUPPORT TO PROJECTS FOR THE LAKE OKEECHOBEE COMPONENT A RESERVOIR (LOCAR)
RECOVER has completed several interaction points during the Lake Okeechobee Component A Reservoir (LOCAR) Feasibility Study (FS) planning process in accordance with CERP Programmatic Regulations (2003), and CERP Guidance Memorandum 66 (CGM 66). These include 1) a consistency review of project-level Performance Measures, 2) a system-wide evaluation of project alternative plans, 3) review of the project monitoring plan, and 4) review of the draft project operating manual. A summary of these interactions are included herein, and attached is the full RECOVER Evaluation of Project Alternative Plans for inclusion in the LOCAR FS and Environmental Impact Statement (EIS). RECOVER conducted the described activities herein to ensure that the project documentation fulfills the Federal requirements once the project is submitted for Congressional approval under the Comprehensive Everglades Restoration Plan (CERP).

The traditional study process is for the U.S. Army Corps of Engineers (USACE) to carry out a water resources development feasibility study using, in addition to the cost share provided by the non-federal interests, funding provided by the Congress. Section 203 of the Water Resources Development Act of 1986 provides language that specifies certain non-federal interests may be capable of producing a feasibility study of a proposed water resources development project without USACE involvement.

Section 203 provides that a non-federal interest can submit a completed feasibility study to the Secretary of the Army for review to determine if the study, and the process under which the study was developed, each comply with federal laws and regulations applicable to feasibility studies of water resources development projects. Section 203 provides that the Assistant Secretary of the Army for Civil Works (ASA[CW]) shall submit to the Committee on Environment and Public Works of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives a report that includes the results of the ASA(CW) review of whether the feasibility study and the process under which the study was developed comply with federal law and regulations; a determination of whether the project is feasible; any recommendations concerning the plan or design of the project; and any conditions that the ASA(CW) may require for construction of the project. For the purpose of ensuring the study complies with federal law and regulations, RECOVER has conducted the aforementioned reviews.

RECOVER
RECOVER is an interagency and interdisciplinary scientific and technical team first described in the "Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement" or "Restudy" in 1999.

RECOVER was established by USACE and SFWMD to conduct assessment, evaluation, and planning and integration activities using the best available science that support implementation of the Comprehensive Everglades Restoration Plan (CERP or Plan) with the overall goal of ensuring that the goals and purposes of the Plan (footnote on Plan is CERP WRDA Section 601(a)(4) Definitions) are achieved. RECOVER has been organized to accomplish activities such as: developing system-wide performance measures; developing and implementing the monitoring and assessment program; evaluating alternatives developed by Project Delivery Teams to achieve the goals and purposes of the Plan; conducting system-wide water quality analyses; developing, refining, and applying system-wide models and tools; and evaluating modifications to the Plan (footnote to Programmatic Regulations 33 CFR Part 385.20 (a)).

RECOVER is not a policy making body but has technical and scientific responsibilities that support implementation of the Plan. (33 CFR Part 385.20 (a)). RECOVER's evaluation of project alternatives fulfills the following requirements as required by the 2003 CERP Programmatic Regulations 33 CFR Part 385.26(c):

1. Support project teams to achieve consistency with the Comprehensive Everglades Restoration Plan's (CERP) goals and objectives;
2. Document the performance of the project alternative plans using RECOVER-approved system-wide performance measures, project performance measures (when appropriate), and best professional judgment. RECOVER determines the ability of each alternative plan to meet the targets established for each performance measure and describes the resulting effects upon the natural system. When appropriate, RECOVER evaluations include a qualitative analysis on how the project fulfills CERP goals and objectives;
3. Suggest improvements to the project, which if pursued could improve project performance or enhance benefits to the natural system;
4. Provide insight, if possible, and alert the project teams of any inconsistent modeling assumptions for the project as originally modeled in the CERP.

Recommendations discussed within the RECOVER regional evaluation report generally fall into one of three categories:

1. Recommendations that can easily be incorporated into the plan formulation process;
2. Recommendations that are more conceptual in nature, which the Project Team may select to incorporate into preliminary designs to improve project performance; and
3. Recommendations that are crucial to the project, but cannot be addressed prior to the TSP Milestone meeting.

RECOVER recommends that for any future projects planned through the Section 203 process intended for Congressional approval under CERP in Water Resource Development Acts, adequate coordination with RECOVER consistent with the CERP Programmatic Regulations and CERP Guidance Memorandum 66 (CGM 66) be conducted in a timely manner.

CONSISTENCY REVIEW OF LOCAR PROJECT-LEVEL PERFORMANCE MEASURES

RECOVER conducted a review of performance measures for the LOCAR study (Appendix G of the FS). RECOVER Consistency Reviews are an effort to ensure that each project's performance measures are consistent with the system-wide view. PDTs are asked to be familiar with the current set of RECOVER system-wide performance measures and to use them as a foundation for their performance measures. See RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #4 – RECOVER Consistency Review of Project-Level Performance Measures (USACE and SFWMD 2023).

RECOVER's review of performance measures fulfills the following requirements, as outlined in the 2003 CERP Programmatic Regulations 33 CFR Part 385.20(e):

1) Support development and refinement of predictive models and tools used in the evaluation of alternative plans developed by PDTs; and
2) Suggest improvements to performance measures and tools for evaluating project alternatives, which if pursued, could improve project performance or enhance benefits to the natural system.

RECOVER Findings:

- Stated LOCAR FS objectives linked to performance measures (PMs) include 1) improve timing and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges; and 2) reduce flows from Lake Okeechobee to improve the salinity regime and the quality of oyster, submerged aquatic vegetation (SAV), and other estuarine community habitats in the Northern Estuaries. These are consistent with CERP Goals and Objectives.
- There were no project-specific PMs developed for the LOCAR, rather, the FS utilized the RECOVER System-Wide Performance Measures for evaluation of project benefits, including the Lake Stage and Northern Estuaries Salinity Envelope.
- The RECOVER PMs for Lake Okeechobee and the Northern Estuaries were used to revise habitat unit (HU) methods for project ecosystem benefits calculations. RECOVER finds these updates to be appropriate and sufficiently documents how RECOVER science underlying the PMs were applied by the project team to the Cost Effectiveness and Incremental Cost Analysis (CE/ICA) process for LOCAR.

RECOVER Recommendations:

- The draft Appendix G of the LOCAR FS does not include the correct Lake Stage Performance Measure Documentation Sheet (Attachment G-1); and includes an outdated version of the RECOVER System-Wide Performance Measure for Northern Estuaries Salinity Envelope (2007) (Attachment G-2). RECOVER requests that the correct Doc Sheets for these two PMs be attached to Appendix G. They will be emailed to the project team.

RECOVER'S LOCAR EVALUATION OF PROJECT ALTERNATIVE PLANS

RECOVER conducted an Evaluation of Project Alternative Plans (RECOVER Evaluation) to determine and document the ability of each alternative plan to achieve the CERP goals and purposes, as outlined by the 2003 CERP Programmatic Regulations 33 CFR Part 385.26(c):

1) Inform the PDT of the compatibility of proposed project alternative plans with regional CERP restoration goals and performance expectations;
2) Determine the performance of each alternative plan toward meeting system-wide goals and objectives using system-wide performance measures, project performance measures, and best professional judgment;
3) Identify improvements for project performance that would improve system-wide performance; and
4) Provide decision-makers required information regarding system-wide performance expectations of specific projects.

See RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #5 – RECOVER Evaluation of Project Alternative Plans (USACE and SFWMD 2023).

RECOVER Evaluation findings:

- RECOVER finds that the LOCAR is compatible with CERP restoration goals and performance expectations: The additional storage capacity provided by the recommended plan (Alternative 1) allows for increased operational flexibility to improve lake and estuary ecology by offering the potential to maximize habitat inundation in some years, and habitat rejuvenation in others for Lake Okeechobee, and by reducing the occurrence of high and damaging freshwater inflows from Lake Okeechobee to the Northern Estuaries.
- All the LOCAR Alternatives perform similarly compared to the Existing Condition Baseline (ECB) and the Future Without (FWO) LOCAR for the Lake Stage and Salinity Envelope performance measures. The proposed storage capacity between alternatives were equal (200,000 ac-ft); thus, there was minimal difference between them as it relates to impact to Lake Okeechobee and the Northern Estuaries.
- While the reservoir will benefit the estuaries by reducing high and damaging freshwater releases derived from Lake Okeechobee, there is a potential for an increase in low flow events that could impact oligohaline habitats under operations with LOCAR.
- Key uncertainties that could impact LOCAR project performance includes climate change, operations under the new Lake Okeechobee System Operating Manual, and others consistent with the CERP Program-Level Adaptive Management Plan.
- The "system-wide perspective" for this review was limited to the northern end of the system, with particular focus to Lake Okeechobee and the St. Lucie and Caloosahatchee Estuaries due to the expected impact of the reservoir and subsequent operations. The RECOVER team consulted with the Interagency Modeling Center about not using the RSM-GL in this study and concurred that the FWO project and LOCAR alternatives did not perform meaningfully different in sending water south to the Water Conservation Areas to merit full RSM-GL modeling of LOCAR performance, nor required performance measure analysis and review for the Greater Everglades and Southern Coastal Systems regions.

RECOVER Evaluation recommendations**:**

- RECOVER does not have any design recommendations for the LOCAR.
- Regarding improvements to the LOCAR, see "RECOVER Review of the Draft Operating Manual" for recommendations pertaining to LOCAR operations to optimize conditions in Lake Okeechobee and the Northern Estuaries.
- While the decrease in high in damaging flows to estuaries derived from Lake Okeechobee are desired, the increase in low flow conditions can be detrimental. RECOVER urges water managers to consider supplemental flows when possible, to decrease salinities in the estuaries when typically oligohaline or mesohaline zones of the estuary are predicted to rise above their optimal salinity range.
- An uncertainty pertaining to both Lake Okeechobee and the Northern Estuaries is climate change: RECOVER recommends that future feasibility/planning studies consider future projections of climate change impact (e.g., increased precipitation, sea-level rise) in RSM-Basins and RSM-Glades LECSA modeling of future-with-project scenarios.

RECOVER REVIEW OF THE LOCAR MONITORING PLAN

RECOVER conducted a review of the LOCAR Project-Level Monitoring Plan (Annex D of the FS) and compared it with the current version of the RECOVER Monitoring and Assessment Plan (MAP, RECOVER

2009) to ensure coordination of project-level and system-wide monitoring. Reviews of project monitoring plans allow RECOVER to make recommendations to ensure that project-level monitoring needs are covered, and a sufficient process has been identified to assess project-level restoration success. RECOVER also assessed where there may be overlap, redundancy, inconsistencies, or leveraging opportunities between project-level and system-wide monitoring. As appropriate, RECOVER should make recommendations to the PDT on monitoring design and data collection methodology (e.g., leveraging of design/data collection methodology from MAP agreements).

RECOVER Findings:

- The LOCAR ecological monitoring plan specifies what monitoring is necessary to measure and detect the benefits of capturing, storing, and redistributing water entering northern Lake Okeechobee to improve lake stage levels for both environmental restoration and water supply purposes, and improving flows to the Caloosahatchee and St. Lucie Estuaries. The goal of surface water quality monitoring is to ensure that surface water quality released from the reservoir will not negatively impact the downstream area(s) and follows applicable state and federal water quality standards.
- In addition to outlining crosswalks with other monitoring programs (e.g., MAP), Table D-5 for AM monitoring and Table D-6 (Annex D) for project-specific monitoring provide detailed summaries of data to be collected; methods of collection; and rationale for collection used in the ecological monitoring. Table D-11 lists the monitoring stations, both water quality and hydrometeorological, used and/or needed to evaluate LOCAR's performance regarding restoration goals and compliance with water quality standards. The water quality data obtained under this program will be used to evaluate water quality status and trends; assess compliance with federal (404 permits) and state (373.1502 permits) water quality statutes; and guide mid- and long-term resource management decisions as part of the AM Plan for the Project.
- The adaptive management process provides implementation guidance on using monitoring information to inform project development, including mechanisms to efficiently incorporate new knowledge in project planning, design, and implementation. At this time, existing monitoring gaps have been identified and addressed. RECOVER supports the recommendations outlined in the LOCAR Adaptive Management and Ecological Monitoring Plans.

RECOVER Recommendations:

- A RECOVER point of contact will be identified by RECOVER to the LOCAR PDT for future project interaction points, including assurance that RECOVER MAP data are leveraged by the project: in particular, ecological data collected in Lake Okeechobee, and the Northern Estuaries to assess impact of the project to these systems.
- The LOCAR PDT should confer with the assigned RECOVER point of contact to share relevant data from the project-level monitoring to RECOVER to aid in system-wide assessment of the CERP.

RECOVER INPUT TO THE LOCAR DRAFT OPERATING MANUAL

RECOVER conducted a review of the LOCAR Operating Manual (see Annex C of the FS). RECOVER reviewed the ability of the tentatively selected plan and defined operations to meet targets established for project purposes, goals, objectives, and identified performance measures and consistency with CERP goals and objectives. See RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #7 – RECOVER Review of Draft Operating Manual (USACE and SFWMD 2023).

RECOVER Findings:

- The operating manual of the LOCAR selected plan (Alternative 1) meets targets established for project purposes, goals, and objectives, including benefits to extreme stages in Lake Okeechobee, and reduction of damaging inflows from Lake Okeechobee to the Northern Estuaries. See RECOVER Evaluation findings attached to this letter for more details.

RECOVER Recommendations:

- While the reservoir will be used to avoid extreme Lake Okeechobee levels, if operations permit, it should be used to also support reparative drawdowns in Lake Okeechobee such as the decadal recession to <11.0 ft NGVD29 per the Lake Stage Performance Measure Documentation Sheet (2020), or to augment wading bird foraging habitat availability during their nesting season.
- To the extent practicable, operations should allow for conveyance of supplemental inflows to the estuaries when salinities are high in typically oligohaline and mesohaline zones (to protect tape grass habitat, reduce salinity-driven disease in oysters, and protect larval fish habitat in the north fork of the St. Lucie), especially during the dry season or in accordance with spawning or other seasonal events.

RECOVER TEAM MEMBER PARTICIPATION

- Phyllis Klarmann, SFWMD RECOVER Program Manager and RECOVER Executive Committee Member (pklarman@sfwmd.gov)
- Dr. Jennifer Chastant, Lake Okeechobee Regional Coordinator, SFWMD (jchastan@sfwmd.gov)
- Dr. Mark Barton (on behalf of the Northern Estuaries Module), Science Supervisor of the Coastal Ecosystems Section, Applied Sciences Bureau, SFWMD (mabarton@sfwmd.gov)

REFERENCES

- *Water Resources Development Act 1986 (U.S. Congress 1986)*
- *Water Resources Development Act of 2000 (U.S. Congress 2000)*
- *Water Resources Development Act of 2014 (U.S. Congress 2014)*
- *Programmatic Regulations for the Comprehensive Everglades Restoration Plan; Final Rule (Department of Defense [DOD] 2003)*
- *Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement, AKA "Yellow Book", excerpts on role of RECOVER (USACE 1999)*
- *Comprehensive Everglades Restoration Plan Guidance Memorandum (CGM) 030.00 dated 22 July 2003 (USACE and SFWMD 2003)*
- *Comprehensive Everglades Restoration Plan Guidance Memorandum (CGM) 66.00. dated 12 July 2018 (USACE and SFWMD 2018)*
- *CERP Program-Level Adaptive Management Plan. (USACE and SFWMD 2015)*
- *RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #4 – RECOVER Consistency Review of Project-Level Performance Measures. (USACE and SFWMD 2023)*
- *RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #5 – RECOVER Evaluation of Project Alternative Plans. (USACE and SFWMD 2023)*
- *RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #6 – RECOVER Review of Monitoring Plan. (USACE and SFWMD 2023)*

- *RECOVER Project Support Standard Operating Procedure (SOP) Interaction Point #7 – RECOVER Review of Draft Operating Manual. (USACE and SFWMD 2023)*
- *RECOVER System-wide Performance Measure: Lake Stage (RECOVER, March 2020)*
- *RECOVER System-wide Performance Measure: Northern Estuaries Salinity Envelope (RECOVER, July 2020)*

Best Regards,

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E INTRODUCTION

E.1 Background and Purpose

This report documents the REstoration COordination and VERification (RECOVER) team regional evaluation of the Lake Okeechobee Component A Reservoir (LOCAR) required by the Comprehensive Everglades Restoration Plan (CERP) Programmatic Regulations 33 Code of Federal Regulations 385.20(e)(2) (herein referred to as the Programmatic Regulations (2003)). RECOVER is an independent, interagency, and interdisciplinary team made-up of scientists charged with helping PDTs ensure their project's plans, designs, and performance are fully linked to the goals and objectives of CERP. The purpose of system-wide evaluations are to: (1) inform the PDT of the compatibility of proposed project alternative plans with regional CERP restoration goals and performance expectations; (2) determine the performance of each alternative plan toward meeting system-wide goals and objectives through the use of system-wide performance measures, project performance measures, and best professional judgment; (3) identify improvements for project performance that would improve system-wide performance; and (4) provide decision-makers required information regarding system-wide performance expectations of specific projects. This report documents the performance of the project alternatives in accordance with these four (4) tenets and, also, highlights the ability of each alternative to meet RECOVER system-wide/regional performance targets and documents expected effects on the natural system.

In accordance with Programmatic Regulations (2003) § 385.26(c) and § 385.32, RECOVER shall assist Project Delivery Teams in ensuring that project design and performance is fully linked to the goals and purposes of the Plan and incorporating, as appropriate, information developed for Project Implementation Reports into the Plan. RECOVER shall conduct evaluation activities, including, but not limited to:

i. Developing proposed evaluation performance measures for evaluating alternative plans developed for the Project Implementation Report;

ii. Conducting evaluations of alternative plans developed for Project Implementation Reports and Comprehensive Plan Modification Reports; and

iii. Supporting development and refinement of predictive models and tools used in the evaluation of alternative plans developed by the Project Delivery Teams.

The South Florida Water Management District (SFWMD) prepared a Feasibility Study to evaluate above-ground storage north of Lake Okeechobee pursuant to Section 203 of the Water Resources Development Act (WRDA) of 1986, as amended, for submission to the Assistant Secretary of the Army for Civil Works (ASA(CW)). The Jacksonville District, U.S. Army Corps of Engineers (Corps), has prepared a Draft Environmental Impact Statement (EIS) to evaluate potential effects on the human environment of the North of Lake Okeechobee Storage Reservoir Section 203 Study (SFWMD Section 203 Study) performed by the SFWMD.

The accelerated schedule of the LOCAR Section 203 Feasibility Study (FS) conducted by the South Florida Water Management District (SFWMD) and the Environmental Impact Statement (EIS) precluded RECOVER from undergoing Steps 1-4 of RECOVER's interaction points with CERP project teams during the planning process (see CERP Guidance Memorandum 66). However, because the FS and EIS will be submitted for eventual inclusion under CERP (Section 601 of WRDA 2000), RECOVER has completed Step 5, "*RECOVER Evaluation of Project Alternative Plans*," with the understanding and expectation that RECOVER will be

involved in future interaction points once approved/authorized by Congress. This system-wide evaluation is limited to the northern end of the C&SF system due to the scale and operational realities of the project (see Section E.4.3). RECOVER also recommends that adequate coordination with RECOVER consistent with CERP Guidance Memorandum 66 (CGM 66) be conducted on any future projects planned through the Section 203 process intended for Congressional Approval under CERP.

E.2 CERP AND LAKE OKEECHOBEE COMPONENT A RESERVOIR (LOCAR) GOALS AND OBJECTIVES

The purpose of CERP is to modify structural and operational components of the Central and Southern Florida (C&SF) Project to achieve restoration of the Everglades and the south Florida ecosystem, while providing for other water-related needs such as urban and agricultural water supply and flood protection (USACE 1999). The sixty-eight (68) components of CERP will work together to benefit the ecological structure and function of the south Florida ecosystem by improving and/or restoring the proper quantity, quality, timing, and distribution of water in the natural system. CERP goals and objectives are provided in (Table E-1).

Table E-1. CERP Goals and Objectives

CERP Goals and Objectives	
1	**Enhance ecological values.**
A	Increase the total spatial extent of natural areas.
B	Improve habitat and functional quality.
C	Improve native plant and animal species diversity.
2	**Enhance economic values and social well-being.**
A	Increase availability of fresh water (agricultural/municipal and industrial).
B	Reduce flood damages (agricultural/urban).
C	Provide recreational opportunities.
D	Protect cultural and archaeological resources and values.

The LOCAR, or Component A as described in the 1999 Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement, is included in CERP. The purpose of Component A is to construct a 200,000 acre-feet (ac-ft) reservoir to capture water during wet periods for later use during dry periods. Increased storage capacity would reduce the duration and frequency of both high and low water levels in Lake Okeechobee that are stressful to littoral ecosystems, and simultaneously prevent stressful or damaging freshwater releases to the Northern Estuaries (i.e. the St. Lucie Estuary (SLE) and the Caloosahatchee Estuary (CRE).

The goals of LOCAR include:

1. Enhance ecological values in Lake Okeechobee and the St. Lucie and Caloosahatchee Estuaries ecosystems (consistent with CERP Goals and Objectives 1A & 1B).
2. Enhance economic values and social well-being (consistent with CERP Goals & Objectives 2A, 2B, and 2C).
3. Maintain the rights of the Seminole Tribe of Florida under the Compact among the Seminole Indian Tribe of Florida, the State of Florida, and the SFWMD (Savings Clause [Section 601 (h)(5)(C) of WRDA 2000]) (Consistent with CERP Goals and Objectives 2D).

The objectives of the LOCAR include:

1. Improve quantity, timing, and distribution of flows into Lake Okeechobee to maintain ecologically desired lake stage ranges more often (consistent with CERP Goals and Objectives 1A & 1B).
2. Improve the timing and volumes of freshwater flows from Lake Okeechobee to improve the salinity regime and the quality of habitats for oyster, submerged aquatic vegetation (SAV), and other estuarine communities in the Northern Estuaries (consistent with CERP Goals and Objectives 1A & 1B).
3. Increase availability of the water supply to existing legal water users of Lake Okeechobee commensurate with improving Lake Okeechobee ecology (consistent with CERP Goals & Objectives 2A-2D).

The three project alternatives (Alt 1, 2, and 3) developed by the LOCAR Project Team ("Project Team") are summarized in Table ES-1 of the FS. Effectively, storage capacity between the alternatives are equal (200,000 ac-ft), while the land area of the reservoir and associated structures, average reservoir depth, and other features differed.

E.2.1 KEY UNCERTAINTIES

Key uncertainties that will inform whether LOCAR will meet its stated objectives are consistent with other hydrologic restoration uncertainties under CERP (CERP Program-Level Adaptive Management Plan, 2015) for Lake Okeechobee and the Northern Estuaries. Uncertainties regarding organismal and habitat responses are difficult to address in the northern end of the system due to a lack of available ecological models (and/or staff required to run them). Both Lake Okeechobee and the Northern Estuaries regions have performance measures (PMs; Section E.3) whose evaluation criteria are hydrologic (i.e., Lake Stage, salinity), and therefore serve as proxies for predicted benefits to system ecology. For this and other evaluations, such as informing progress towards Interim Goals and Interim Targets, some uncertainties, their relevance (and actionable management options), and risk will remain until CERP projects are implemented and sufficient time passes to detect changes in the system. Please refer to the CERP Program-Level Adaptive Management Plan (2015) for a detailed description of regional and system-wide uncertainties.

An uncertainty pertaining to both Lake Okeechobee and the Northern Estuaries is climate change. The frequency and magnitude of precipitation events, increasing temperatures, and sea-level rise will impact volumes of water entering the system, where that water can be stored and conveyed, and whether saltwater intrusion will impede benefits of environmental flows in the coastal zone.

Additionally, a new regulation schedule for Lake Okeechobee, the Lake Okeechobee System Operating Manual (LOSOM; Graham et al. 2020) is in the process of being finalized (at the time of writing). The U.S. Army Corps of Engineers will operate under the 2008 Lake Okeechobee Regulation Schedule (LORS; USACE 2007) until completion of the LOSOM effort. Adoption of the LOSOM regulation schedule is anticipated in the early 2024 but remains pending. Depending on the ultimate outcome of these future lake schedule revisions, including the level of inherent operational flexibility provided with these revisions, LOCAR implementation may still require further lake schedule revisions to optimize system-wide performance.

E.3 PERFORMANCE MEASURES

Two RECOVER performance measures were used to evaluate performance of the LOCAR alternative plans. These include the RECOVER System-Wide Performance Measures for Lake Okeechobee Stage ("Lake Stage") (RECOVER 2020a), and Northern Estuaries Salinity Envelope (RECOVER 2020b).

Lake Stage Ecological Envelope: The Lake Stage PM looks at maintaining stages within a seasonally variable, ecologically preferred envelope of 11.5 to 15.5 ft NGVD29 as often as possible (i.e., 100% of the time). Durations within, above, and below the envelope are evaluated here (RECOVER 2020a).

Numerous studies of Lake Okeechobee (summarized in Havens 2002) have established the ecological benefits of seasonal variation in water depth within the range of 11.5 ft National Geodetic Vertical Datum (NGVD29), in June and July, and 15.5 ft, from November to January. Winter (January) water levels near 15.0 ft NGVD29 inundate nesting habitat for wading birds (Smith and Collopy 1995), while water levels near 14.0 ft NGVD29 in mid-March support peak snail kite nest initiations (Fletcher et al. 2017). Falling water levels in late winter to spring benefit wading birds by concentrating prey resources in the littoral zone where they forage (Smith et al. 1995). Water levels near 11.5-12.0 ft benefit submerged plants and bulrush by providing optimal light levels for photosynthesis during the summer months (i.e., growing season; Havens et al. 2004). Variation in water level results in annual flooding and drying of upland areas of the littoral zone, which favors development of a diverse emergent plant community (Richardson et al. 1995; Keddy and Frazer 2000). The ecological envelope encompasses a range of stages that should result in increased spatial extent of bulrush along the western lakeshore; increased spatial extent of spike rush, beak rush, willow, and other native plants in the littoral zone; increased spatial extent of vascular submerged plants; a shift in taxonomic structure of zooplankton to better support fishery resources; increased diversity, distribution, and abundance of forage fish in the littoral and nearshore zones; and increased use of the littoral zone for wading bird and snail kite foraging and nesting. However, periodic low stage events (11.0 ft NGVD29; approximately once per decade and persisting for three months – a "reparative drawdown"), are considered beneficial to the littoral zone because they allow for periodic exposure of seed banks, oxidation of accumulated organic material, and prescribed fire to maintain species diversity (Havens 2002; Graham et al. 2020).

Lake Stage Ecological Envelope - Extreme Lake Stages: Frequent and prolonged high and low water levels in Lake Okeechobee impact lake ecology (Havens 2002; Havens and Gawlik 2005). The goal of this PM is to reduce the frequency of extreme stages as often as possible (i.e., 0% of the time). High lake stages (> 16.0 ft NGVD29) can cause extirpation or reduced germination and growth of submerged plants (James and Havens 2005), reductions in fish spawning and fish reproductive success (Havens et al. 2005; Rogers and Allen 2008), increased potential for harmful algal blooms (Graham et al. 2020), and shifts among species of the macroinvertebrate community (Warren et al. 2009; Cifoni et al. 2022). Extreme high stage (> 17.0 ft NGVD29) can transport turbid nutrient-laden water into the littoral zone, reducing littoral extent

and changing vegetation communities in interior marshes (Havens 2002; Julian and Welch 2022). Low water levels (< 11.0 ft NGVD29) impact both the lake ecosystem and water supply for existing legal users. Extreme low stage (< 10.0 ft NGVD29) can result in desiccation of the entire littoral zone, the nearshore bulrush zone, and lakebed areas that host submerged aquatic plants (Harwell and Havens 2003). Extreme low stage also encourages invasive exotic plants such as torpedo grass to establish and spread in the upper reaches of the marsh, displacing native vegetation.

Extreme high stages lead to a loss of woody species used as nesting substrate for wading birds (Chastant et al. 2017) and snail kites (Rodgers 2007), the spread of invasive or nuisance vegetation (Smith et al. 2004; Bansal et al. 2019), and a loss of submerged aquatic vegetation (Havens et al. 2005). Stages above the ecological envelope, which would be reduced by 7% with any Alternative, cause transport of nutrient-laden sediment from the pelagic zone into the nearshore and littoral zones of the lake (Havens 1997; James and Havens 2005); reduce light penetration resulting in a decrease of overall littoral extent through loss of plants in deeper areas; and alter the plant community to one dominated by invasive or nuisance species.

Extreme low stages desiccate the entire littoral zone, nearly eliminating in-lake habitat for the reptiles, amphibians, fish, and birds that depend on the marsh for successful foraging and recruitment. Extreme low stages also encourage expansion of cattail into former areas of open-water and/or submerged aquatic plants, resulting in long-term conversion (>10 yrs) of habitat (Zhang and Welch 2018). Low lake stages can severely limit or even eliminate entire breeding seasons for many species of fish and wildlife [e.g. Snail kites (Fletcher et al. 2017), apple snails (Darby et al. 2004), wading birds (Chastant et al. 2017), and Largemouth bass (Havens et al. 2005)]. Likewise, stages below the ecological envelope expose peat substrates in southern portions of the lake, increasing the risk of peat fires which can result in permanent loss of marsh elevation.

Northern Estuaries Salinity Envelope: The estuaries under consideration include the St. Lucie River and Estuary (SLE) and the Caloosahatchee River and Estuary (CRE). The Salinity Envelope PM evaluates freshwater inflows and their expected salinity improvements throughout the estuary (including maintaining a suitable salinity gradient for multiple indicator species such as the Eastern oyster and submerged aquatic vegetation species (RECOVER 2020b).

The Northern Estuaries Salinity Envelope Performance Measure (RECOVER 2020b) provides Optimal Flow targets (in cubic feet per second [cfs]) for each of the estuaries, including: 14-day moving average (ma) of all gauged flows 150 to 1,400 cfs for the SLE; and 14-day ma 750 to 2,100 cfs for the CRE. It also includes flow bin(s) below the Optimal Flows (i.e., low flows), and above the Optimal. Those above Optimal are categorized as either stressful flows (in some figures referred to as “high flows”), or damaging flows, which are based on the magnitude of deleterious impacts to the ecological indicator organisms with salinities falling outside of their optima.

The RSM-Basins model tabulates the number of times (or “events”) the 14-day criteria for each flow category is observed in its period of record simulations assuming the existing condition baseline, future-without project, and for each project alternatives.

Managing freshwater flows to an estuary is challenging because the proper flow maintains a variety of salinity (haline) gradients, or zones, throughout the estuary starting with the mostly freshwater oligohaline zone at the river mouth, to the mostly brackish mesohaline zone in the middle estuary and the euhaline zone consisting of mostly oceanic salt water. The amount of freshwater entering the estuary can

shift these zones up or downstream with low and high flows, respectively. Each of these zones have distinct communities, and while many species in the estuary are euryhaline (able to live in a wide range of salinities) many can only tolerate a narrow range. As haline zones shift with flows, mobile species can stay within their desired salinity range, but sedentary species are forced to deal with salinity fluctuations as inflows change. However, many of those sedentary species such as oysters and submerged aquatic vegetation offer optimal forage and habitat to mobile species, thus the entire ecosystems benefits when salinity fluctuations are consistently small to moderate and occur gradually. The Optimal flows defined in the Salinity Envelope PM was defined based on this estuarine variability.

E.4 EVALUATION

All LOCAR Alternatives perform similarly compared to the Existing Condition Baseline (ECB) and the Future Without (FWO) LOCAR. The additional storage capacity provided by all LOCAR Alternatives allows for increased operational flexibility to improve lake and estuary ecology by offering the potential to maximize habitat inundation in some years with habitat rejuvenation in others for Lake Okeechobee, and by reducing the occurrence of high and damaging freshwater inflows *from* Lake Okeechobee to the Northern Estuaries.

Our system-wide evaluation is limited to the northern end of the C&SF system due to the scale and operational realities of the project (see Section E.4.3). There is great potential to balance hydrologic needs for the lake and the estuaries with the recommended plan (Alternative 1), but negative effects to tape grass and larval fish habitat in the oligohaline and mesohaline reaches of the estuaries is possible as indicated by higher salinities observed under low flow conditions, if water management operations prioritize minimizing inflows to the SLE. Where operational flexibility is possible, Lake Okeechobee can supplement environmental flows to the coast: if salinities are high in the oligohaline and mesohaline zones of the estuaries, and Lake Okeechobee levels are within the desired envelope, supplemental flows to the estuaries can mitigate the predicted increases in low inflows as predicted with implementation of Alternative 1.

E.4.1 LAKE OKEECHOBEE

The CERP goals for Lake Okeechobee are to have no frequent or prolonged departures of lake stage outside of the prescribed lake stage ecological envelope, other than an approximately once-per-decade drop to 11.0 ft NGVD29 for three months. Additionally, extreme high and low lake stage events would preferably be rare and of short duration (RECOVER 2020). A reservoir north of Lake Okeechobee will support these goals by delivering water to the lake when lake levels are low and accepting water from the lake when lake levels are high, thus reducing the frequency and severity of both extremes.

There is clear improvement in all stage level PM metrics when any Alternative is compared to the Existing Conditions Baseline (ECB) and the Future Without Project (FWO). All Alternatives, compared to FWO, improve ecological conditions for Lake Okeechobee by increasing the amount of time lake stage is within the ecological envelope (6%) and reduce the frequency and duration of moderate (4.5%) and extreme high stages (1.5%) (Table 2). There are slight increases in the frequency of low stages; however, they are minimal compared to reductions of high stages.

TABLE 2. LAKE OKEECHOBEE STAGE PERFORMANCE METRICS AS MODELED IN RSM-BN (POR 1965-2016).

Lake Okeechobee Stage Levels (NVGD29)	ECB	FWO	Alternative 1	Alternative 2	Alternative 3	Desired Outcome
% Time inside Envelope (11.5–15.5 ft)	19%	22%	28%	28%	28%	**Increase**
% Time above Envelope (>12.5–15.5 ft)	49%	48%	41%	41%	41%	**Decrease**
% Time below Envelope (<11.5–14.5 ft)	32%	30%	31%	31%	31%	**Decrease**
% Time above Extreme High Stage (>17.0 ft)	1.4%	2.1%	0.6%	0.6%	0.6%	**Decrease**
% Time above Moderate High Stage (>16.0 ft)	17.9%	10.3%	5.8%	5.8%	5.8%	**Decrease**
% Time below Moderate Low Stage (<11.0 ft)	11.9%	9.9%	10.3%	10.1%	10.3%	**Decrease**
% Time below Extreme Low Stage (<10.0 ft)	4.4%	3.05%	4.1%	4.0%	4.1%	**Decrease**

Ecological recovery from extreme stage events can take multiple years of appropriate water level regimes before improvement is realized. Inter-annual variability in water depth and the trade-off between wet and dry years during the breeding/growing season of many lake species is inherent to a healthy functioning littoral ecosystem (Keddy and Fraser 2000). For example, reductions in frequency and duration of stages in the 11.0-13.0 ft NGVD range reduce opportunities for deeper-marsh vegetation to rebound from high stage or hurricane events (Havens et al. 2005). The additional storage capacity provided by all LOCAR Alternatives allows for increased operational flexibility to improve lake ecology; offering the potential to maximize habitat inundation in some years with habitat rejuvenation in others. The reservoir will be used to avoid extreme lake levels but, if operations permit, may also support reparative drawdowns such as the decadal recession to <11.0 ft NGVD29 or to augment wading bird foraging habitat availability during their nesting season. As water managers work towards regional restoration efforts, LOCAR is an essential tool for achieving system-wide objectives; balancing flood protection and water supply with maintaining a diverse lake ecological community.

E.4.2 NORTHERN ESTUARIES

The restoration goal is to reestablish salinity regimes suitable for the maintenance of healthy, naturally diverse, and well-balanced estuarine ecosystems. The alternative plans perform similarly (Table 3; Table 4) having both positive (reduction in high and damaging flows) and negative (increase in low flows) compared to the FWO and ECB. The selected plan benefits the ecosystems of the Northern Estuaries as it results in substantial reductions in high and damaging flows driven by Lake Okeechobee regulatory releases than the FWO and ECB. However, it is noteworthy that not all flow metrics are improved by the recommended plan as there is an increase in low flows in both the St. Lucie and Caloosahatchee Estuaries compared to the FWO and ECB, which can have various ecological impacts. Furthermore, all three of the presented alternatives result in similar flows to both estuaries for all categories, thus the following assessments can be applied to either of the alternatives if it were necessary to select a different alternative.

With LOCAR, there is an observed increase in stressful and damaging flows driven by basin runoff compared to FWO, but a decrease compared to ECB. This increase in basin flows is more an artefact of water management operations and the methodology in which the RSM tabulates flow events, rather than LOCAR contributing to more water onto the associated watersheds. For example, a hypothetical, significant rain event would result in large volumes of runoff regardless of water management operations; and, given operational flexibility from additional storage with LOCAR, releases from Lake Okeechobee can be minimized. This would be reflected in a higher number of basin-triggered high and damaging flow events, but not due to any flaw of the project under evaluation.0

Finally, there is a general decrease across all alternatives in damaging flows in both estuaries over the ECB and FWO, however, in the Caloosahatchee the extremely damaging flows category (≥6500 cfs) is lower than the ECB but remains higher than FWO for all three alternatives.

The increase in low flows across alternatives will lead to temporary shifts of haline zones upstream in the estuary, allowing tidal waters to reach further into the typically meso- and oligohaline zones. While these perturbations are not likely to have great impacts on inhabitants of the lower estuary, those in the middle and upper estuary are likely to be negatively impacted. This is particularly significant in the Caloosahatchee River where tape grass once dominated the upper estuary (Bartleson et al., 2014). Tape grass has a low salinity tolerance and requires salinities of less than 5 to survive. To maintain the correct salinity in the upper estuary for this species, low flow scenarios should be avoided. Similarly, a recent study has identified fish species hotspots in the upper St. Lucie Estuary that are dependent on these low salinity habitats, including the Opossum Pipefish, Smallscale Fat Snook, and Bigmouth Sleeper (Stevens et al., 2023). The Opossum Pipefish is currently identified by the American Fisheries Society as a threatened species and the Indian River Lagoon including the St. Lucie Estuary) is one of the last and largest permanent populations of this species (Moore, 2009). The Bigmouth Sleeper and Smallscale Fatsnook are both amphidromous species, depending on oligohaline habitats during most of their adult life, making short term excursions downstream for spawning activities (Bacheler 2002; Stevens et al 2023).

Middle estuarine communities are also likely to be affected, as eastern oysters (Crassostrea virginica) prefer salinities between 10 and 25 (Barnes et al., 2007). Low flows can cause salinities in the middle estuary to rise above 25, causing stressful conditions and increased parasitism. These conditions are not likely to lead to death in adult oysters, but if these high salinity conditions persist for extended periods of time, they can lead to decreases in condition and other health parameters which will affect the oysters ability to spawn in the following spawning season thus hampering the recovery and regeneration of lost oyster reef habitats.

These oyster reefs are a keystone species on which many other species depend as both food, refuge and foraging habitat. The increase in high, stressful and damaging flows associated with the recommended plan will lead to temporary shifts of haline zones downstream in the estuary. Depending on the magnitude and duration, these flows can have detrimental impacts on communities in the middle and lower estuary. Oysters in the middle estuary may be exposed to low salinities which can be stressful (5-10) or even damaging (<5) leading to declines in oyster reef coverage (Parker et al., 2013).

TABLE 3. ST. LUCIE ESTUARY PERFORMANCE METRICS AS MODELED IN RSM-BN (POR 1965-2016).

Scenario	# of 14-day ma Low Flow Events <150 cfs Fewer is better	# of 14-day ma Optimal Flow Events ≥150 cfs and ≤1,400 cfs More is better	# of 14-day ma Stressful (High) Flow Events ≥1,400 cfs and ≤1,700 cfs (from LOK)* Fewer is better	# of 14-day ma Stressful (High) Flow Events ≥1,400 cfs and ≤1,700 cfs (from Basin Runoff)* Fewer is better	# of 14-day ma Damaging Flow Events ≥1,700 cfs* (from LOK)* Fewer is better	# of 14-day ma Damaging Flow Events ≥1,700 cfs* (from Basin Runoff)* Fewer is better	# of 14-day ma Damaging Flow Events ≥1,700 cfs and ≤4,000 cfs Fewer is better	# of 14-day ma Damaging Flow Events ≥4,000 cfs Fewer is better
ECB	183	910	30	279	41	452	427	166
FWO	163	997	49	238	58	344	352	129
Alternative 1	209	1013	20	262	29	350	337	118
Alternative 2	208	1011	20	261	30	350	339	118
Alternative 3	210	1012	20	263	27	351	339	118

*Flow events triggered by either LOK (Lake Okeechobee Regulatory Releases) or basin runoff. Note: ma = moving average.

TABLE 4. CALOOSAHATCHEE ESTUARY PERFORMANCE METRICS AS MODELED IN RSM-BN (POR 1965-2016).

Scenario	# of 14-day ma Low Flow Events <750 cfs Fewer is better	# of 14-day ma Optimal Flow Events ≥750 cfs and ≤2,100 cfs More is better	# of 14-day ma Stressful (High) Flow Events ≥2,100 cfs and ≤2,600 cfs (from LOK)* Fewer is better	# of 14-day ma Stressful (High) Flow Events ≥2,100 cfs and ≤2,600 cfs (from Basin Runoff)* Fewer is better	# of 14-day ma Damaging Flow Events ≥2,600 cfs* (from LOK)* Fewer is better	# of 14-day ma Damaging Flow Events ≥2,600 cfs* (from Basin Runoff)* Fewer is better	# of 14-day ma Damaging Flow Events ≥2,600 cfs and ≤4,500 cfs Fewer is better	# of 14-day ma Damaging Flow Events ≥4,500 cfs and ≤6,500 cfs Fewer is better	# of 14-day ma Damaging Flow Events ≥6,500 cfs Fewer is better
ECB	549	638	77	166	86	230	241	105	84
FWO	752	549	66	124	66	160	181	80	56
Alternative 1	586	688	42	153	55	179	179	75	64
Alternative 2	584	686	42	154	56	178	178	77	64
Alternative 3	586	689	41	154	55	179	178	76	64

*****Flow events triggered by either LOK (Lake Okeechobee Regulatory Releases) or basin runoff. Note: ma = moving average.

Seagrasses become more prevalent in the middle and lower estuaries, and these can also be impacted by high flow events. There are a variety of seagrasses present in the Northern Estuaries, but in both cases they play similar roles as oysters as they provide food, refuge and foraging habitat for a variety of species. While seagrasses are generally quite resistant to short term changes in salinity, they are far more susceptible to changes in light availability (Choice et al., 2014). As water flows faster it becomes more turbulent, increasing sediment resuspension and entrainment. This in turn increases turbidity and decreases light attenuation downstream. If these conditions persist, seagrasses cannot survive. In addition, Seagrasses have an important baffling effect that reduces wave energy and turbulence, encouraging sediments to be deposited over seagrass beds. This can benefit the seagrasses when turbulent flows are infrequent, but as frequency increases the deposited sediments can cover the seagrasses further preventing light penetration (Cabaço et al., 2008).

Furthermore, high flow events can interfere with natural reproductive activities of many species in the estuarine community. Many species of fish, oysters and crustaceans in the estuary are broadcast spawners, releasing their spawn into the water column allowing planktonic eggs and larvae to disperse through the estuary before settlement. The location of this settlement is highly dependent on freshwater and tidal flows. When larvae settle in suboptimal habitat or substrate, survival is unlikely. When high flows occur during spawning activities, the larvae can be flushed out of the system and washed out so sea where they will not survive (Whitman and Reidenbach, 2012).

In summary, the benefits from the LOCAR recommended plan aligns with RECOVER's goals for the Northern Estuaries, but operations should consider providing supplemental releases during periods in which salinities are high in typically mesohaline and oligohaline zones. The predictive model indicates that there may be an increase in low flow and high flow events, and RECOVER recommends to water managers that if the opportunities arise in practice, that they avoid these detrimental flows by opting for optimal flow rates.

E.4.3 GREATER EVERGLADES

The LOCAR FS did not make use of the Regional Simulation Model (RSM) Glades LECSA (Lower East Coast Service Area) (RSM-GL) for LOCAR due to stated project objectives, and that the project would not have anticipated impacts in the southern portion of the system, as summarized by volume of water delivered to different areas of the system (Table 5). There are notable changes between the ECB and the FWO, which indicates benefits to the system from CERP projects and operations already authorized (not LOCAR); whereas for water deliveries "south" to the Water Conservation Areas, comparison between the FWO and three LOCAR alternatives did not indicate significant benefits that warranted additional modeling.

TABLE 5. VOLUME (K ACRE-FEET PER YEAR) OF WATER DELIVERIES TO FOLLOWING RESOURCE AREAS: WATER CONSERVATION AREAS, ST. LUCIE RIVER, CALOOSAHATCHEE RIVER, AND L8 TO TIDE (LAKE WORTH LAGOON) AS MODELED IN RSM-BN AND RSM-GL (POR 1965-2016).

Resource Area	ECB	FWO	Alternative 1	Alternative 2	Alternative 3
Water Conservation Areas	207	533	539	540	539
St. Lucie Estuary	123	125	68	68	68
Caloosahatchee Estuary	520	243	346	345	345
L8 to Tide (Lake Worth Lagoon)	11	5	13	13	13

E.4.4 SOUTHERN COASTAL SYSTEMS

See Section E.4.3. regarding RSM-GL.

E.5 SUMMARY AND CONCLUSIONS

All the LOCAR Alternatives perform similarly compared to the Existing Condition Baseline (ECB) and the Future Without (FWO) LOCAR. The additional storage capacity provided by the recommended plan (Alternative 1) allows for increased operational flexibility to improve lake and estuary ecology by offering the potential to maximize habitat inundation in some years, and habitat rejuvenation in others for Lake Okeechobee, and by reducing the occurrence of high and damaging freshwater inflows from Lake Okeechobee to the Northern Estuaries.

Key uncertainties that could impact LOCAR project performance includes climate change, operations under the new Lake Okeechobee System Operating Manual, and others consistent with the CERP Program-Level Adaptive Management Plan.

The reservoir will be used to avoid extreme lake levels but, if operations permit, it should be used to also support reparative drawdowns such as the decadal recession to <11.0 ft NGVD29 or to augment wading bird foraging habitat availability during their nesting season.

While the reservoir will have the greatest benefit to the estuaries by reducing high and damaging freshwater releases derived from Lake Okeechobee, there is a potential for an increase in low flow events that could impact oligohaline habitats under LOCAR. To the extent practicable, operations should allow for conveyance of supplemental inflows to the estuaries when salinities are high in typically oligohaline and mesohaline zones (to protect tape grass habitat, reduce salinity-driven disease in oysters, and protect larval fish habitat in the St. Lucie River), especially during the dry season.

E.6 LITERATURE CITED

Bansal, S., S.C. Lishawa, S. Newman, B.A. Tangen, D. Wilcox, D. Albert, M.J. Anteau, M.J. Chimney, R.L. Cressey, E. DeKeyser, K.J. Elgersma, S.A. Finkelstein, J. Freeland, R. Grosshans, P.E. Klug, D.J. Larkin, B.A. Lawrence, G. Linz, J. Marburger, G. Noe, C. Otto, N. Reo, J. Richards, C. Richardson, L. Rodgers, A.J. Schrank, D. Svedarsky, S. Travis, N. Tuchman, and L. Windham-Myers. 2019. *Typha* (Cattail) Invasion in North American Wetlands: Biology, Regional Problems, Impacts, Ecosystem Services, and Management. Wetlands 39: 645-684.

Barnes, T.K., Volety, A.K., Chartier, K., Mazzotti, F.J., Pearlstine, L., 2007. A habitat suitability index model for the eastern oyster (Crassostrea virginica), a tool for restoration of the caloosahatchee estuary, Florida. J. Shellfish Res. 26, 949–959. https://doi.org/10.2983/0730-8000(2007)26[949:AHSIMF]2.0.CO;2

Bartleson, R.D., Hunt, M.J., Doering, P.H., 2014. Effects of temperature on growth of Vallisneria americana in a sub-tropical estuarine environment. Wetl. Ecol. Manag. 22, 571–583. https://doi.org/10.1007/s11273-014-9354-6

Cabaço, S., Santos, R., Duarte, C.M., 2008. The impact of sediment burial and erosion on seagrasses: A

review. Estuar. Coast. Shelf Sci. 79, 354–366. https://doi.org/10.1016/j.ecss.2008.04.021

Chastant, J.E., M.L. Peterson, and D.E. Gawlik. 2017. Nesting substrate and water-level fluctuations influence wading bird nesting patterns in a large shallow eutrophic lake. Hydrobiologia 788:371-383.

Choice, Z.D., Frazer, T.K., Jacoby, C.A., 2014. Light requirements of seagrasses determined from historical records of light attenuation along the Gulf coast of peninsular Florida. Mar. Pollut. Bull. 81, 94–102. https://doi.org/10.1016/j.marpolbul.2014.02.015

Cifoni, M., A. Boggero, M. Rogora, M. Ciampittiello, A. Martínez, D.M.P. Galassi, B. Fiasca, and T. Di Lorenzo. 2022. Effects of human-induced water level fluctuations on copepod assemblages of the littoral zone of Lake Maggiore. Hydrobiologia 849: 3545–3564.

Darby, P., P. Valentine-Darby, F. Percival, and W. Kitchens. 2004. Florida apple snail (*Pomacea paludosa* SAY) responses to lake habitat restoration activity. Archiv für Hydrobiologie 161(4):561-575.

Fletcher, R., C. Poli, E. Robertson, B. Jeffery, S. Dudek, and B. Reichert. 2017. Snail Kite Demography 2016 Annual Report. University of Florida, Gainesville, FL.

Graham, W.D., M. Brenner, J.W. Fourqurean, C. Jacoby, and J. Obeysekera. 2020. Scientific synthesis to inform development of the new Lake Okeechobee System Operating Manual; An independent technical review coordinated by the University of Florida Water Institute. University of Florida, Gainesville, FL.

Harwell, M.C. and K.E. Havens. 2003. Experimental studies on the recovery potential of submerged aquatic vegetation after flooding and desiccation in a large subtropical lake. Aquatic Botany 77: 135-151.

Havens, K.E. 1997. Water levels and total phosphorus in Lake Okeechobee. Lake and Reservoir Management 13: 16-25.

Havens, K.E. 2002. Development and application of hydrologic restoration goals for a large subtropical lake. Lake and Reservoir Management 18: 285-292.

Havens, K.E., B. Sharfstein, M.A. Brady, T.L. East, M.C. Harwell, R.P. Maki, and A.J. Rodusky. 2004. Recovery of submerged plants form high water stress in a large subtropical lake in Florida, USA. Aquatic Botany 78: 67-82.

Havens, K.E., D. Fox, S. Gornak and C. Hanlon. 2005. Aquatic vegetation and largemouth bass population responses to water-level variations in Lake Okeechobee, Florida (USA). Hydrobiologia 539: 225-237.

Havens, K.E. and D.E. Gawlik. 2005. Lake Okeechobee conceptual ecological model. Wetlands 25: 908-925.

James, R.T. and K.E. Havens. 2005. Outcomes of extreme water levels on water quality of offshore and nearshore regions in a large, shallow subtropical lake. Archiv für Hydrobiologie, Advances in Limnology 163: 225-239.

Julian, P. and Z. Welch. 2022. Understanding the ups and downs: application of hydrologic restoration measures for a large subtropical lake. Lake and Reservoir Management 38: 304-317.

Keddy, P. and L.H. Fraser. 2000. Four general principles for the management and conservation of wetlands in large lakes: the role of water levels, nutrients, competitive hierarchies and centrifugal organization. Lake and Reservoir Management 5: 177-185.

Moore, J., 2009. Species of Concern Opossum pipefish.

Parker, M., Arnold, W., Geiger, S., Gorman, P., Leone, E., 2013. Impacts of Freshwater Management Activities on Eastern Oyster (Crassostrea virginica) Density and Recruitment: Recovery and Long-Term Stability in Seven Florida Estuaries. J. Shellfish Res. 32, 695–708.

RECOVER. 2015. CERP Program-Level Adaptive Management Plan, Version 1.0. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. March, 2020.

RECOVER. 2020a. CERP System-wide Performance Measure Documentation Sheet. Lake Okeechobee Performance Measure, Lake Stage. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. March, 2020.

RECOVER. 2020b. CERP System-wide Performance Measure Documentation Sheet. Northern Estuaries Salinity Envelope. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. July, 2020.

Richardson, J.R., T.T. Harris, and K.A. Williges. 1995. Vegetation correlations with various environmental parameters in the Lake Okeechobee marsh ecosystem. Archiv für Hydrobiologie, Advances in Limnology 45: 41-61.

Rodgers, J.A. 2007. Breeding Success of *Rostrhamus sociabilis* (Snail Kites) at Two Florida Lakes. Southeastern Naturalist 6: 35-46.

Rogers, M.W. and M.S. Allen. 2008. Hurricane impacts to Lake Okeechobee: altered hydrology creates difficult management trade-offs. Fisheries 33: 11-17.

Smith, J.P. and M.W. Collopy. 1995. Colony turnover, nest success and productivity, and causes of nest failure among wading birds (Ciconiiformes) at Lake Okeechobee, Florida (1989-1992). Archiv für Hydrobiologie, Advances in Limnology 45: 287-316.

Smith, J.P., J.R. Richardson and M.W. Collopy. 1995. Foraging habitat selection among wading birds (*Ciconiiformes*) at Lake Okeechobee, Florida, in relation to hydrology and vegetative cover. Archiv für Hydrobiologie, Advances in Limnology 45: 247-285.

Smith, D.H., R.M. Smart, and C.G. Hanlon. 2004. Influence of water level on torpedograss establishment in Lake Okeechobee, Florida. Lake and Reservoir Management 20: 1-13.

Stevens, P.W., Paperno, R., Beal, J.L., MacDonald, T.C., Miller, H.N., Klarmann, P.A., Malinowski, C.R., 2023.

Identification of fish habitat hotspots for use in prioritizing conservation and restoration projects in coastal rivers. Environ. Biol. Fishes 106, 221–235. https://doi.org/10.1007/s10641-022-01226-8

USACE. 2007. Final supplemental environmental impact statement: Lake Okeechobee regulation schedule study, Lake Okeechobee, Florida. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL.

Warren, G.L., E.B. Nelson, J.L Bernatis and D.A. Hohlt. 2009. Structural dynamics of benthic invertebrate communities of the Lake Okeechobee pelagic region. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Final Report to the South Florida Water Management District. Contract No. CP051040. Gainesville, FL.

Whitman, E.R., Reidenbach, M.A., 2012. Benthic flow environments affect recruitment of Crassostrea virginica larvae to an intertidal oyster reef. Mar. Ecol. Prog. Ser. 463, 177–191. https://doi.org/10.3354/meps09882

Zhang. J. and Z. Welch. 2018. Chapter 8B: Lake Okeechobee Watershed Research and Water Quality Monitoring Results and Activities. *In*: 2018 South Florida Environmental Report – Volume I, South Florida Water Management District, West Palm Beach, FL.